HANDBOOK OF THE PSYCHOLOGY OF AGING

EIGHTH EDITION

THE HANDBOOKS OF AGING

Consisting of Three Volumes

Critical comprehensive reviews of research knowledge,
theories, concepts, and issues

Editors-in-Chief
Laura L. Carstensen

and

Thomas A. Rando

Handbook of the Biology of Aging, 8th Edition
Edited by Matt Kaeberlein and George M. Martin

Handbook of the Psychology of Aging, 8th Edition
Edited by K. Warner Schaie and Sherry L. Willis

Handbook of Aging and the Social Sciences, 8th Edition
Edited by Linda K. George and Kenneth F. Ferraro

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Foreword

The near-doubling of life expectancy in the twentieth century represents extraordinary opportunities for societies and individuals. Just as sure, it presents extraordinary challenges. In the years since the last edition of the *Handbook of Aging* series was published, the United States joined the growing list of "aging societies" alongside developed nations in Western Europe and parts of Asia; that is, the U.S. population has come to include more people over the age of 60 than under 15 years of age. This unprecedented reshaping of age in the population will continue on a global scale and will fundamentally alter all aspects of life as we know it.

Science is responsible for the extension of life-expectancy and science is now needed more than ever to ensure that added years are high quality. Fortunately, the scientific understanding of aging is growing faster than ever across social and biological sciences. Along with the phenomenal advances in the genetic determinants of longevity and susceptibility to age-related diseases has come the awareness of the critical importance of environmental and psychological factors that modulate and even supersede genetic predispositions. The *Handbooks of Aging* series, comprised of three separate volumes, the *Handbook of the Biology of Aging*, the *Handbook of the Psychology of Aging*, and the *Handbook of Aging and the Social Sciences*, is now in its eighth edition and continues to provide foundational knowledge that fosters continued advances in the understanding of aging at the individual and societal levels.

Attention to the science of aging involves a concomitant increase in the number of college and university courses and programs focused on aging and longevity. With this expansion of knowledge, the *Handbooks* play an increasingly important role for students, teachers and scientists who are regularly called upon to synthesize and update their comprehension of the broader field in which they work. The *Handbooks of Aging* series provides knowledge bases for instruction in these continually changing fields, both through reviews of core and newly emerging areas, historical syntheses, methodological and conceptual advances. Moreover, the interdisciplinary nature of aging research is exemplified by the overlap in concepts illuminated across the *Handbooks*, such as the profound interactions between social worlds and biological processes. By continually featuring new topics and involving new authors, the series has pushed innovation and fostered new ideas.

One of the greatest strengths of the chapters in the *Handbooks* is the synthesis afforded by preeminent authors who are at the forefront of research and thus provide expert perspectives on the issues that current define and challenge each field. We express our deepest thanks to the editors of the individual volumes for their incredible dedication and contributions to the series. It is their efforts to which the excellence of the products is largely credited. We thank Drs. Matt Kaeberlein and George M. Martin editors of the *Handbook of the Biology of Aging*;

Drs. K. Warner Schaie and Sherry L. Willis, editors of the *Handbook of the Psychology of Aging*; and Drs. Linda K. George and Kenneth F. Ferraro, editors of the *Handbook of Aging and the Social Sciences*. We would also like to express our appreciation to our publishers at Elsevier, whose profound interest and dedication has facilitated the publication of the *Handbooks* through their many editions. And we continue to extend our deepest gratitude to James Birren for establishing and shepherding the series through the first six editions.

Thomas A. Rando and
Laura L. Carstensen
Stanford Center on Longevity,
Stanford University

Preface

The *Handbook of the Psychology of Aging* provides a basic reference source on the behavioral processes of aging for researchers, graduate students, and professionals. It also provides perspectives on the behavioral science of aging for personnel from other disciplines.

The eighth edition of the *Handbook* continues to reflect both the continuing interest of the scientific community as well as the needs and worldwide growth of the older portion of the population as well as the increase in active life expectancy. The growth of the research literature provides new opportunities to replace chronological age as the primary variable with other variables that represent causal mechanisms and hence present the potential for control or experimental modification. Both academic and public interests have been contributing to the emergence of the psychology of aging as a major subject in universities and research institutions. Issues of interest to the psychology of aging touch upon many features of daily life, from the workplace and family life to public policy matters covering health care, retirement, social security, and pensions.

The psychology of aging is complex and many new questions keep being raised about how behavior is organized and how it changes over the course of life. Results of the markedly increasing number of longitudinal studies are providing new insights into the casual factors in behavior changes associated with adult development and aging. They are contributing to our understanding of the role of behavior changes in relation to biological, health and social interactions. Parallel advances in research methodology particularly directed towards the problems of studying change allow us to explicate in greater detail, patterns and sub-patterns of behavior over the lifespan.

Facing the rapidly accelerating growth of the relevant research literature, the editors once again have had to make choices about what new topics should be included in the handbook. But the growth in research activity does not occur uniformly across all fields. Hence, some topics covered in earlier editions of the *Handbook* are not included in the present edition. In this edition we have again markedly expanded coverage of the section on Neuroscience, Cognition and Aging. Other new topics first introduced in this edition include: Relationships between adults and their aging parents, intergenerational communication practices, assessment of emotional and personality disorders in older adults, neuropsychological assessment of the dementias of late life, and family caregiving for cognitively or physically frail older adults.

We continue the editorial principle of not inviting previous contributors to revise their earlier contribution. Instead if we felt that a topic needed updating we asked a new author to approach the topic from a different perspective. When a previous contributor reappears in a subsequent edition, it is typically on a different topic that the contributor has developed expertise in. For these reasons, readers are advised to consult earlier volumes of the *Handbook*, both for data and for interpretations.

The previous editions should be consulted for a perspective on the development of the subject matter of the psychology of aging. To assist the reader, Table A present a list of topics (and authors for each topic) across the eight editions of the *Handbook*.

TABLE A Topics and Authors Across the Eight Editions of the *Handbook of the Psychology of Aging*

Topic	1st edition (1977)	2nd edition (1985)	3rd edition (1990)	4th edition (1996)	5th edition (2001)	6th edition (2006)	7th edition (2011)	8th edition (2016)
Accidents	Sterns et al.							
Activity and exercise				Stones & Kozma				
Animal memory and learning			Woodruff					
Attention processes			McDowd & Birren		Rogers & Fisk			
Attitudes towards aging		Rosenmayr				Hess	Hummert	
Auditory perception	Corso	Osho et al.	Fozard	Kline & Scialfa	Fozard & Gordon-Salant			Winfield & Lash
Autobiographical memory						Birren & Schroots		
Autonomic system	Frolkis							
Behavior genetics	Omenn	McClearn & Foch	Plomin & McClearn	Pedersen	McClearn & Vogler	Vogler	Kremen & Lyons	Reynolds & Finkel
Biological influences	Shock		Elias et al.					
Brain and life span in primates				Hakeem et al.				
Caregiving							Knight et al.	
Clinical assessment	Schaie & Schaie	Zarit et al.	Kaszniak				Manley et al.	
Cognitive neuroscience							Kramer et al.	
Cognitive intervention					Willis		Stine-Morrow & Basak	Willis & Belleville

(*Continued*)

TABLE A (Continued)

Topic	1st edition (1977)	2nd edition (1985)	3rd edition (1990)	4th edition (1996)	5th edition (2001)	6th edition (2006)	7th edition (2011)	8th edition (2016)
Control							Lachman et al.	
Creativity and wisdom			Simonton		Sternberg & Lubart	Brugman	Ardelt	
Culture and ethnicity	Guttman	Fry	Jackson et al.				Whitfield et al.	Fung & Jiang
Death and dying	Kastenbaum		Berg	Lawton				Biak
Decision making							Peters	Marson et al.
Disability and rehabilitation	Kemp							
Ecology of aging	Scheidt & Windley		Parmelee & Lawton	Wahl		Scheidt & Windley		
Educational psychology		Willis						
Electrophysiology of aging			Prinz et al.					
Elder abuse and victimization				Wilbur & McNeilly				
Emotion and affect		Schulz		Fillip			Charles	
Environment	Lawton							
Ethical issues			Kimmel & Moody				Moye et al.	
Exercise and cognition								Erickson & Liu-Ambrose
Executive functions								Reuter-Lorenz et al.
Experimental principles	Birren & Renner	Birren & Cunningham						
Family in late life		Aizenberg & Treas		Gatz et al.			Fingerman & Birditt	
Fragile aging								Smith & Ryan

(*Continued*)

TABLE A (Continued)

Topic	1st edition (1977)	2nd edition (1985)	3rd edition (1990)	4th edition (1996)	5th edition (2001)	6th edition (2006)	7th edition (2011)	8th edition (2016)
Gender differences			Huyck			Sinnott & Shifren		
Health behaviors		Siegler & Costa		Deeg et al.	Leventhal et al.	Aldwin et al.		Carstensen & Antonucci
History and concepts	Riegel		Birren & Birren	Birren & Schroots	Birren & Schroots		Schaie	
Hormones & behavior								Resnick et al.
Human factors and aging			Charness & Bosman			Scialfa & Fernie		
Human memory	Craik	Poon	Hultsch & Dixon	Smith		Hoyer & Verhaeghen	Nyberg & Bäckman	Lustig & Lin
Impact of social structure	Bengtson, Kaschau, & Ragan							
Intellectual abilities	Botwinick	Labouvie-Vief	Schaie	Schaie			Park	
Intergenerational communications								Giles, Gasiorek, Abrams, Albert, & Light
Learning	Arenberg & Robertson-Tchabo		Hultsch & Dixon					
Measurement	Nesselroade	Schaie & Hertzog	McArdle & Anderson	Collins		Rudinger & Rietz	Ferrer & Ghisletta	Stuart & Stawsky
Mood and anxiety disorders								Barry & Byers
Mood and cognition								Knight et al.
Motivation	Elias & Elias		Kausler	Fillip		Carstensen et al.		
Motor performance	Welford		Spirduoso & McRae		Ketcham & Stelmach	Newell et al.		

(*Continued*)

TABLE A (Continued)

Topic	1st edition (1977)	2nd edition (1985)	3rd edition (1990)	4th edition (1996)	5th edition (2001)	6th edition (2006)	7th edition (2011)	8th edition (2016)
Neural basis	Bondareff	Bondareff			Vinters			Kühn & Lindenberger
Other senses	Kensho							
Personality	Neugarten	Bengtson et al.	Kogan	Ruth & Coleman	Ryff et al.	Mroczek et al.	Edelstein & Segal	Hill & Roberts
Problem solving	Rabbitt	Reese & Rodeheaver		Willis		Marsiske & Margrett		
Psychol. theories	Baltes & Willis	Whitbourne				Salthouse	Dixon	Schaie
Psychophysiology	Marsh & Thompson							
Psychological intervention	Eisdorfer & Stotsky	Gatz et al.	Smyer et al.	Willis		Knight et al.	Stine-Morrow & Basak	Teri et al.
Psychopathology	Pfeiffer		Cohen	Gatz et al.	Gatz & Smyer		Whitbourne & Meeks	Park
Reading and aging						Meyer & Pollard		
Research design	Schaie	Nesselroade & Labouvie	Schroots & Birren	Hertzog	Schaie & Hofer	Hofer & Sliwinski		
Religion and aging				McFadden		Krause		
Selection, optimization, and compensation							Riediger et al.	
Sleep and sleep disorders								McCrae et al.
Social cognition and aging				Blanchard-Fields & Abeles				
Social influences	Lowenthal		Schooler		Antonucci			Hoppmann & Gerstorf
Speed of behavior		Salthouse		Cerella	Madden	Hartley		
Stress	Eisdorfer & Wilkie						Almeida et al.	

(*Continued*)

TABLE A (Continued)

Topic	1st edition (1977)	2nd edition (1985)	3rd edition (1990)	4th edition (1996)	5th edition (2001)	6th edition (2006)	7th edition (2011)	8th edition (2016)
Structural and functional brain change				Scheibel			Rodrigue & Kennedy	
Taste and smell	Engen							
Technology								Charnell & Boot
Vestibular system		Ochs et al.		Simoneau & Leibowitz				
Visual perception	Fozard et al.			Kline & Scialfa	Fozard & Gordon-Salant	Schieber		
Work	Chown	Stagner		Salthouse & Maurer	Czaja		Bowen et al.	Wang & Shi

The chapters are organized into four divisions: Part I, Concepts, Theory and Methods in the Psychology of Aging; Part II, Biopsychosocial Factors in Aging; Part III, Behavioral Processes that Impact Aging; and Part IV, Complex Behavioral Processes and the Psychopathology of Aging.

An extensive review process recommended many changes in the draft manuscripts. The draft of each chapter was reviewed by one associate editor and by the two senior editors. The senior editors thank the associate editors, Bob G. Knight, Becca Levy, and Denise C. Park for their advice on the selection of topics, authors, and their reviews of the chapter drafts. Their careful reading of the manuscripts and their detailed editorial suggestions are gratefully acknowledged.

K. Warner Schaie and Sherry L. Willis

About the Editors

K. Warner Schaie holds an appointment as affiliate professor of Psychiatry and Behavioral Sciences at the University of Washington. He is also the Evan Pugh Professor Emeritus of Human Development and Psychology at the Pennsylvania State University. He received his Ph.D. in clinical and developmental psychology from the University of Washington, an honorary Dr. Phil. from the Friedrich-Schiller University of Jena, Germany, and an honorary Sc.D. degree from West Virginia University. He received the Kleemeier Award for Distinguished Research Contributions and the Distinguished Career Contribution to Gerontology Award from the Gerontological Society of America, the MENSA lifetime career award, and the Distinguished Scientific Contributions award from the American Psychological Association. He is a past president of the APA Division of Adult Development and Aging and currently represents that Division on the APA Council of Representatives. He is author or editor of more than 60 books including the textbook *Adult Development and Aging* (5th edition, with S.L. Willis) and of all previous editions of the *Handbook of the Psychology of Aging* (with J.E. Birren or S.L. Willis). He has directed the Seattle Longitudinal Study of cognitive aging since 1956 and is the author of more than 300 journal articles and chapters on the psychology of aging. His current research interest is in the life course of adult intelligence, its antecedents and modifiability, the impact of cognitive behavior in midlife upon the integrity of brain structures in old age, the early detection of risk for dementia, as well as methodological issues in the developmental sciences.

Sherry L. Willis is a research professor in the Department of Psychiatry and Behavioral Sciences at the University of Washington. She previously held an appointment as professor of Human Development at the Pennsylvania State University. Her research has focused on age-related cognitive changes in later adulthood. In particular she is known for her work on behavioral interventions to remediate and enhance cognitive performance in community-dwelling normal elderly. She was a principal investigator on the ACTIVE study, a randomized controlled trial to examine the effects of cognitive interventions in the maintenance of everyday functioning in at-risk community-dwelling elderly, funded by NIA. She has been the co-director of the Seattle Longitudinal Study. In addition to her cognitive intervention research, she has conducted programmatic research on changes in everyday problem-solving competence in the elderly and cognitive predictors of competence. She and colleagues have developed several measures of Everyday Problem Solving. She is the co-author of the textbook *Adult Development and Aging* (with K.W. Schaie, now in its 5th edition). She has edited more than ten volumes on various aspects of adult development and cognition and has authored over a hundred publications in adult development. She has served as President of Division 20, Adult Development and Aging, American Psychological Association. She was a Fulbright

Fellow in Sweden. She received a Faculty Scholar Medal for Outstanding Achievement and the Pauline Schmitt Russell Distinguished Research Career Award from the Pennsylvania State University, and the Paul and Margret Baltes award from Divison 20 of the American Psychological Association. She currently has funding from NIA (MERIT Award) to examine midlife predictors of cognitive risk in old age and on the relationship of structural and functional MRI changes and cognitive stability or change in older adults.

Bob G. Knight is associate dean of the USC Davis School of Gerontology, the Merle H. Bensinger Professor of Gerontology and professor of Psychology at the Andrus Gerontology Center, University of Southern California. He also serves as director of the Tingstad Older Adult Counseling Center. He helped to organize and served as founding Chair of the Council of Professional Geropsychology Training Programs (2008). He has served as the president of both the Society for Clinical Geropsychology and the APA Division of Adult Development and Aging. His research interests include cross-cultural issues in family caregiving, age difference in the effects of emotion on cognition, and the development of wisdom. He received his Ph.D. in clinical psychology from Indiana University, Bloomington, IN.

Becca Levy is an associate professor in the Department of Epidemiology and Public Health and the Department of Psychology at Yale University. She received her doctoral training in Social Psychology, with a focus on the Psychology of Aging, from Harvard University. She was awarded a Brookdale National Fellowship, a Margret M. Baltes Early Career Award in Behavioral and Social Gerontology from the Gerontological Society of America, the Springer Award for Early Career Achievement on Adult Development and Aging from the American Psychological Association and an Investigator Award from the Donaghue Medical Research Foundation. Her research explores psychosocial influences on aging. Ongoing projects explore psychosocial determinants of longevity, psychosocial factors that contribute to elders' successful cognitive and physical functioning, and interventions to improve aging health.

Denise C. Park is the Distinguished University Professor of Behavioral and Brain Sciences as well as a Regents Research Scholar at the University of Texas at Dallas where she directs the Center for Vital Longevity. She is interested in not only how the function of the brain and mind changes with age, but also is focused on interventions that can be used to delay cognitive aging and support cognitive function in everyday life. Using both brain scans and behavioral studies, she tries to understand the role of age-related changes in memory function. Before joining UT Dallas, she was a professor at the University of Illinois, Urbana-Champaign, where she was director of the Center for Healthy Minds. She received her Ph.D. from the State University of New York at Albany. She is a fellow of the American Association for the Advancement of Science; received the American Psychological Association's award for Distinguished Contributions to the Psychology of Aging, and has served on the Board of Directors of the American Psychological Society as well as chaired the Board of Scientific Affairs of the American Psychological Association.

List of Contributors

Toni C. Antonucci Department of Psychology, University of Michigan, Ann Arbor, MI, USA

David E. Balk Department of Health and Nutrition Sciences, Brooklyn College of the City University of New York, Brooklyn, NY, USA

Lisa C. Barry University of Connecticut Health Center, Center on Aging, Farmington, CT, USA

Sylvie Belleville Department of Psychology, University of Montreal, Montréal, Canada

Lisa Berkman Harvard Center for Population and Development Studies, Harvard University, Cambridge, MA, USA

Walter R. Boot Psychology Department, Florida State University, Tallahassee, FL, USA

Axel Börsch-Supan Munich Center for the Economics of Aging, University of Munich, Germany

Amy L. Byers University of California, San Francisco, CA, USA and San Francisco Veterans Affairs Medical Center, San Francisco, CA, USA

Laura L. Carstensen Department of Psychology, Stanford University, Stanford, CA, USA

Neil Charness Psychology Department, Florida State University, Tallahassee, FL, USA

Christina A. Coulter University of Washington School of Nursing, Biobehavioral Nursing & Health Systems, Seattle, WA, USA

Natalie Dautovich Department of Psychology, The University of Alabama, Tuscaloosa, AL, USA

Kirk I. Erickson Department of Psychology, University of Pittsburgh, Pittsburgh, PA, USA

Michelle E. Farrell Center for Vital Longevity, School of Behavioral and Brain Sciences, University of Texas at Dallas, Richardson, TX, USA

Sara B. Festini University of Texas at Dallas, Dallas, TX, USA

Deborah G. Finkel Department of Psychology, Indiana University Southeast, New Albany, IN, USA

Linda P. Fried Mailman School of Public Health, Columbia University, New York, NY, USA

Helene H. Fung Department of Psychology, Chinese University of Hong Kong, Hong Kong, China

Frank F. Furstenberg Department of Sociology Department, University of Pennsylvania, Philadelphia, PA, USA

Denis Gerstorf Institute of Psychology, Humboldt University, Berlin, Germany

Dana Goldman Schaeffer Center for Health Policy and Economics, University of Southern California, Los Angeles, CA, USA

Patrick L. Hill Department of Psychology, Carleton University, Ottawa, ON, Canada

Christiane A. Hoppmann Department of Psychology, University of British Columbia, Vancouver, Canada

James S. Jackson Department of Psychology, University of Michigan, Ann Arbor, MI, USA

Tiffany K. Jantz University of Michigan, Ann Arbor, MI, USA

Da Jiang Department of Psychology, Chinese University of Hong Kong, Hong Kong, China

Deborah L. Kerr Department of Neurology, University of Alabama at Birmingham, AL, USA; Department of Psychiatry and Behavioral Neurobiology, University of Alabama at Birmingham, AL, USA

Seungyoun Kim School of Gerontology, University of Southern California, Los Angeles, CA, USA

Melissa H. Kitner-Triolo Laboratory of Behavioral Neuroscience, National Institute on Aging, Baltimore, MD, USA

Bob G. Knight School of Gerontology, University of Southern California, Los Angeles, CA, USA; Department of Psychology, University of Southern California, Los Angeles, CA, USA

Martin Kohli Bremen International Graduate School of Social Sciences, European University Institute, San Domenico di Fiesole, Italy

Simone Kühn Center for Lifespan Psychology, Max Planck Institute for Human Development, Berlin, Germany

Amanda Lash Department of Psychology and Volen National Center for Complex Systems, Brandeis University, Waltham, MA, USA

Kenneth L. Lichstein Department of Psychology, The University of Alabama, Tuscaloosa, AL, USA

Ziyong Lin University of Michigan, Ann Arbor, MI, USA

Ulman Lindenberger Center for Lifespan Psychology, Max Planck Institute for Human Development, Berlin, Germany; Max Planck University College London Centre for Computational Psychiatry and Ageing Research, Berlin, Germany

Teresa Liu-Ambrose Department of Physical Therapy, University of British Columbia, Vancouver, BC, Canada

Cindy Lustig University of Michigan, Ann Arbor, MI, USA

Stuart W.S. MacDonald Department of Psychology, University of Victoria, Victoria, BC, Canada

Daniel C. Marson Department of Neurology, University of Alabama at Birmingham, AL, USA; University of Alabama at Birmingham Alzheimer's Disease Center, Birmingham, AL, USA

Anna C. McCarrey Laboratory of Behavioral Neuroscience, National Institute on Aging, Baltimore, MD, USA

Christina S. McCrae Department of Clinical and Health Psychology, University of Florida, Gainesville, FL, USA

Glenise McKenzie Oregon Health & Science University School of Nursing, Ashland, OR, USA

Donald G. McLaren Department of Neurology, Massachusetts General Hospital, Boston, MA, USA and Harvard Medical School, Boston, MA, USA

S. Jay Olshansky School of Public Health, University of Illinois at Chicago, Chicago, IL, USA

Denise C. Park Center for Vital Longevity, School of Behavioral and Brain Sciences, University of Texas at Dallas, Richardson, TX, USA

Megan E. Petrov College of Nursing and Health Innovation, Arizona State University, Phoenix, AZ, USA

Sarah Rastegar Department of Psychology, University of Southern California, Los Angeles, CA, USA

Susan M. Resnick Laboratory of Behavioral Neuroscience, National Institute on Aging, Baltimore, MD, USA

Patricia A. Reuter-Lorenz University of Michigan, Ann Arbor, MI, USA

Chandra A. Reynolds Department of Psychology, University of California – Riverside, Riverside, CA, USA

Brent W. Roberts Department of Psychology, University of Illinois at Urbana-Champaign, Champaign, IL, USA

John Rother National Coalition on Health Care, Washington DC, WA, USA

John W. Rowe Department of Health Policy & Management, Mailman School of Public Health, Columbia University, New York, NY, USA

Lindsay H. Ryan Institute for Social Research, University of Michigan, Ann Arbor, MI, USA

K. Warner Schaie Department of Psychiatry and Behavioral Sciences, University of Washington, Seattle, WA, USA

Junqi Shi Department of Management, Lingnan (University) College, Sun Yat-sen University, Guangzhou, China

Jacqui Smith Institute for Social Research, University of Michigan, Ann Arbor, MI, USA; Department of Psychology, University of Michigan, Ann Arbor, MI, USA

Robert S. Stawski School of Social and Behavioral Health Sciences, Oregon State University, Corvallis, OR, USA

Linda Teri University of Washington School of Nursing, Psychosocial & Community Health, Seattle, WA, USA

Mo Wang Department of Management, Warrington College of Business Administration, University of Florida, Gainesville, FL, USA

Sherry L. Willis Department of Psychiatry and Behavioral Sciences, University of Washington, Seattle, WA, USA

Arthur Wingfield Department of Psychology and Volen National Center for Complex Systems, Brandeis University, Waltham, MA, USA

Julie Zissimopoulos Schaeffer Center for Health Policy and Economics, University of Southern California, Los Angeles, CA, USA

CHAPTER

1

Theoretical Perspectives for the Psychology of Aging in a Lifespan Context

K. Warner Schaie

Department of Psychiatry and Behavioral Sciences, University of Washington, Seattle, WA, USA

OUTLINE

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INTRODUCTION

Most of the editions of the *Handbook of the Psychology of Aging* have contained a chapter on theoretical issues, some combined with some methodological issues and/or the history of geropsychology (Baltes & Willis, 1977; Bengtson & Schaie, 1999; Birren & Birren, 1990; Birren & Cunningham, 1985; Birren & Schroots, 1996, 2001; Dixon, 2011; Salthouse, 2006). In this introductory chapter some of the major theoretical perspectives in studying normal aging from a lifespan perspective are summarized. This discussion is begun by challenging the often-voiced assumption that pathology is an inevitably aspect of normal aging and then examples of theories of aging that cover the adult lifespan are described.

K.W. Schaie & S.L. Willis (Eds)
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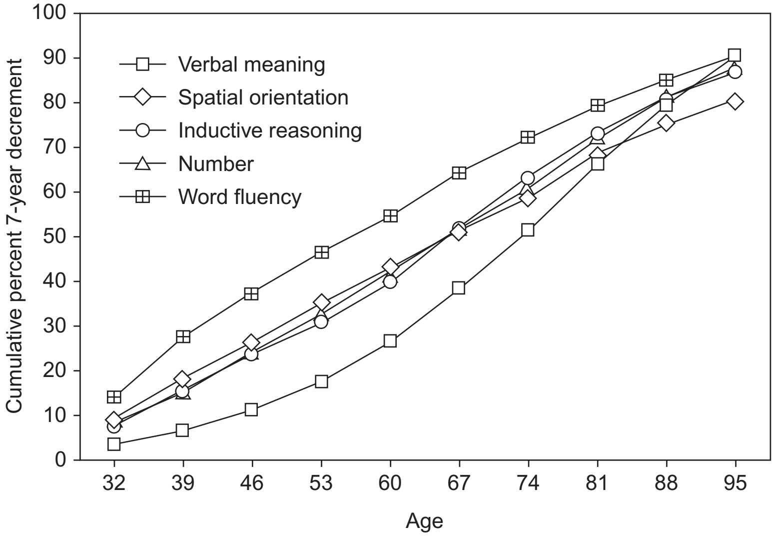

FIGURE 1.1 Cumulative proportion of significant decrement in different abilities occurring at successive ages from 32 to 95. Reproduced with permission from Schaie (2013).

THE ROLE OF PATHOLOGY IN NORMAL AGING

From a lifespan perspective, many of the statements made by psychologists about normal development in the last third of life have been clouded by what can only be described as buying into common societal stereotypes that we now call ageism (Hummert, 2011; Schaie, 1988). Such ageism seems to be informed by the assumption of universal declines in cognitive competence and the development of other undesirable psychological characteristics with advanced age. They have also been informed by clinicians' experiences in encountering primarily older clients with psychological problems rather than the large number of elderly whom we would describe as aging successfully. In a rapidly changing society we also continue to confuse differences between old and young that are a function of greater educational and other opportunity structures for the younger cohorts with age-related changes. This confusion leads to language in the scientific literature that interprets age differences that reflect complex population differences as "aging decline" (Schaie, 1993).

ASSUMPTION OF UNIVERSAL DECLINE

Negative stereotypes about the elderly are ubiquitous with respect to many domains of behavior and perceived attributes (Hess, 2006), even though some exceptions are found in attributed wisdom and altruistic behavior (cf. Pasupathi & Löckenhoff, 2002). Perhaps one of the most serious assumptions made by many psychologists is that of universal cognitive decline. While it is true that the proportion of individuals who show cognitive decline increases with each decade after the 60s are reached, it is equally true that many individuals do not show such decline until close to their demise, and that some fortunate few, in fact, show selective ability gains from midlife into old age. Figure 1.1 shows data from the Seattle Longitudinal Study to document this point (Schaie, 2013).

The data showing that there is no universal decline with increasing age of behavioral effectiveness however should not be interpreted as the absence of biological deficits with increasing age. In fact, disease-free aging is an infrequent experience for only a lucky few (cf. Solomon, 1999). Indeed, effective health behaviors are significantly associated with optimal aging (Aldwin, Spiro, & Park, 2006).

SUCCESSFUL, NORMAL AND PATHOLOGICAL AGING

It is readily apparent that there are vast individual differences in patterns of psychological changes from young adulthood through old age. Scrutiny of a variety of longitudinal studies of psychological aging (cf. Schaie & Hofer, 2001) suggests that four major patterns will describe most of the observed aging trajectories, although further subtypes could, of course, be considered (Schaie, 2008). These patterns would classify individuals into those who age successfully (the super-normals), those who age normally, those who develop mild cognitive impairment (MCI), and finally those who become clinically diagnosable as suffering from dementia.

The most common pattern is what we could denote as the *normal aging* of psychological functions. This pattern is characterized by most individuals reaching an asymptote in early midlife, maintaining a plateau until the late 50s or early 60s, and then showing modest decline on most cognitive abilities through the early 80s, with more marked decline in the years prior to death (cf. Bosworth, Schaie, & Willis, 1999). They also tend to become more rigid and show some changes on personality traits in undesirable directions (Schaie, Willis, & Caskie, 2004). Among those whose cognitive aging can be described as normal, we can distinguish two subgroups. The first include those individuals who reach a relatively high level of cognitive functioning who, even if they become physically frail, can remain independent until close to their demise. The second group who only reach a modest asymptote in cognitive development, on the other hand, may in old age require greater support and be more likely to experience a period of institutional care.

A small subgroup of adults experience what is often described as *successful aging* (Fillit et al., 2002; Rowe & Kahn, 1987). Members of this group are often genetically and socioeconomically advantaged, they tend to continue cognitive development later than most and typically reach their cognitive asymptotes in late midlife. While they too show some very modest decline on highly speeded tasks, they are likely to maintain their overall level of cognitive functioning until shortly before their demise. They are also likely to be less neurotic and more open to experience than most of their age peers. These are the fortunate individuals whose active life expectancy comes very close to their actual life expectancy.

The third pattern, *MCI* (Petersen et al., 1999), includes that group of individuals who, in early old age, experience greater than normative cognitive declines. Various definitions, mostly statistical, have been advanced to assign membership to this group. Some have argued for a criterion of 1 *SD* of performance compared to the young adult average, while others have proposed a rating of 0.5 on a clinical dementia rating scale, where 0 is normal and 1.0 is probable dementia. Earlier on, the identification of MCI required the presence of memory loss, in particular. However, more recently the diagnosis has been extended to decline in other cognitive abilities and clinicians now distinguish between amnestic and non-amnestic MCI patterns. There has also been controversy on the question of whether individuals with the diagnosis of MCI inevitably progress to dementia, or whether this group of individuals represents a unique entity; perhaps one that could be denoted as *unsuccessful aging* (cf. Petersen, 2003).

The final pattern includes those individuals who, in early or advanced old age, are diagnosed as suffering from *dementia*. Regardless of the specific cause of the dementia these individuals have in common dramatic impairment in cognitive functioning. However, the pattern of cognitive change, particularly in those whose diagnosis at post mortem turns out to be Alzheimer's disease, is very different from the normally aging. When followed longitudinally, at least some of these individuals show earlier decline, perhaps starting in midlife. But other individuals may have become demented because of increased and sometimes profound vascular brain lesions.

LIFESPAN THEORIES OF PSYCHOLOGICAL AGING

There have been few comprehensive theories of psychological development that have fully covered the period of adulthood (Schaie & Willis, 1999). The broadest approaches have been those of Erikson (1982), Erikson, Erikson, and Kivnick (1986), and Baltes (1997). Baltes' selection, optimization, and compensation (SOC) theory represents a dialectical lifespan approach. Psychological gains and losses occur at every life stage, but in old age losses far exceed the gains. Baltes considers evolutionary development incomplete for the very last stage of life, during which societal supports no longer fully compensate for declines in physiological infrastructure and losses in behavioral functionality (see Baltes, 1987; Baltes & Smith, 1999; Baltes, Staudinger, & Lindenberger, 1999). SOC, however, can also be seen as strategies of life management, and thus may be indicators of successful aging (Baltes & Freund, 2003). For a fuller exposition of SOC theory and review of relevant empirical studies, see Riedinger, Li, and Lindenberger (2006). The SOC theory has recently been expanded to a co-constructionist biosocial theory (Baltes & Smith, 2004; Willis & Schaie, 2006; see below). Theoretical models limited to the domain of cognition have also been proposed by Schaie and Willis (2000), Willis & Schaie (2006), and Sternberg (1985). I will here describe more fully, the Eriksonian, and the Schaie and Willis stage theories, as well as the more recent co-constructive theory.

Erikson's Stage Model

Traditional psychodynamic treatments of the lifespan have been restricted primarily to the development of both normal and abnormal personality characteristics. With the exception of some ego psychologists (Loevinger, 1976), however, Erik Erikson remains the primary theorist coming from a psychoanalytic background who has consistently pursued a lifespan approach. Although Erikson's most famous concept, the identity crisis, is placed in adolescence, the turmoil of deciding "who you are" continues in adulthood, and identity crises often recur throughout life, even in old age (Erikson, 1979). Moreover, Erikson (1982) takes the position that "human development is dominated by dramatic shifts in emphasis."

In his latest writing, Erikson (influenced by his wife Joan) redistributed the emphasis on the various life stages more equitably. He argued that the question of greatest priority in the study of ego development is "how, on the basis of a unique life cycle and a unique complex of psychosocial dynamics, each individual struggles to reconcile earlier themes in order to bring into balance a lifelong sense of trustworthy wholeness and an opposing sense of bleak fragmentation" (Davidson, 1995; Erikson et al., 1986; Goleman, 1988).

The *intimacy crisis* is the primary psychosocial issue in the young adult's thoughts and feelings about marriage and family. However, recent writers suggest that this crisis must be preceded by identity consolidation that is also thought to occur in young adulthood (cf. Pals, 1999).

The primary issue of middle age, according to Erikson, is *generativity versus stagnation* (McAdams & de St. Aubin, 1998; Snarey, Son, Kuehne, Hauser, & Vaillant, 1987). Broadly conceived, *generativity* includes the education of one's children, productivity and creativity in one's work, and a continuing revitalization of one's spirit that allows for fresh and active participation in all facets of life. Manifestations of the generativity crisis in midlife are career problems, marital difficulties, and widely scattered attempts at "self-improvement."

Successful resolution of the generativity crisis involves the human virtues of caring, giving, and teaching, in the home, on the job, and in life in general. In Erikson's view of ego development, the final years of life mark the time of the *integrity versus despair crisis*, when individuals look back over their lives (Haight, Coleman, & Lord, 1994) and decide that they were well ordered and meaningful (integrated) or unproductive and meaningless (resulting in despair).

Those who despair approach the end of life with the feeling that death will be one more frustration in a series of failures. In contrast, the people with integrity accept their lives (including their deaths) as important and on the whole satisfying. In a sense, ego integrity is the end result of the lifelong search for ego identity, a recognition that one has coped reasonably successfully with the demands of both the id and society (Erikson, 1979,1982; Whitbourne, 1996). Once old age is reached it may be most advantageous for the person to rigidly maintain this identity (Tucker & Desmond, 1998).

The final stage of life includes an exploration of personal grounds for faith. Erikson points out that the aged share with infants what he calls the "numinous" or the experience of the "ultimate other." Its mother provided the latter experience for the infant. By contrast, the experience of ultimate confidence is provided for the older person by the confirmation of the distinctiveness of their integrated life and by its impending transcendence (Erikson, 1984).

A formal investigation of the progression through the Eriksonian stages from young adulthood into midlife has been conducted by administering an inventory of psychosocial development to three cohorts of college students, followed-up after 11 and 22 years (Whitbourne, Zuschlag, Elliot, & Waterman, 1992). This study showed not only inner psychological changes as postulated by Erikson, but also showed effects of exposure to particular historical, cultural, and social realities of the environment.

As higher stages were attained there also seemed further resolution of the earlier stages of development, suggesting a process of continuous reorganization, beyond the stage-specific issues confronted by the individual. In addition, this study raises the possibility that the sequencing of stages may not be unidirectional, and it further suggests cohort differences that implied less favorable resolution of ego integrity versus despair over the decade of the 1980s (Whitbourne & Connolly, 1999).

Schaie and Willis' Stage Theory of Cognition

This theory uses findings from research on adult intellectual development to formulate eight adult stages. They argue that while Piaget's childhood stages describe increasing efficiency in the acquisition of new information, it is quite doubtful that adults progress beyond the powerful methods of science (formal operations) in their quest for knowledge. Therefore, if one is to propose adult stages, they should not be further stages of acquisition; but, instead, such stages should reflect different uses of intellect.

In young adulthood, for example, people typically switch their focus from the acquisition to the application of knowledge, as they use what they know to pursue careers and develop their families. This is called the *achieving* stage. It represents most prominently the application of intelligence in situations that have profound consequences for achieving long-term goals. The kind of intelligence exhibited in such situations is similar to that employed in educational tasks, but it requires careful attention to the possible consequences of the problem-solving process.

Young adults who have mastered the cognitive skills required for monitoring their own behavior and, as a consequence, have attained a certain degree of personal independence will next move into a stage that requires the application of cognitive skills in situations involving social responsibility. Typically, the *responsible* stage occurs when a family is established and the needs of spouse and offspring must be met. Similar extensions of adult cognitive skills are required as responsibilities for others are acquired on the job and in the community.

Some individuals' responsibilities become exceedingly complex. For example, officials of churches, and a number of other positions need to understand the structure and the dynamic forces of organizations. They must monitor organizational activities not only on a temporal dimension (past, present, and future), but also up and down the hierarchy that defines the organization. They need to know not only the future plans of the organization, but also whether policy decisions are being adequately translated into action at lower levels of responsibility. Attainment of the *executive* stage, as a variation on the responsibility stage, depends on exposure to opportunities that allow the development and practice of the relevant skills (Avolio, 1991; Smith, Staudinger, & Baltes, 1994).

In the later years of life, beyond the ages of 60 or 65, the need to acquire knowledge declines even more and executive monitoring is less important because frequently the individual has retired from the position that required such an application of intelligence. This stage, *reintegration*, corresponds in its position in the life course to Erikson's stage of ego integrity. The information that elderly people acquire and the knowledge they apply become a function of their interests, attitudes, and values. It requires, in fact, the *reintegration* of all of these.

The elderly are less likely to "waste time" on tasks that are meaningless to them. They are unlikely to expend much effort to solve a problem unless that problem is one that they face frequently in their lives. This stage frequently includes a selective reduction of interpersonal networks in the interest of reintegrating one's concern in a more self-directed and supportive manner (cf. Carstensen, 1993; Carstensen, Gross, & Fung, 1997).

In addition, efforts must be directed towards planning how one's resources will last for the remaining 15–30 years of postretirement life that are now characteristic for most individuals in industrialized societies. These efforts include active planning for that time when dependence upon others may be required to maintain a high quality of life in the face of increasing frailty. Such efforts may involve changes in one's housing arrangements, or even one's place of residence, as well as making certain of the eventual availability of both familial and extra-familial support systems. The activities involved in this context include making or changing one's will, drawing up advanced medical directives and durable powers of attorney, as well as creating trusts or other financial arrangements that will protect resources for use during the final years of life or for the needs of other family members.

Although some of these activities involve the same cognitive characteristics of the responsible stage, these objectives involved are far more centered upon current and future needs of the individual rather than the needs of their family or of an organizational entity. Efforts must now be initiated to reorganize one's time and resources to substitute a meaningful environment, often found in leisure activities, volunteerism, and involvement with a larger kinship network.

Eventually, however, activities are also engaged in to maximize quality of life during the final years, often with the additional objective of not becoming a burden for the next generation. The unique objective of these demands upon the individual represent an almost universal process occurring at least in the industrialized societies, and designation of a separate *reorganizational* stage is therefore warranted.

The skills required for the reorganizational stage require the maintenance of reasonably high levels of cognitive competence. In addition, maintenance of flexible cognitive styles is needed to be able to restructure the context and content of life after retirement, to relinquish control of resources to others and to accept the partial surrender of one's independence (Schaie, 1984, 2013).

Many older persons reach advanced old age in relative comfort and often with a clear mind albeit a frail body. Once the reintegrative efforts described above have been successfully completed, yet one other stage is frequently observed.

This last stage is concerned with cognitive activities by many of the very old that occur in anticipation of the end of their life. This is a *legacy-creating* stage that is part of the cognitive development of many, if not all, older persons. This stage often begins by the self- or therapist-induced effort to conduct a life review (Butler, Lewis, & Sunderland, 1998). For the highly literate and those successful in public or professional life this will often include writing or revising an autobiography (Birren, Kenyon, Ruth, Schroots, & Swensson, 1995; Birren & Schroots, 2006).

There are also many other more mundane legacies to be left. Women, in particular, often wish to put their remaining effects in order, and often distribute many of their prized possessions to friends and relatives, or create elaborate instructions for distributing them. It is not uncommon for many very old people to make a renewed effort at providing an oral history or to explain family pictures and heirlooms to the next generation. Last, but not least, directions may be given for funeral arrangements, occasionally including donation of one's body for scientific research, and there may be a final revision of one's will.

The Co-Constructive Perspective

Both neurobiological and sociocultural influences on development have long been recognized. Co-evolutionary theorists (Dawkins, 1989; Dunham, 1991; Tomasello, 1999) suggest that both biological and cultural evolution have occurred and that recent, cohort-related advances in human development in domains such as intelligence can be attributed largely to cumulative cultural evolution. Cultural activities impact the environment, thereby influencing mechanisms such as selection processes; and thus allow humans to co-direct their own evolution (Cavalli-Sforza & Feldman, 1981; Dunham, 1991). Baltes' and his colleagues' (Baltes, 1997; Li, 2003; Li & Freund, 2005) co-constructionist approach imposes a lifespan developmental perspective on co-evolutionary theory and provides principles regarding the timing of the varying contributions of neurobiology and culture at different developmental periods and across different domains of functioning. Three principles are proposed regarding the relative contributions of biology and culture influences across the lifespan:

1. Beneficial effects of the evolutionary selection process occur primarily in early life and are less likely to optimize development in the later half of life.
2. Further advances in human development depend on ever-increasing cultural resources. From a historical perspective, increases in cultural resources have occurred via cumulative cultural evolution and have resulted in humans reaching higher levels of functioning. At the individual level,

increasing cultural resources are required at older ages for further development to occur or to prevent age-related losses.

3. The efficacy of increasing cultural resources is diminished in old age, due to decline in neurobiological functions.

Li (2003) proposes a triarchic view of culture involving three aspects of culture that are related to the co-constructionist perspective: resource, process, and developmental relevancy. Culture as social resources involves the knowledge, values, and material artifacts accumulated by a society and transmitted to future generations; these resources continue to develop and change through cumulative cultural evolution (Tomasello, 1999). Expanding upon Li's triarchic view of cultural domains, Willis and Schaie (2006) view accumulated cultural resources as being represented by structural variables such as educational level, occupational status, and ability level. These variables reflect the individual's acquisition and accumulation of cultural knowledge and skills primarily during the first half of adulthood.

Culture as ongoing social process involves the routines, habits, and performances of the individual in daily life that take place in the individual's proximal developmental context and that are shaped by the momentarily shared social reality (Li, 2003). The third component of developmental relevancy suggests that the impact of particular cultural resources and processes on an individual is partially determined by the individual's developmental stage, which has also been termed the "developmental niche" (Gauvain, 1998; Super & Harkness, 1986).

The increased influence of neurobiological factors in old age is thought to be based in part on the assumption among evolutionary theorists that positive selection effects are most clearly manifest early in the lifespan and that the expression of deleterious genes in old age has been less constrained by the evolutionary process (Finch & Kirkwood, 2000).

SUMMARY AND OUTLOOK

This chapter started by discussing the role of pathology in the study of normal aging by critiquing the concept of universal decline with increasing age and by distinguishing between successful, normal, and pathological aging. Then the limited number of theoretical perspectives that address behavioral changes across the adult lifespan was reviewed and the aging aspects of Erikson's stage theory, and its extension to old age by Schaie and Willis, as well as the co-constructive perspective exemplified by Baltes and Li's SOC theory were described in greater detail.

Given the mushrooming interest of behavioral and neuroscientists in the interface of normal and neuropathological change in brain tissues and neural networks with age, we can expect much theoretical attention in the coming years on concepts such as neural and behavioral reserve, both in terms of neural mechanisms as well as the influence of behavioral factors on the maintenance of high-level neural functioning. And instead of the preoccupation with the prediction of neuropathology, greater interest is likely to develop in mechanisms which lead to slower relates of normal decline in successive cohorts and the retention of a higher level of function in greater proportions of the older population.

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CHAPTER

2

Methodological Considerations for the Study of Adult Development and Aging

Stuart W.S. MacDonald[1] *and Robert S. Stawski*[2]

[1]**Department of Psychology, University of Victoria, Victoria, BC, Canada** [2]**School of Social and Behavioral Health Sciences, Oregon State University, Corvallis, OR, USA**

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INTRODUCTION

This chapter explores key methodological and analytical considerations for the study of adult development and aging. In particular, we focus on central themes that are routinely encountered in conducting current aging research. We address a range of topics, from design selection and sampling considerations (including novel developmental research designs) to key considerations regarding missing data as well as the impact of attrition and retest on statistical parameter estimates. Given recent advances in research design and statistical modeling of developmental phenomena and their application to the study of the psychology of aging, we overview several analytic procedures and approaches that help to efficiently characterize aging-related change for various phenomena. In particular, we summarize several models for measuring change, explore multivariate approaches for examining correlated and coupled change, as well as compare alternative metrics for parameterizing developmental time. Finally, we conclude by highlighting emerging methodological trends in the study of adult development and aging, including recent emphasis on integrated data analysis and harmonization, as well as adopting an intraindividual variability approach for informing dynamic aging-related processes.

RESEARCH DESIGNS AND SAMPLING CONSIDERATIONS FOR THE STUDY OF ADULT DEVELOPMENT AND AGING

This section overviews two classic research designs for the psychology of aging, contrasts their relative strengths and weaknesses, and concludes with a thorough overview of a specific subtype of longitudinal design (the measurement burst design) and its merits for studying select developmental phenomena.

Cross-Sectional Versus Longitudinal Designs

The theoretical focus of any study, as well as its corresponding research questions, helps to predetermine selection of the most suitable research design. Research designs for studies of adult development and aging reflect a combination of age, cohort, and period effects (Schaie, 2013). Further, for any study of the psychology of aging and underlying developmental processes, it is essential to distinguish between age-related differences and aging-related changes. The following section briefly addresses these issues; rather than an exhaustive overview of possible research designs, we focus in particular on cross-sectional versus longitudinal approaches to the study of adult developmental and aging.

Age Differences Versus Change

Age differences are indexed using cross-sectional research designs and reflect differences in constructs (e.g., cognitive function, wellbeing) across age-heterogeneous groups or samples of individuals measured at *a single point* in time. Comparisons across these individuals or groups would afford insight into *age differences* in level(s) of cognitive function or wellbeing, but provide no information about how these constructs may be changing over time. In contrast, the study of aging-related change is the province of longitudinal research designs. Such designs index changes in constructs by testing a group of individuals over multiple occasions of assessment. By studying the same individuals over time, we are able to derive within-person estimates for the direction and rate of change.

Relative Advantages Versus Disadvantages

Cross-sectional studies offer a number of advantages including efficiency (e.g., less time required to collect data) as well as avoiding select confounds such as retest effects (Salthouse, 2009). However, with regard to the study of adult development and aging, notable weaknesses of cross-sectional designs include an overestimation of age-related performance differences due to cohort effects (Nilsson, Sternäng, Rönnlund, & Nyberg, 2009), as well as an inability to address arguably the most *important aim* of aging research—whether *aging-related change* is occurring (Hofer & Sliwinski, 2001). As cross-sectional assessments are conducted at a single point in time, such designs necessarily confound age and cohort effects. Consequently, it is not possible to differentiate whether observed group differences are due to developmental age processes or to shared experiences characterizing cohort effects. In contrast, longitudinal studies facilitate the direct estimation of within-person change, as well as the possibility of investigating individual differences in change (Hofer & Sliwinski, 2001). Most if not all research questions and theories in adult development and aging are interested in such effects. To be sure, longitudinal designs also entail a number of limitations including the cost (both in terms of added expense for longitudinal collections and the time required to conduct repeated assessments to study aging processes that typically span years rather than months), as well as design considerations and analytic complexities (Curran & Bauer, 2011; Hertzog, Lindenberger, Ghisletta, & Oertzen, 2006; Hoffman & Stawski, 2009). Furthermore, longitudinal designs confound age and time of measurement—observed changes in outcomes of interest may be due to age- and/or cohort-related processes (if an age-heterogeneous cohort is being studied longitudinally), or to events at the time of measurement that exerted a pervasive influence on all individuals.

When contrasting patterns and magnitude of effects, decades of research have demonstrated differences in results between cross-sectional (i.e., age-related differences) and longitudinal (i.e., aging-related changes) designs. More specifically, estimates of longitudinal aging-related changes are routinely smaller than estimates of cross-sectional age-related differences. Cross-sectional age-related differences are often greatly influenced by cohort effects between the age groups under study, such as societal shifts in formal education and the corresponding impact on cognitive performance (Nilsson et al., 2009). Longitudinal aging-related changes are often influenced by selective attrition from longitudinal follow-up (e.g., more frail individuals discontinue participation), as well as practice or retest effects (with repeated exposure/assessments tending to obscure true age-related decline). The topics of attrition and retest are reviewed in detail in the subsequent section concerning key methodological considerations for the study of aging.

Which Design Is Best Suited for the Study of Aging?

A recent special issue in *Neurobiology of Aging* (Volume 30, 2009) focused on an enduring question in research on the psychology of aging—"*When does age-related cognitive decline begin?*" Perhaps better than any description we can offer, this collection of articles directly addresses the conundrum regarding whether cross-sectional versus longitudinal designs are best suited for the study of aging. Despite consistently reported negative associations between age and cognitive function in cross-sectional studies (cf. Salthouse, 2009), many theorists and methodologists alike posit that the study of *aging-related change* necessitates longitudinal data. Indeed, Molenaar (2004) has forcefully argued that inferences about longitudinal aging-related change can only be drawn from studies of cross-sectional age-related differences when very strict (and often unrealistic) assumptions are met (also see Curran & Bauer, 2011; Hoffman & Stawski, 2009). Similarly, Hofer and Sliwinski (2001) contend that aging is a *within-person phenomenon*, and that longitudinal research designs are requisite for evaluating aging-related theories and propositions in particular. A central tenet of their argument is that the study of aging is a process that transpires within-persons over time, and can only be observed through the study of change. Moreover, as findings have clearly shown (MacDonald, Hultsch, Strauss, & Dixon, 2003; Sliwinski & Buschke, 1999), the correspondence between age-cognition trends for between-person versus within-person variance and covariance estimates is often modest at best.

One might question the relative importance of this issue and why it matters. To address this, consider an example regarding the process of forgetting from the episodic memory literature, where for decades, general consensus was that rates of forgetting were invariant across persons, despite known individual differences in encoding and retrieval processes (cf. MacDonald, Stigsdotter-Neely, Derwinger, & Bäckman, 2006). The generally accepted interpretation was that rates of acquisition and forgetting are asymmetrical, rather than processes anchoring disparate ends of a memory continuum. However, a competing explanation as to why individual differences in forgetting were rarely identified may be based upon this literature's more typical reliance on between- as opposed to within-person designs and estimates. With regard to forgetting, it is tenuous to assume that mean group differences will exhibit identical patterns to individual differences (Hofer & Sliwinski, 2001). For example, a negative correlation between learning and forgetting reported at the between-participants level (those individuals who learned more will also forget less) does not guarantee that a similar negative association will be observed at the within-person level (for any given individual, learning information at a faster rate will be associated with a slower rate of forgetting over time). Such discrepancies have been long described by the ecological fallacy (Robinson, 1950), stating that mean (group-level) findings can differ in both magnitude and valence relative to individual results (Molenaar, 2004).

Of direct relevance to the question regarding which research design is best suited to the study of aging, the *aggregation bias* just described represents perhaps the most critical weakness of cross-sectional designs. Specifically, due to considerable between-subject age heterogeneity (e.g., samples that span 50–90 years of age) at the single point of assessment, associations between measures (e.g., memory and sensory function) observed in cross-sectional designs are positively biased due to the confounding influence of population average age trends. Virtually any variables that exhibit cross-sectional age differences on average (e.g., poorer memory function and auditory acuity for those in the ninth versus seventh decades of life) will result in a positively biased association at the between-person level *even if* corresponding within-person associations for rates of change for the very same measures are nonsignificant or inversely associated (for further discussion, see

Hofer & Sliwinski, 2001). This bias introduced in cross-sectional studies due to population mean confounds is particularly troubling for hypotheses and theories predicated largely upon cross-sectional data. For example, evidence from cross-sectional studies consistently provided strong support for the processing speed hypothesis (Salthouse, 1996), indicating that age-related differences in higher order cognitive function could be explained by age-related decreases in processing speed. However, when examined using longitudinal data, evidence for this hypothesis was modest at best (MacDonald et al., 2003; Sliwinski & Buschke, 1999; Stawski, Sliwinski, & Hofer, 2013). Whereas cross-sectional studies routinely reported that greater than 90% of age-related differences in cognitive function could be accounted for by processing speed, the use of identical constructs and measures in longitudinal designs found that *change* in perceptual speed accounted for only 20% (or less) of change variance in other cognitive outcomes. Such a discrepancy provides an important example of the cross-sectional fallacy—within-person aging-related changes spanning longitudinal segments of time cannot be necessarily inferred from cross-sectional age-related differences indexed at any single point in time (cf. Schaie, 2009).

Summary

Beyond the mere passage of time, understanding how the aging process unfolds requires research designs that incorporate between-person differences, within-person rates of change, as well as individual differences in change. There is a long history in the study of human development, and adulthood development and aging in particular, advocating for longitudinal designs in keeping with key foci including the study of performance change over time as well as an idiographic emphasis (Nesselroade & Baltes, 1979). With regard to the study of aging-related change, we side with many other aging scholars who advocate for the use of longitudinal designs (Ferrer & Ghisletta, 2011; Schaie, 2009).

Longitudinal Designs: Select Subtypes

Whereas longitudinal designs provide a vehicle for directly examining aging-related changes, simply collecting longitudinal (or repeated measures data), without consideration of the temporal cadence of the phenomena under study, may offer relatively limited theoretical and empirical yield. For example, whether one's focus concerns ontogenetic versus microgenetic forms of within-person change will necessitate selection of a specific subtype of longitudinal design. Thus, if the focus concerns aging-related changes in cognitive function, such characteristically slow(er) and more enduring within-person change reflects processes that transpire across months, years, or decades, with a typically employed longitudinal design characterized by single assessments separated by months or years (cf. Nesselroade, 1991). In contrast, more labile (i.e., transient, fluctuating) phenomena (e.g., neuroendocrine or emotional responses to stressful experiences, trial-to-trial variability in response times (RTs)) require indexing change across much shorter time periods (e.g., seconds, minutes, days, or weeks). Failure to consider the (hypothesized) temporal interval of the process or phenomena of interest and design a longitudinal study accordingly could lead to results and conclusions that are misaligned with theory and process (Neupert, Stawski, & Almeida, 2008). Employing longitudinal research designs (e.g., multiple time points with well-reasoned retest intervals) and corresponding analytic techniques (e.g., linear mixed models) represent critical considerations when attempting to study processes in their appropriate time courses in service of the study of aging. In particular, the measurement burst design facilitates the study of dynamic aging processes that unfold across distinct temporal intervals. The following subsection briefly overviews the longitudinal intensive measurement burst design (Nesselroade, 1991; Rast, MacDonald, & Hofer, 2012; Sliwinski, 2008) and its utility for studying select aging processes.

Intensive Measurement Burst Design

The measurement burst design incorporates data sampling across distinct temporal intervals: bursts of intensive repeated assessments within a relatively short duration (e.g., spanning hours, days, or weeks), with these bursts repeated longitudinally across longer temporal intervals (e.g., months, years). A cross-sectional study conducting assessment for a single point in time confounds trait-like (e.g., stable characteristics of a person such as intelligence or personality), state-like (e.g., a person's momentary state characterized by stress, fatigue, or anger), and developmental (e.g., developmental metastates such as pre- vs. postretirement, pre- vs. postdisease state) influences. Single assessment designs simply cannot distinguish among these competing sources of variance. By blending intensive repeated measures designs (e.g., ecological momentary assessment, daily diaries) within traditional longitudinal designs (e.g., annual retests), the measurement burst design attempts to address these shortcomings.

There are numerous advantages of the measurement burst design, including: (i) the use of multiple assessments within a short period of time offering improved measurement properties of variables and for the detection of change, (ii) the ability to disambiguate shorter-term and transient fluctuations (i.e., intraindividual variability) from longer-term and durable changes (i.e., intraindividual change), and (iii) the ability to formally examine how faster-moving processes, reflected in intraindividual variability, influence slower-moving processes reflected in intraindividual change (Nesselroade, 1991; Ram & Gerstorf, 2009; Rast et al., 2012; Stawski, MacDonald, & Sliwinski, in press; Stawski, Smith, & MacDonald, 2015).

Of particular note is the third point above—that the measurement burst design represents an invaluable methodological tool for the study of dynamic processes that unfold across both near- and long-term intervals, as well as how these processes influence one another (see related discussion in later section on *intraindividual variability*). As with standard longitudinal studies, the sampling timescale of the measurement burst design must be carefully matched to the particular aging process under study. However, in contrast to traditional longitudinal designs that only need to consider the interval between successive assessments, measurement burst designs require consideration of the temporal interval of the intensive burst of assessments, as well as the temporal interval over which these successive bursts of assessments will be repeated. Such decisions should be informed on both theoretical and empirical grounds. For example, for cognitive processes like memory, a well-suited decision might entail a series of short-term assessments spanning days or weeks as well as longer-term follow-up assessments spanning years, with the former elucidating intraindividual variability in memory processes (e.g., learning) and the latter informing more durable, developmental change. In contrast, processes such as emotional reactivity to stressors that transpire over much shorter timescales will need to consider the appropriate interval of assessment and design accordingly. By conducting assessments within (e.g., ecological momentary assessment) and/or across (e.g., daily diary designs) days, such designs are particularly effective at capturing dynamic processes. In some instances, employing variation in the spacing of assessments may be particularly advantageous, both within bursts (e.g., random or event contingent sampling for ecological momentary assessment) as well as across bursts (e.g., more frequent assessments for at-risk populations—such as 6-month retests for those in the early stages of dementia versus every few years for otherwise healthy older adults). To be sure, it should be emphasized that different timescales are not necessarily interchangeable (Neupert et al., 2008), and that variance in processes observed across these distinct timescales is not necessarily a function of the same causes or correlates (Hoffman & Stawski, 2009; Sliwinski, Smyth, Stawski, & Wasylyshyn, 2005).

KEY THREATS TO THE VALIDITY OF LONGITUDINAL DESIGNS

Although longitudinal designs have many definitive advantages for addressing central research questions in the study of adult development and aging, to be sure, there are some notable limitations that must be considered including attrition, retest effects, and missingness. In this section, we provide an overview of these limitations, as well as offer some basic guidelines for researchers to consider when analyzing data influenced by these factors.

Attrition

Selection processes including non-representative initial sampling and attrition pose important concerns for drawing inferences from our data. The potential impact of incomplete data is invariably first encountered during the participant recruitment phase. At this initial stage, attrition due to refusal to participate or failure to respond to the invitation is often discounted as an important source of sampling bias (Ferrer & Ghisletta, 2011). However, to the extent that the initial sample in a longitudinal study is less or non-representative of the target population, then parameter estimates and corresponding inferences drawn about longitudinal change may be biased or inaccurate (Hofer & Sliwinski, 2001). Participant attrition in a longitudinal study may be due to illness (self or other), lack of interest, adverse reactions to testing, relocation, or death. In addition, it is not uncommon for participants to selectively complete certain tasks in the measurement battery, and to avoid attempting others. Such observed attrition within a longitudinal study represents an internal validity threat to the research study design (Hultsch, Hertzog, Dixon, & Small, 1998). Of even greater concern is the issue of whether attrition is non-random. If there is a systematic relationship between attrition, missing an entire retest assessment, or failing to complete specific measures, such non-random or selective attrition is likely to systematically bias patterns or rates of change, with the most pronounced effects of attrition usually occurring between the first and second measurement occasions (Hultsch, Hertzog, Dixon, & Small, 1998). Individuals who remain in longitudinal studies often tend to be more select, exhibiting better health and cognitive functioning (Radler & Ryff, 2010). In addition to threatening internal validity, attrition may also result in diminished statistical power (Ferrer & Ghisletta, 2011; Gustavson, von Soest, Karevold, & Roysamb, 2012). Longitudinal studies provide opportunity to explore the impact of a given selection process (e.g., dropout, death) as well as to incorporate such processes into the model to improve our inferences about change based on tenable assumptions regarding the underlying attrition process (Graham, 2009; Little & Rubin, 1987).

Retest Effects

For some time, practice or retest effects have been recognized as a threat to the internal validity of longitudinal studies (Salthouse, 2009). In the case of cognitive function, the process under study (e.g., episodic memory) may be directly influenced by repeated exposure to memory tasks, thereby benefitting performance on subsequent occasions. Any systematic association between the process under study (i.e., aging-related declines in episodic memory) and the repeated longitudinal assessment (i.e., retest or practice-related improvements) exert opposing influences on performance and (potentially) bias observed developmental trajectories (Hultsch et al., 1998; Schaie, 2013). The degree of retest effect bias is influenced by several determinants including the amenability of the construct under study to practice, the length of time spanned by the retest interval, and the number of longitudinal assessments (Ferrer & Ghisletta, 2011; McArdle & Woodcock, 1997). Certain attributes such as measures of biological function (e.g., markers of blood chemistry, pulmonary function) can remain largely uninfluenced by repeated assessments, whereas other abilities are far more amenable to practice (e.g., developing strategies for successfully completing cognitive tasks). In the study of adult development and aging, cognitive functions are putatively the most susceptible to retest effects (Hultsch et al., 1998; McArdle & Woodcock, 1997; Schaie, 2013). Similarly, longer retest intervals (e.g., >5 years between retest intervals) are suggested to exert a more modest effect on patterns of change (Rönnlund, Nyberg, Bäckman, & Nilsson, 2005; Schaie, 2013), with the most marked retest effects observed between the first two repeated assessments and the positive benefits of retest diminishing for three or more assessments (Hultsch et al., 1998; McArdle & Woodcock, 1997; Rabbitt, Diggle, Smith, Holland, & McInnes, 2001).

Concerns about retest effects in longitudinal studies include the possibility that they mask aging-related declines due to the benefits conferred by prior test experience, and may in part account for the oft-reported discrepancies between trends reported in cross-sectional versus longitudinal studies (cf. Rönnlund et al., 2005; Salthouse, 2009). Retest effects may result in the systematic underestimation of rates of aging-related change, or may even enhance performance, for various reasons including recall of the correct response when exposed to the very same task, the reflection upon and development of generalized strategies for completing tasks, or the diminishment of anxiety during follow-up testing occasions (Hultsch et al., 1998). In order to have confidence in such inferences drawn, it is necessary to disambiguate estimates of change by attempting to differentiate sources due to developmental shifts versus retest effects.

Assessing the Impact of Repeated Practice on Trajectories of Age-Related Change

Gauging the impact of retest effects is commonly accomplished in one of several traditions, either via the *sampling approach* (research design) or *quantitative model parameterization* (statistical control). The sampling approach involves retaining a randomly sampled select subset of participants who are not administered any measures that are to be assessed for retest effects (Baltes, Reese, & Nesselroade, 1977). Other than not being tested on the target measures that represent the focus of study for assessing practice effects, this reserve sample is identical to the parent longitudinal sample. The magnitude of practice effects are evidenced by comparing the time 2 performance of the longitudinal sample (tested on two occasions) to the time 2 performance of the reserve sample (tested only at time 2), with observed performance differences between groups reflecting retest effects (Schaie, 2013). Problems with this approach include: (i) attrition in the longitudinal sample that may positively bias both individual differences and change in performance; as well as (ii) the fact that the refreshment sample is drawn at a different time of measurement and is thus subject to changes over time in selection effects including population change, sampling methods, and volunteering behaviors (Hultsch et al., 1998). Recent research using an age-heterogeneous sample and sampling-based approach revealed very modest evidence for retest effects on performance level for two of five cognitive outcomes assessed (Thorvaldsson, Hofer, Berg, & Johansson, 2006). Thus, sampling-based approaches to assessing retest effects can provide invaluable insights, but can be time-consuming and expensive.

Many longitudinal studies of aging do not include reserve or refreshment samples, but rather conduct repeated longitudinal assessments for a single cohort. As such, quantitative modeling approaches have been developed to distinguish the effects of within-person change from repeated exposure (Ferrer, Salthouse, Stewart, & Schwartz, 2004; McArdle & Woodcock, 1997; Rabbitt et al., 2001). Ferrer et al. (2004), for example, employed a statistical approach to estimate separate effects for retest and within-person age-related change for select measures of cognitive function. Of particular note, when analyses were conducted that excluded the parameterization for practice effects, the estimates for age-related cognitive decline were underestimated. However, a profound issue related to quantitative modeling approaches for assessing retest effects involves estimating the *separate* effects of retest and within-person developmental change in the same model. This requires the inclusion of specific time parameterizations—one per effect. However, the time structures underlying processes of retest and change (maturation) are not independent (Nilsson et al., 2009). In order for such models to converge and provide estimates for both retest and developmental change, it has been suggested that they rely upon between-person age differences to estimate effects of repeated testing (Thorvaldsson et al., 2006), and as such are susceptible to population mean confounds discussed earlier (cf. Hofer & Sliwinski, 2001).

In concluding this subsection, it should be noted that retest effects are not solely applicable to longitudinal studies. Cross-sectional studies that employ testing batteries comprised of multiple indicators of the same construct (e.g., various measures of executive function) are also susceptible to retest, and may require counterbalancing the order of task administration (Ferrer & Ghisletta, 2011). Further, regardless of whether a design-based or quantitative approach is adopted for indexing retest effects, additional confounds may influence estimates. For example, with either the design-based or statistical approach, cohort effects (e.g., history-graded influences) may bias retest estimates as it is assumed that the groups being compared differ primarily in terms of the number of repeated assessments. If the samples also differ as a function of cohort effects, this confounds interpretation of any observed retest effect differences (Hultsch et al., 1998; Schaie, 2013).

Missingness: Causes, Consequences, and Potential Solutions

As first introduced in the section on participant attrition, missing data due to various sources—from initial sampling selectivity, to dropout, to non-random completion of tasks in the test battery—can adversely bias parameter estimates, particularly in studies of adult development and aging. This section overviews how patterns of missingness are classified, the corresponding implications, and outlines approaches for effectively addressing missingness.

Classifications of Missingness

Prior to analyzing data, it is imperative for the adult development and aging researcher to assess whether data missingness, due in particular to non-random factors, is present. A greater degree of non-random dropout begets greater concern about the representativeness of a given sample. The nature of missingness can exert influences ranging from the relatively benign (reducing statistical power) to those eliciting great concern (e.g., resulting in the substantial bias of parameter estimates). This awareness led to formal classifications identifying three distinct patterns or classes of missingness, each with different implications for interpreting one's data (Graham, 2009; Little & Rubin, 1987; McKnight, McKnight, Sidani, &

Figueredo, 2007; Rubin, 1976,1987; Schafer & Graham, 2002): missing completely at random (MCAR), missing at random (MAR), and missing not at random (MNAR). Each class refers to the probability of missing data values given information about the dependent variable(s) of interest, other associated predictor variables under study, and the hypothetical mechanism thought to underlie the missing data (Enders, 2010; McKnight et al., 2007).

Data are classified as MCAR if the missing data occur by virtue of a random process. In such instances, the reason for the missing data is unrelated to observed or unobserved variables in a study, the mechanism underlying missingness is ignorable, and the missing data can be safely ignored. Data are classified as MAR if the missing data for a given variable occur by virtue of a random process after taking other observed variables in the study into account. That is, the mechanism of underlying missingness has been accounted for based on associations with other measured variables and any potential threat has been negated. Data are classified as MNAR if the reason for the missing data on a particular variable is directly attributable to the construct that variable reflects. That is, data are missing because the variable (or outcome) of interest carries information about why the variable is missing in the first place. These three distinct classes or mechanisms reflect the degree to which missingness may bias any statistical analysis; from MNAR through MAR to MCAR, in order of greatest to least concern. The missing data mechanism is considered ignorable for MCAR or MAR, but is nonignorable for MNAR (Rubin, 1976). In actual practice, data are rarely MCAR, with the primary distinction between MAR and MCAR reflecting whether additional variables under study are associated with missing data for a given variable (Rubin, 1976); it is difficult to distinguish between MAR and MNAR (McKnight et al., 2007). Fortunately, considerable advancements have been made with respect to statistical analysis in the presence of missing data (Enders, 2010).

Approaches for Dealing with Missing Data: A Brief Overview

Methodologists have developed modern statistical approaches that facilitate obtaining unbiased model estimates for incomplete datasets. Over the past few decades, imputation approaches have emerged as a popular approach for addressing missingness. Initially, approaches like mean or regression-based imputation were adopted. Mean imputation entails replacing a missing observation for a given variable with the sample mean, or with a person-level mean if longitudinal data are available. Although often employed, there are many concerns with this approach including the systematic reduction of observed variance for the mean-imputed variable, as well as biased parameter estimates. Although regression-based substitution represented an improvement, it is still a single imputation procedure that systematically underestimates variance. Such limitations led to the development of multiple imputation (MI) approaches that replace missing data with multiple possible values (5–10 or more; Schafer, 1999). There are many advantages to the MI approach including unbiased and precise estimation of parameters as well as its easy implementation in many modern statistical software packages. In contrast to single imputation approaches, the MI approach entails generating a distribution of estimates to replace missing values (for further details, see Allison, 2002; McKnight et al., 2007; Rubin, 1987; Schafer & Graham, 2002). The optimal number of MI estimates ranges from 3 to 10, with the estimates iteratively derived based on observed between- and within-person sources of variance. For example, if ten new estimates are derived via MI to replace missing values for a variable, then a corresponding number of new datasets (i.e., 10) is generated—one new dataset per imputed value. Analyses of interest are then computed for each of these imputed datasets, with the corresponding parameter estimates obtained subsequently combined to derive a single best estimate. Whereas single imputation approaches tend to reduce variance in the observed variable and underestimate standard errors for parameter estimates, the multiple estimates involved in the MI approach permit more accurate estimates of standard errors and reduce Type I errors (McKnight et al., 2007).

Another approach for analyzing incomplete data involves likelihood-based estimation procedures, such as full information maximum likelihood (FIML) estimation. Unlike imputation-based approaches, FIML derives parameter estimates based upon all available information as opposed to complete (e.g., listwise deleted) or imputed data. Further, FIML will preferentially weight cases with greater numbers of observations (less missing data). Benefitting from a number of desirable statistical properties, maximum likelihood estimates are known to be consistent (are unbiased and converge on unknown true values of population parameters) and efficient (yield smaller standard errors), with normally distributed sampling distributions (Singer & Willett, 2003). In contrast however to MI approaches, likelihood-based approaches do require a correctly specified model to explain the structure of the data (Ferrer & Ghisletta, 2011), and are most appropriately employed on larger sample sizes (Singer & Willett, 2003). Despite the presence of missing data, approaches such as FIML use all available data (including all partial data) to produce estimates for various population parameters that maximize the probability of having observed patterns (e.g., aging-related rates of change in cognitive function) for the given sample under study. Maximum likelihood derived estimates of population parameters require the computation of a likelihood function to characterize the probability of observing associations in the sample data as a function of unknown model parameters (for further details, see Dempster, Laird, & Rubin, 1977; Singer & Willett, 2003). The process proceeds iteratively, with competing estimates compared until estimates are identified that maximize the log-likelihood function (i.e., the final estimates yield the greatest probability of having been observed given the sample data under study). When the difference between competing successive estimates is sufficiently small (i.e., the model converges), the final model estimates are identified. FIML assumes that missing data are MCAR or MAR (Rubin, 1987; Schafer, 1999), and thus requires valid inferences about the reasons for missingness. Thus, it is critical to examine differences between those individuals with complete versus missing data. Key questions to be addressed include whether any observed group differences are systematically related to variables under study. Further, regardless of whether an MI or FIML approach is employed, the inclusion of *auxiliary variables* can reduce: (i) bias by facilitating a closer approximation of the MAR assumption, (ii) marked variability in the imputed values, and (iii) standard errors of estimates derived for the final model (Allison, 2012). Auxiliary variables are not intended for inclusion in the final model, but are rather selected based upon their association with model-based variables with missing data. By including auxiliary variables in the imputation or modeling process, the resulting imputation or model-based estimates are conditioned upon the reasons for missingness (i.e., the auxiliary variables are associated with other variables under study that are related to missingness), thereby increasing the tenability of the MAR assumption and improving the quality of parameter estimates (Allison, 2012; Ferrer & Ghisletta, 2011; Graham, 2009). Virtually all quantitative analysis software packages include likelihood-based estimation algorithms, which make them an accessible and attractive option for researchers.

Because longitudinal studies on adult development and aging typically involve attrition and missing data, both imputation- and likelihood-based estimation procedures are frequently employed. Either modern approach has proven superior to more traditional methods of listwise deletion or single imputation regression methods. However, although both MI and likelihood-based approaches benefit from similar statistical properties and make similar assumptions, some important differences should be noted. Allison (2012), for example, notes that MI approaches yield a distribution of results predicated upon the multiple random draws that are central to the MI process. How varied this distribution of results is depends upon the number of new MI datasets created. Whereas MI requires a decision about the number of random draws to be made, the maximum likelihood approach yields a single deterministic result. MI also requires a logical consistency between your analysis model and your imputation model; nuances in one model (e.g., interaction terms, transformed variables) should be reflected in the other (Allison, 2012). In contrast, FIML employs a single model, which may improve generalizability of findings.

Planned Missingness

To this point, we have introduced some of the analytic-based solutions for dealing with missing data from longitudinal studies that have already been conducted. Recently, Little and Rhemtulla (2013) have offered a design-based complement for missing data in longitudinal studies. Planned missingness designs involve the a priori specification of a study design such that participant data will be incomplete or "missing," but this missingness is determined in an a priori fashion and controlled by the researcher. Such designs are attractive as they reduce participant burden as well as the total volume of data collection and resources needed to field longitudinal studies. Recent research has provided empirical support for the successful use of planned missingness designs in developmental research with minimal loss of fidelity or statistical efficiency (Rhemtulla, Jia, Wu, & Little, 2014). Combined with the contemporary and advanced analytic techniques for accommodating missing data (e.g., MI and maximum likelihood approaches), planned missingness designs can be a powerful, efficient and attractive option for longitudinal research in aging and human development in general (Little, Jorgensen, Lang, & Moore, 2014).

Section Summary: Key Methodological Considerations for Incomplete Data

To summarize, reasons for missingness range from sampling selectivity during initial recruitment to attrition in longitudinal studies due to health or mortality. In order to minimize threats to internal validity, as well as to maximize both efficiency and consistency in the computation of model-based parameter estimates, the analyst should attend to several basic considerations. A step that is often ignored involves assessing patterns of missingness in one's data, as well as contemplating the feasibility of MCAR and MAR assumptions vis-à-vis the appropriateness of a specific analytic technique. With regard to assumptions regarding missingness classifications, some statistical packages (e.g., SAS, SPSS) have incorporated basic statistical tests, such as Little's (1998) MCAR test. A significant chi-square value associated with Little's test indicates that the data are not MCAR. Imputing missing data using MI approaches requires careful consideration of the imputation model and its correspondence with the planned statistical model. Similarly, likelihood-based approaches require that the model be appropriately specified and based upon a sufficient number of cases to yield consistent and efficient estimates.

MODELING CHANGE IN STUDIES OF AGING

As a corollary to the discussion on longitudinal research designs, a corresponding increase in attention has been devoted to accompanying statistical models that examine the dynamic nature of both growth and decline associated with various aging processes. In the following section, we overview some basic analytic approaches for modeling both continuous and categorical outcomes, differentiate correlated from coupled change as foci in developmental analyses, and discuss the modeling of change based upon alternative parameterizations of developmental time.

Select Statistical Models for Change

Multilevel and Latent Growth Curve Approaches for Continuous Outcomes

Until several decades ago, most studies of developmental change for longitudinal panel data employed balanced research designs and general linear model (GLM) approaches such as repeated measures ANOVA. The experimental tradition at the time often resulted in longitudinal studies that failed to detect change due to limited sample size, the inclusion of few measurement occasions, compromised statistical power for detecting differences, and a differential focus on between-group differences as opposed to within-participant change (MacDonald et al., 2006). Among the shortcomings, these initial GLM approaches for assessing change focused on mean estimates aggregated across individuals, with the assumption that all individuals from a specific group were characterized by the very same pattern of (mean) change over time, and any deviation from this average assumed to reflect error.

Several vastly improved approaches are now typically employed to analyze change for continuous outcomes in adult development and aging (e.g., aging-related change in cognitive function). Both multilevel or linear mixed models of change (Raudenbush & Bryk, 2002; Singer & Willett, 2003) as well as latent growth curve (LGC; Willett & Sayer, 1994) approaches are commonly employed. These approaches consider both intraindividual change over time and interindividual differences in change over time (Baltes & Nesselroade, 1979). In addition to the linear analysis of continuous change, multilevel and growth curve models are also particularly well suited to the study of discontinuous developmental processes (Ram & Grimm, 2007; Singer & Willett, 2003). For example, in research on aging, it is of particular theoretical interest to contrast patterns of change both prior to and following critical events, such as the onset of menopause to gauge the impact of estrogen depletion on cognitive function (Thilers, MacDonald, Nilsson, & Herlitz, 2010), to differentiate normal from pathological cognitive aging by identifying the inflection point thought to indicate the onset of the prodromal phase of dementia (Thorvaldsson et al., 2011), or to disambiguate rates of longitudinal change in outcomes attributable to aging- versus mortality-, disease-, or disablement-related processes (Fauth, Gerstorf, Ram, & Malmberg, 2014; Gerstorf, Ram, Lindenberger, & Smith, 2013). Patterns of change prior to and following such critical events might be characterized quite differently, with both differences in the magnitude of change as well as the transition point for such differences of particular research interest (Cohen, 2008; Cudeck & Klebe, 2002). Thus, contemporary modeling frameworks provide considerable flexibility for examining developmental and other time-dependent processes.

Modern approaches have notable statistical advantages for the assessment of change (Hertzog & Nesselroade, 2003; MacDonald et al., 2006). First, they do not assume equality of slopes across individuals, but rather empirically test this notion by including variance terms for various fixed effects (including change slopes) in the model. Another advantage is the ability to examine change despite heterogeneity in retest schedules. Further, both the multilevel and LGC approaches yield parameter estimates using FIML based upon all available information, assuming that missing data are MAR.

The mutlilevel and LGC approaches are similar in that both provide estimates of individual differences and change in performance, and indeed can be structured to be equivalent and to yield identical estimates (Curran, 2003; Ghisletta & Lindenberger, 2004). However, important differences should also be noted. For example, time is treated differently between the multilevel and LGC models, introduced as a level 1 predictor yielding a fixed effect in the former case, and incorporated into the model via the factor loadings for the latent slope variable for the latter. This represents a fundamental distinction: the treatment of time is univariate for multilevel models (time is parameterized as distinct observations for the same variable) versus multivariate for LGC models (each time point represents a distinct variable; Stoel, Van den Wittenboer, & Hox, 2003). Other advantages of LGC models including more flexible specifications of residual covariance structures, as well as simple extensions of LGC estimates of change to other outcomes within a broader SEM framework (Stoel et al., 2003). In contrast, multilevel models are advantageous for incorporating higher levels of nested structures (e.g., three-level structures common in measurement burst designs such as weekly sessions within annual retests within persons). On balance, the differences between the multilevel and LGC approaches are modest, with many modern software packages (e.g., Mplus; Muthén & Muthén, 2012) seamlessly estimating both statistical models of change.

Generalized Linear Mixed and Survival Models for Categorical Outcomes

Research applications for the psychology of aging are also based upon longitudinal responses that are not continuous (e.g., presence or absence of a disease process over time, counts of specific event occurrences such as stressors, etc.). As such, this requires separate models including *generalized linear mixed effects models* (Fitzmaurice, Laird, & Ware, 2004) as well as *survival models* (Singer & Willett, 2003). Generalized linear mixed effects models represent an extension to linear mixed models of continuous data where longitudinal categorical outcomes can be examined by transforming the mean response using a *link function* and then relating the transformed outcome to predictors. Appropriate selection of the link function transformation of the non-normal outcome depends upon the distribution of the outcome data (e.g., a logit transform for binary data characterized by a Bernoulli distribution). The transformed outcome can then be predicted by covariates of interest using the familiar GLM; effectively, continuous models with normal distributions are simply special cases of GLMs (see Fitzmaurice et al., 2004, for further reading).

Survival (or event history) analysis models the risk of a particular event occurrence (e.g., disease onset, death) as a function of specific predictors in your model. In a longitudinal analysis, this risk of event occurrence is referred to as a hazard—the probability that an individual will experience the event within a period of time. A key feature of survival models is the ability to consider both event occurrence and time-to-event occurrence. In psychological aging research, survival models have been commonly used for the study of disease risk, as well as for the study of terminal decline that examines an accelerated decline or drop in cognitive function in proximity to death (MacDonald, Hultsch, & Dixon, 2011). The terminal decline hypothesis has been examined using both conventional survival methods (Schaie, 1989), as well as modern analytic approaches that combine the statistical analysis of change (e.g., linear mixed models) with survival models (Ghisletta, McArdle, & Lindenberger, 2006). Such joint modeling approaches have also been employed to examine how individual differences in levels and rates of change in cognitive function from LGCs are related to onset of Alzheimer's disease (McArdle, Small, Bäckman, & Fratiglioni, 2005).

Correlated and Coupled Change

The analysis of change goes beyond a simple decision regarding which type of analytic approach to employ. Indeed, the primary research question itself has an important bearing on the nature of change examined. Multilevel and LGC approaches offer flexibility for examining change in one outcome, and potential moderators or sources of individual or group differences in rates of change (i.e., interindividual differences in intraindividual change). However, such approaches can be expanded to consider scenarios where researchers might be interested in how two or more variables may be changing together over time. As such, multivariate approaches allow the consideration of how variables and rates of change in these variables are related over time.

To facilitate a more stringent test of a developmental hypothesis, a researcher might be interested in examining whether two processes (cognitive and physiological function) change together within an individual over time. In order to examine the time-varying covariation between these two processes, a researcher could explore either *correlated* or *coupled* change between physiological and cognitive function (Sliwinski & Mogle, 2008). These two approaches actually address disparate questions. By way of example, one could correlate two separate slopes of aging-related change—one for cognitive and one for physiological function. Such an analysis would yield insight regarding *correlated change*—the extent to which individuals' whose cognitive function is changing at a faster rate is also exhibiting faster rates of change in physiological function. Alternatively, one could examine the time-varying covariation of cognitive and physiological function after taking the longitudinal trends for each into account. Such an analysis would yield insights into *coupled change*—the extent to which an individual's level of cognitive function at a particular sampling occasion is related to their level of physiological function at the same sampling occasion. Here, it is important to note that correlated change involves the examination of individual differences (or between-person associations), whereas coupled change involves the examination of intraindividual differences (or within-persons associations). The approaches often yield similar estimates, but may diverge due to aggregation bias in longitudinal research (Sliwinski & Buschke, 1999).

Although analyses of correlated and coupled change address complementary questions about how variables are related over time, such approaches are ultimately correlational and preclude inferences about causation or lead or lagged effects. Models such as the bivariate dual change score model (McArdle & Hamagami, 2001) represent an analytic alternative that incorporates both the longitudinal modeling of two variables, as well as lead and lag parameters to allow for the rate of change in one variable to be prospectively predictive in the other variable (and vice versa). Such an approach affords researchers the ability to examine individual differences in and correlations between rates of change among variables, as well as how individual differences in rates of change among variables can be antecedent to each other to reveal unidirectional and/or bidirectional causal influence among variables.

Developmental Parameterizations of Time

A critical issue for longitudinal studies on adult development and aging concerns how we define the time continuum used for characterizing change. In this section, we highlight examples from the literature that demonstrate how employing various parameterizations of time can influence results observed in longitudinal investigations (cf. Morrell, Brant, & Ferrucci, 2009).

Is Chronological Age the Only Metric?

Despite considerable advances in research designs (Stawski et al., in press) and statistical procedures (McArdle, 2009) for the study of the psychology of aging, chronological age perseveres as arguably the most used predictor and developmental time metric for charting performance differences and changes (MacDonald, DeCarlo, & Dixon, 2011). Despite this popularity, the weaknesses of age as a developmental index have been well documented (Birren, 1999; Dixon, 2011). Specifically, rather than a causal mechanism underlying cognitive and functional decline, chronological age is said to merely reflect a temporal dimension along which causal factors (e.g., biological, environmental, health, and neurological) operate (MacDonald, Karlsson, Fratiglioni, & Bäckman, 2011). Consequently, observing that chronological age is associated with performance decline (e.g., in cognition) does not inform the specific or general mechanisms underlying age-related cognitive impairment—rather, age is likely an indirect reflection (i.e., a proxy) of true mechanistic changes (e.g., accumulated biological and environmental factors) that influence cognition across time.

Beyond these theoretical concerns with the use of chronological age as the primary developmental time metric for charting change, the selection of a specific time parameterization is known to influence the interpretation of results in longitudinal studies. In particular, for longitudinal studies characterized by considerable age heterogeneity in the sample at baseline assessment, opting to model long-term change using chronological age as the time basis without accounting for differences in age at study entry (i.e., different age cohorts were sampled) assumes the equivalence (or convergence) of cross-sectional and longitudinal aging effects (Morrell et al., 2009; Sliwinksi, Hoffman, & Hofer, 2010). The advantage of such a model is that a single trajectory of change spanning the entire observed age range (e.g., 60–90 years) can be estimated—a combination of age information spanning various cohorts that is much larger than the range measured over the longitudinal follow-up (e.g., three retests spanning a 6-year period; cf. Singer & Willett, 2003). Of course, such failures of age convergence—the assumption that cross-sectional age differences and longitudinal age changes converge onto a common trajectory—are well documented in the adult development and aging literature (Hoffman & Stawski, 2009; Sliwinksi et al., 2010). The impact that between-person difference in age at baseline can exert upon appropriate inferences regarding within-person change has led researchers to consider additional parameterizations of developmental time.

Alternative Parameterizations of Time

In reviewing recent literature in adult development and aging, it is not uncommon to observe the use of various time parameterizations for modeling within-person change in various aging processes. Most longitudinal research parameterizes developmental time using three *time basis structures*: chronological age (e.g., years since birth), measurement occasion (e.g., 0, 1, 2), and time in study (years from baseline assessment) (Morrell et al., 2009).

The *age-as-time* parameterization estimates within-person change as a function of chronological age. However, as mentioned in the preceding section, such an approach not only assumes age convergence, but may also fail to capture important sources of heterogeneity. Variance due to underlying health conditions such as cardiovascular disease, for example, may be misattributed to chronological age (Spiro & Brady, 2008). Additionally, using age-as-time can reveal complex non-linear trends that potentially reflect cross-sectional mean differences introduced by heterogeneity in age at baseline (Hofer & Sliwinski, 2001).

Employing measurement occasion as a time basis is common, but this approach fails to capture important individual differences in time sampling. Specifically, such an approach fails to capture important variation in individual retest intervals; regardless of whether the first retest interval spanned 6 months for some individuals versus 16 months for others, the time as measurement occasion parameterization would treat these as equivalent. Such an assumption may be entirely reasonable for certain processes and populations under study, but may be grossly inefficient in other contexts. When examining changes in cognitive function during the prodromal phase of dementia, for example, changes across even relatively short retest intervals can be meaningful (i.e., individual differences of even several months matter).

To improve precision, many opt to parameterize time using a *time-in-study* metric. This approach charts time elapsed from the beginning of the study, including a precise incorporation of individual differences in retest intervals. Morrell et al. (2009) directly compared such competing time parameterizations, and report that accurate inference about within-person change in longitudinal studies is best accomplished by parameterizing time as *time-in-study* as well as by including a between-subject term indexing age heterogeneity at entry into the study (baseline assessment). Moreover, this approach allows for explicit examination of whether rates of aging-related longitudinal change vary as a function of cross-sectional age-related differences at baseline (e.g., is the rate of decline in memory faster among individuals who were older upon entry into the study?).

Recently, *time-to-event* (or time-as-process) parameterizations have been proposed as another promising developmental metric for indexing change (Sliwinski & Mogle, 2008). A time-to-event approach indexes change in relation to the onset of central events or processes. Biological age represents one such alternative marker of developmental time, with recent empirical findings and theorizing linking biological processes (e.g., vascular health) to age-related cognitive decline (DeCarlo, Tuokko, Williams, Dixon, & MacDonald, 2014; MacDonald et al., 2011). Other examples include examining change in cognitive function in relation to specific processes including dementia progression or menopause. For the former, one recent study explored within-person change in cognition as a function of years following dementia diagnosis (MacDonald et al., 2011)—understanding why some individuals progress through the dementia stages more rapidly than others could inform efforts to lessen caregiver burden or to target effective drug trials. For the latter, another study examined cognitive change as a function of time prior to and following menopause (Thilers et al., 2010). Structuring cognitive change in relation to the menopause event failed to support claims that estrogen depletion for postmenopausal women leads to cognitive decline.

Beyond cognitive domains, time-to-event approaches have been employed to examine longitudinal changes in mental and physical health with respect to disablement- (Fauth et al., 2014), and mortality- (Gerstorf et al., 2013) related processes. Echoing the findings of terminal decline in cognitive function using time-to-event approaches, these recent research findings indicate that mental and physical health exhibit accelerated decline proximal to specific health-related events. This suggests that time-to-event-based examinations are incredibly valuable for articulating processes other than aging that impact mental, physical and cognitive health during the later years, and there is considerable promise for applying such approaches for understanding multiple dimensions and processes in the context of later life (Gerstorf & Ram, 2013).

EMERGING METHODOLOGICAL TRENDS FOR THE STUDY OF AGING

In this final section, we overview several trends that are exerting considerable influence on the current scope of adult development and aging research—the integrated data analysis and intraindividual variability approaches.

Select Approaches to Integrated Data Analysis

Over the past decade, a clear trend in research on the psychology of aging has seen innovative efforts to comprehensively integrate data *across* studies. Such integration affords a number of advantages including improved statistical power, improved precision of parameter estimation, and, perhaps most importantly, the testing of whether findings from single sample studies are generalizable. Several approaches to integrated data analysis are overviewed here.

Meta-Analysis

The meta-analytic approach to integrated data analysis involves synthesizing various summary statistics (effect sizes, regression coefficients, probability values) across individual studies that share a number of important similarities (Cumming, 2012). In effect, a meta-analysis is an aggregate study about a number of prior studies. This accumulation of evidence yields a quantitative summary of findings, including an omnibus measure of effect size (e.g., Hedges' *g*) as well as the identification of key variables that moderate this effect and explain variation between studies. The degree to which summary statistics from individual studies influence the final measure of effect can be weighted according to important factors (e.g., sample size). Key steps involved in conducting a meta-analysis include deciding upon the target research questions, deciding upon the parameters governing the literature search and choosing studies that clearly meet criteria, requesting data from researchers as required, addressing incomplete data, and data analysis (Sternberg, Baradaran, Abbott, Lamb, & Guterman, 2006). There are important assumptions when conducting a meta-analysis, including the need to ensure the psychometric comparability of pooled constructs, measures, and measurement scales. Advantages of the meta-analytic approach over individual studies include the improvement of statistical power and precision, a direct means of addressing equivocal findings within a research field (e.g., are opposing findings due to systematic between-study differences), as well as drawing inference regarding generalizability of findings (Cumming, 2012). However, meta-analytic approaches are also subject to notable concerns including the impact of publication bias (as many nonsignificant findings are not represented in the literature) as well as the ecological fallacy, where inaccurate inferences about individuals are based upon population mean trends (Hofer & Sliwinski, 2001; Sternberg et al., 2006).

Mega-Analysis

In contrast to a meta-analytic approach, mega-analytic studies derive similar quantitative benefits through the actual pooling of raw data across many studies/samples (Cooper & Patall, 2009; McArdle, Grimm, Hamagami, Bowles, & Meredith, 2009). The distinguishing feature between meta- versus mega-analysis concerns the type of information that is concatenated across studies. For meta-analysis, various summary statistics are compiled, whereas the actual raw data are concatenated across study for the mega-analysis. In this sense, a mega-analysis shares greater similarity with a conventional research study where the researcher collects and analyzes person-level data from multiple research contexts. Advantages of the mega-analytic approach include the ability to conduct a meaningful investigation even when few studies are available (a distinct problem for meta-analysis), improved reliability and precision of model-based parameter estimates, and perhaps most importantly an increased flexibility with regard to research questions that can be pursued and analytic techniques that can be employed (Sternberg et al., 2006). While there are limitations involved with the mega-analytic approach, such as the need for identical measures across studies, it is certainly a powerful and attractive approach for large-scale examinations of research questions.

Data Harmonization

Data harmonization, whether retrospective or prospective, represents another approach to pooled data analysis. In contrast to a mega-analysis, a *retrospective* harmonized dataset reflects more than the mere pooling of raw data across studies; rather, the harmonized dataset derives novel variables and constructs based upon complex harmonization procedures (cf. Anstey et al., 2009). Not only are raw data concatenated across studies, but entirely new variables are generated to index constructs of interest. For example, in the Dynamic Analyses to Optimize Ageing (DYNOPTA) project, Anstey et al. (2009) created a retrospectively pooled dataset spanning nine Australian Longitudinal Studies of Ageing, and applied harmonization procedures to create new variables to facilitate comparison with clinically meaningful scores (e.g., harmonized data on physical activity to reflect national recommendations for weekly participation levels).

Recently, efforts have been championed toward *prospective* harmonization across studies, where across-study consensus guidelines are adopted that govern *new* data collection and measurement. For example, some international research on dementia has adopted prospective guidelines for the selection of standardized measures (e.g., the measurement of biomarkers like CSF, common neuroimaging protocols) across studies (Frisoni, 2010). Similarly, the U.S. National Institutes of Health has developed the NIH Toolbox, a common battery of performance measures (cognition, emotion, motor, and sensory function), as a standardized testing platform that can be administered across studies of human development and aging (Bauer & Zelazo, 2014). Although promising, the process of data harmonization is laborious, with numerous challenges including common across-study variation in how constructs have been measured, the development and application of harmonization methods to facilitate comparability, and the retrospective versus prospective nature of the harmonization initiative (Erten-Lyons, et al., 2012).

Coordinated Analysis with Replication

The coordinated and integrated analysis of original data from multiple studies can augment scientific knowledge through the *replication* and *extension* of key findings. For the study of aging, the process involves identifying central research questions, conducting *parallel analyses* across multiple studies to ascertain whether the effect(s) of interest can be replicated, and interpreting similarities (or differences) across patterns of results to further inform generalizability and theory development (Curran & Hussong, 2009; Hofer & Piccinin, 2009). With particular regard to longitudinal studies, data pooling approaches can be problematic. For example, meta-analytic approaches can be quite limited by the body of longitudinal research published on particular research questions, as well as the types of research designs and analyses employed. Similarly, pooled analysis approaches (mega-analyses) are often limited by the lack of overlap of specific measures across studies, requiring more involved harmonization efforts. In these instances, a coordinated analysis platform is particularly advantageous, such as the Integrative Analysis of Longitudinal Studies of Aging (IALSA) project consisting of over 40 longitudinal studies of aging (Hofer & Piccinin, 2009). IALSA facilitates access to member studies data, analysis scripts, and output, with the strengths (e.g., immediate replication of novel findings in the literature and/or consideration of alternative hypotheses, generalizability of findings, improved statistical power) of such coordinated efforts having furthered our knowledge of the psychology of aging and its associated theories.

An Intraindividual Variability Approach

Beyond the First Order Moment

Recently, aging theorists and developmentalists alike have demonstrated a renewed interest on approaches for studying intraindividual variability for a host of domains in aging and across the lifespan (for a comprehensive overview, see Diehl, Hooker, & Sliwinski, 2015). The reemergence of variability derives from a growing body of evidence demonstrating that short-term fluctuations often reflect more than random error or measurement unreliability, are systematically associated with numerous developmental outcomes, and are informative vis-a-vis theories of processing dynamics (MacDonald & Stawski, 2015; Ram & Gerstorf, 2009; Stawski et al., 2015). Intraindividual variability, however, does not necessarily reflect a psychological primitive (e.g., processing speed) per se, but rather *an approach* to the study of adult development and aging that facilitates the examination of dynamic fluctuations in function that confer *meaning beyond mean* and static considerations. To be certain, the examination of mean remains a central focus, contributing essential information for characterizing behavior over time. However, recent findings have demonstrated that this knowledge should be supplemented by also asking how variable this performance is over time. Do trajectories of performance reflect mean stability characterized by modest or substantial variability? Variability not only contributes unique information independent of mean (cf. MacDonald & Stawski, 2015), but it also improves our understanding of the dynamic nature of the developmental process under study (Ram & Gerstorf, 2009). The following subsections overview examples of variability research from the adult development and aging literature.

RT Inconsistency Across Response Latency Trials

Growing consensus from various scientific disciplines including lifespan psychology, cognitive neuroscience, neuropsychology, and mathematical modeling suggests that theoretically interesting aspects of cognitive function are not completely captured by mean performance (Garrett, Kovacevic, McIntosh, & Grady, 2010). RT inconsistency, as defined by trial-to-trial fluctuations in RT latencies on performance-based measures of cognition, has emerged as one index thought to capture important features of behavioral and systemic integrity (MacDonald & Stawski, 2015), including mental noise (Van Gemmert & Van Galen, 1997), transient lapses of attention (West, Murphy, Armilio, Craik, & Stuss, 2002), and a more enduring behavioral signature of compromised brain and neural function (MacDonald, Karlsson, Rieckmann, Nyberg, & Bäckman, 2012) and cognitive status (Dixon et al., 2007). Numerous indices may be computed to index intraindividual variability across response latency trials. Among the simplest, the intraindividual standard deviation (ISD) can be computed within persons and across trials to index fluctuations in response latencies. In order to adjust for potential confounds (e.g., individual differences in average level of performance, response speed, or systematic learning over time), effects associated with age, disease status, and trial can be partialled (Hultsch, Strauss, Hunter, & MacDonald, 2008). Other operationalizations of variability that may be considered include the coefficient of variation (each person's SD/M), high versus low percentiles from RT distributions (Hultsch et al., 2008), as well as approaches that simultaneously model mean and variability (Schmiedek, Lövdén, & Lindenberger, 2009).

Disambiguating state- and trait-like variation in dynamic characteristics and processes within measurement burst designs. Measurement burst designs (Rast et al., 2012; Sliwinski, 2008; Stawski et al., in press), which involve assessing individuals intensively over shorter intervals (e.g., across trials or over days), and repeating this intensive assessment longitudinally over longer intervals (e.g., over months or years), are ideal for examining and quantifying variability within persons across shorter or longer time horizons, or between persons. Evidence of significant intraindividual variability and interindividual differences in RT inconsistency would suggest that RT inconsistency exhibits both state-like and trait-like variation, and that this variation is potentially related to time-varying and time-invariant predictors (Hoffman & Stawski, 2009). Most research has focused on RT inconsistency as a trait-like characteristic (e.g., changes in CNS, changes in brain structure/function or underlying disease/pathology) for differentiating individuals and/or subgroups, ignoring potentially important variation that may exist within persons across shorter intervals such as days, weeks, or months that may reflect variation in a person's context (e.g., increased stress, distress, diminished sleep, attention).

In future research, the analysis of indices of variability for various processes (e.g., cognition, gait, neural function) in the context of measurement burst designs represents a novel empirical approach to examining both the state-like and trait-like modulators of performance fluctuation. Empirical decomposition of variation in RT inconsistency, for example, will help better understand the utility of RT inconsistency as a behavioral indicator of cognitive, brain and CNS function, and may facilitate identification of risks (e.g., falls, delirium) for individuals with dementia. Consistent with this proposition, recent research on daily stress employing a measurement burst design has shown that among older adults, only 25% of the variability in emotional reactivity to daily stressors reflects individual differences or dispositional variation. This suggests that dynamic processes, in and of themselves, may be susceptible to vicissitudes of other time-varying processes or influences that operate at difference timescales (Schmiedek, Lovden, & Lindenberger, 2013), and underscores the need to examine factors beyond individual and group differences as important sources of variation in dynamic processes.

Linking intraindividual variability to long(er)-term outcomes using intensive repeated measures and measurement burst designs. The vast majority of research in cognition and aging has focused on the utility of intraindividual variability as a more static indicator and proxy for dynamic processes that are reflected in behavior/performance. Intraindividual variability has a rich history in other domains, particularly affect and emotion, whereby intraindividual variability is thought to reflect, in part, the systematic impact of contextual and experiential forces such as stressful experiences (Almeida, 2005). Thus, intensive repeated measures designs (e.g., ecological momentary assessment and daily diaries) can be exploited to examine the time-varying covariation of stressors and affect as a way to examine individuals' emotional reactivity to stressors (and individual differences therein) as dynamic phenomena. Importantly, these intensive repeated measures design protocols can be repeated at periodic intervals, effectively yielding a measurement burst study. Such an approach is attractive as it allows for examining a dynamic process (e.g., emotional reactivity to stressors), how that process changes developmentally, and how that process impacts change in other outcomes of interest.

For example, theoretical accounts of the impact of stress on long-term health have emphasized the importance of dynamic, micro-level processes including stressor reactivity as the mechanism underlying the stress–health link (Cacioppo, 1998). In the daily stress literature, links between micro-level stress reactivity processes and long-term health outcomes have only recently been explored. Mroczek et al. (2013) showed that greater emotional reactivity to daily stressors was associated with an increased likelihood of mortality among older men. Similarly, individual differences in emotional reactivity to daily stressors have been linked to increased distressed affect and self-reported affective disorders (Charles, Piazza, Mogle, Sliwinski, & Almeida, 2013) and increased risk of chronic health conditions (Piazza, Charles, Sliwinski, Mogle, & Almeida, 2012) 10 years later. Additionally, Sliwinski, Almeida, Smyth, and Stawski (2009) reported that emotional reactivity to daily stressors increases longitudinally across 2.5 and 10 years from two separate measurement burst studies of midlife and old age. These recent findings from the stress and affect literature exemplify the promise measurement burst designs hold for examining the longitudinal dynamics and impact of fast-acting processes.

CONCLUSIONS

In writing this chapter, our goal was to selectively highlight methodological considerations and concerns that characterize current research on the psychology of aging. The overview of sampling and design considerations emphasized missing data considerations and retest effects, as well as their corresponding impact on model-based parameter estimates and (in) accuracy of inferences drawn. In particular, we emphasized the strengths of the measurement burst design. Such intensive measurement designs hold real promise for improving our understanding of dynamic aging-related processes, including current trends such as whether intraindividual variability reflects both state-like and trait-like influences. We reviewed common analytic approaches for analyzing change in both continuous (LGC, multilevel models) and categorical (survival) outcomes, as well as emphasized the need to carefully consider alternative parameterizations of developmental time to chronological age. Finally, we concluded by exploring some emerging trends in the study of the psychology of aging, including the promise of integrated data analysis for informing the key scientific issues of generalizability and theory development. The advances in design and analysis and their corresponding recent applications have given rise to an exciting time for research in the psychology of aging, as we strive to further our understanding of dynamic developmental processes.

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CHAPTER

3

Society and the Individual at the Dawn of the Twenty-First Century

Toni C. Antonucci[1,], Lisa Berkman[2,*], Axel Börsch-Supan[3,*], Laura L. Carstensen[4,*], Linda P. Fried[5,*], Frank F. Furstenberg[6,*], Dana Goldman[7,*], James S. Jackson[1,*], Martin Kohli[8,*], S. Jay Olshansky[9,*], John Rother[10,*], John W. Rowe[11,*], and Julie Zissimopoulos[7,*]*

***MacArthur Foundation Research Network on an Aging Society, [1]Department of Psychology, University of Michigan, Ann Arbor, MI, USA, [2]Harvard Center for Population and Development Studies, Harvard University, Cambridge, MA, USA, [3]Munich Center for the Economics of Aging, University of Munich, Germany, [4]Department of Psychology, Stanford University, Stanford, CA, USA, [5]Mailman School of Public Health, Columbia University, New York, NY, USA, [6]Department of Sociology Department, University of Pennsylvania, Philadelphia, PA, USA, [7]Schaeffer Center for Health Policy and Economics, University of Southern California, Los Angeles, CA, USA, [8]Bremen International Graduate School of Social Sciences, European University Institute, San Domenico di Fiesole, Italy, [9]School of Public Health, University of Illinois at Chicago, Chicago, IL, USA, [10]National Coalition on Health Care, Washington DC, WA, USA, [11]Department of Health Policy & Management, Mailman School of Public Health, Columbia University, New York, NY, USA**

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INTRODUCTION

Societies exert profound influences on the developmental paths of their citizens. Whether engaged or disengaged, satisfied or dissatisfied, socially embedded or lonely, healthy or disabled; whether people feel in control of their lives or view themselves as victims of circumstance, all are intrinsically tied to broad sociocultural contexts in which people come of age. Indeed, the historical era and related social norms into which we are born influence not only how much formal education we attain, when we marry, and how many children we have, but life histories also influence the efficiency with which our brains process information.

In the last volume of the *Handbook of Psychology and Aging*, Warner Schaie (2011) contributed an insightful historical analysis of the role of policies, such as the GI Bill, and public education in shaping life course trajectories. He also noted more elusive cohort effects such as steady and worldwide increases in (primarily) fluid intelligence, referred to as the Flynn effect (Flynn & Flynn, 2012).

In this chapter, rather than take a historical perspective, we document current trends in health, family structure, education, work, and retirement and consider how these changes may affect the wellbeing of future generations of aging individuals. Forecasting the long-term future is perilous, and we do not aim to do so. Rather, we consider the ways in which important social institutions, like the family, work, and retirement, are changing and consider ways in which policies and social norms could help or hinder wellbeing in future generations.

Societies have long sought to shape the lives of their citizens. At the turn of the twentieth century governments, communities, and families crafted education in the early years of life to contribute to the growth of patriotic and capable citizens. It was a time when only a minority of boys or girls attended secondary school (Fussell & Furstenberg, 2005). Home economics was developed to teach basic household skills to young girls so that they would better manage family life. Boys were ushered into "shop" classes where they learned about woodworking and machinery. The research community studied how parenting and schooling affected adult outcomes (e.g., The Child Guidance Study, initiated by Jean McFarlane and her colleagues in the 1920s and the Oakland Growth Study by Harold Jones and Herbert Stolz in the 1930s). Although investigators have tracked some of the participants of these longitudinal studies into older ages, the studies were designed to focus on the early stages of life.

Now, for the first time in human history, societies are presented with the need for an even longer view of lifespan development. We need to ask not only how to raise children to become productive workers and good citizens, but also what kind of *elderly* people we want our children to become (Berkman & Glymour, 2006). How do we delay illness until very advanced ages? What kinds of policies and social norms might encourage family stability, support, and caregiving when step-families are common and three and four generations are alive at the same time? How can we ensure that education continues throughout adulthood? How do we ensure financial security throughout long lives? In this chapter, we briefly overview the current status of health, education, family, work, and retirement in the United States. We also consider policies and practices that may optimize long-term outcomes.

A COMMENT ON LIFESPAN PSYCHOLOGY

From its inception, lifespan psychology has recognized that broad contextual forces powerfully shape individuals' lives. As lifespan theory emerged in developmental psychology in the 1970s, theorists including Paul Baltes, John Nesselroade, Hayne Reese, and K. Warner Schaie, articulated sociocultural, historical, biological, and social factors as key influences on adult development. Lifespan approaches encompass multi-disciplinary perspectives and are, therefore, well poised to benefit from the current emphasis on cross-disciplinary fertilization through team science, and inter- as well as multi-disciplinary collaborations. Current efforts at the National Institutes of Health, the National Institute of Aging, the National Science Foundation, and the Institute of Medicine are all promoting modern instantiations of this mission.

The present chapter is authored by members of the MacArthur Research Network on Aging Societies, formed in 2008 when the MacArthur Foundation charged John W. Rowe with the formation and leadership of a new network. Its mission was to consider how population aging will likely change societies and how best to prepare for those changes. The Network on an Aging Society includes members with expertise in developmental and social psychology, demography, economics, medicine, neuroscience, policy, political science, public health, and sociology. The choice of Rowe to lead the Network was significant in that he had previously lead the MacArthur Network on successful aging which focused on aging at the individual level. In contrast, the unit of analysis considered by the current Network is *society*, as it transitions from a young age structure, represented by a pyramid, to an old age structure, better represented by a rectangle and including more older, than younger, people.

There is no question that population aging will change life in profound and far-reaching ways. The Network has authored a number of articles about societies and policies (Furstenberg, Hartnett, Kohli, & Zissimopoulos, 2015; MacArthur Foundation Research Network on an Aging Society, 2009, 2010; Ryan, Smith, Antonucci, & Jackson, 2012; Zissimopoulos, Goldman, Olshansky, Rother, & Rowe, 2015). In this chapter, we consider how the psychological wellbeing of *individuals* will be affected by the fact that today, and in the foreseeable future, people will be born into and grow old in societies with many more long-surviving elders than in the past. Greater longevity is a profound achievement. It also presents many challenges. Chronic health problems among seniors are on the rise (Martin & Schoeni, 2014). Disparities in old age outcomes are increasingly stark. Increases in life expectancy in the last quarter century are essentially occurring only among the college-educated (Meara, Richards, & Cutler, 2008) while reversing among those at the very bottom of the educational ladder; hope that all can achieve the American dream is diminishing (Olshansky et al., 2012). The importance of education is increasing as a predictor of wellbeing and longevity, and the absence of education is more lethal today than it was just 20 years ago (Olshansky et al., 2012).

Population aging is not occurring in a vacuum. The diffusion of technology into virtually all aspects of life from social relations to employment means that education is becoming increasingly essential for accessing global opportunities. Education facilitates work attainment, which subsequently predicts how long and in what types of jobs people work. Employment, in turn, positively influences cognitive functioning. Thus, in our society today, education affects the entire course of life. Moreover, the nature of work has changed over the same period of time that life expectancy in adulthood has increased. Most people no longer work for a lifetime employer who provides a pension at the end of a career. The average American Baby Boomer holds multiple jobs over their lifetime (Bureau of Labor Statistics, 2012), a trend that is increasing among younger generations. Pensions have been replaced by 401k plans, shifting retirement saving responsibility and financial market risk from employers to employees, many of whom are currently saving far too little to retire comfortably. The family is changing as well; 40% of American children are born outside marriage, increasingly people are opting out of parenthood and multiple, serial marriages and cohabitational unions are increasingly common, creating complex families. At the same time, families now often include more generations. A 20-year-old today has a better chance of having a living grandmother than a 20-year-old one century ago had of having a living mother (Taylor, 2014).

All of these broad societal trends are connected to individual wellbeing. Physical health is a key predictor of psychological wellbeing (Naylor et al., 2012). A subjective sense of social isolation predicts mortality as well as smoking a pack of cigarettes a day predicts mortality (Luo, Hawkley, Waite, & Cacioppo, 2012; Holt-Lunstad, Smith, & Layton, 2010). In contrast, social networks that support close bonds with others (Antonucci, Birditt, & Ajrouch, 2011) and emotional balance in daily life (Carstensen et al., 2011) predict how long people live. We maintain that the dramatic aging of the population calls for widespread changes in the ways that we live. Policies and practices that support longer lives can greatly improve the individual wellbeing of everyone in our aging society. However, if we continue to let social norms that evolved in response to shorter lives guide us, we jeopardize present and future generations.

To date there has been relatively little discussion about proactive policies and practices that positively shape long lives. Indeed, most public discourse about aging societies is focused on the potential costs and loss of productivity that aging societies may bring. Strategic policies and innovative practices could enhance education, strengthen families, and improve the quality of working life and retirement preparedness, while heightening the overall wellbeing of the population. Changes that increase educational attainment, extend engagement in workplaces and communities, and improve health practices, will benefit individuals, families, and communities in aging societies. At the same time, persistent disadvantage has been shown to affect societies at all levels and will exponentially affect the aging society. In the absence of efforts to reduce disparities in the population, entire societies will be negatively affected, not due to aging per se, but to the cumulative effects of inequality.

HEALTH AND HEALTH CARE

The health status of older Americans has greatly improved over time, with a dramatic reduction in premature death beginning in the twentieth century and continuing into the twenty-first. The healthy lifespan increased over the same period with the physical health of older adults reliably improving as increasingly younger cohorts reached old age. For decades across successive age cohorts in the United States health span has increased as well. The physical health of older adults reliably improved as increasing numbers of people from younger cohorts are reaching old age. For decades, across successive age cohorts in the United States, older people, especially the "young-old" have been more fit than their parents were at the same age. For the period from 1980 to 2000, there was a significant and progressive reduction in the age-specific incidence of functional impairments among older persons. This includes the capacity to conduct basic activities such as bathing, dressing, eating, grooming, transferring from bed to chair (i.e., activities of daily living—ADLs) without assistance and also more complex activities such as shopping, using a telephone, and cooking (i.e., instrumental activities of daily living—IADLs) (Freedman et al., 2013). The changes were so great that by 2000 there were several million functionally independent older persons who would have been counted among the disabled had the disability rates of 1980 prevailed. This steady positive progression continues today among the oldest old. Disability rates continue to decline among those over 85 years of age, a likely effect of educational attainment in today's 85-year-olds compared to the prior oldest-old cohorts. However, as noted below, there have been some disturbing new trends in younger ages (Freedman et al., 2013).

Psychological wellbeing and functioning in day-to-day life are tightly linked to disease, pain, and disability. Good physical health is an important resource for older persons to be engaged in society, either through paid work or volunteering, both of which appear to have beneficial effects on wellbeing (Ajrouch, Antonucci, & Webster, 2014; Bonsang, Adam, & Perelman, 2012; Carlson et al., 2009), as well as the cost of health care at the individual and societal level. Because the incidence of most diseases increases with chronological age, population aging demands serious attention to the maintenance of functional health in aging individuals and the prevention of disease. Mental health in today's older cohorts is relatively good compared to middle-aged and younger cohorts (Blazer & Hybels, 2014), although both caregiving and institutionalization are associated with substantial psychological distress, as well as increased morbidity and mortality (Schulz & Beach, 1999). Moreover, like diabetes, increases in psychiatric disorders in younger cohorts, particularly depression and anxiety, raise concern about future generations' ability to manage the long-term sequelae of early-onset psychiatric disorders, as well as adapt to age-related losses and disease (Greenberg et al., 2003).

News about the physical health status of younger Americans bodes poorly for the future. Although the incidence of acute diseases is relatively low compared to earlier periods, the incidence of chronic disease is increasing. The global rise in chronic diseases (WHO, 2003), is especially evident among Americans and now represents the leading cause of disability and death in the United States. It is not simply due to a lack of health insurance coverage. A recent study that compared the health of middle-aged white Americans who had health insurance—in other words, relatively privileged Americans—with middle-aged British citizens concludes that even these Americans were sicker across a range of measures (Banks, Muriel, & Smith, 2010). A study by Seeman, Merkin, Crimmins, and Karlamangla (2010) observed increases in every type of disability measured in people aged 60–69 years. The increases are evident across social class and are exacerbated in ethnic minorities, particularly African Americans and Hispanics, as well as people who are overweight and obese. Even more disturbing is evidence that substantial numbers of young American children are experiencing peripheral biology that precedes diabetes and hypertension (Lee et al., 2009;

Seeman, Epel, Gruenewald, Karlamangla, & McEwen, 2010). Childhood obesity and resulting diabetes rates have risen dramatically. Because the effects of diabetes generally worsen over time there is great concern that early-onset diabetes may lead to an epidemic of kidney failure, amputations, and blindness later in life.

Even though the age of disability onset has been pushed back as health status and longevity have improved, late life disabilities remain common. Indeed, one direct consequence of reducing premature death is that people are more likely to survive into very advanced ages at which point large numbers of survivors experience multiple and concurrent disabilities leading to the loss of independence and the need for supportive care. There is a distressingly high probability that elders will lose some functional abilities and need supportive services as they live into their 80s and 90s (Freedman et al., 2014). By the age of 90, for example, only 4% of the population remains completely free of impairment in either instrumental or physical function.

Supportive services for those with some form of limitation will be increasingly needed with greater longevity. Today while 11% of those aged 65–70 need assistance from others, 42% of those over 85 do. Family members, especially spouses, are typically the first to be affected. A range of home- and community-based services now accounts for half of all Medicaid spending. Finally, institutional care is declining, but is still needed for those most severely disabled, typically those 85 years and older. Three major conditions that lead to institutionalization in late life are urinary incontinence, hip fractures, and dementia. Mental incapacity associated with Alzheimer's disease and other dementias is particularly distressing, as individuals slowly lose their identities and caregivers are pushed to exhaustion. An estimated 80% of supportive care is provided by family members or other informal caregivers, resulting in an often overwhelming burden on the caregiver (Sherman, Webster, & Antonucci, 2013). Late-life disabilities and the resulting loss of independence and autonomy are the major causes of stress and depression in late life, not only for the one experiencing the limitations but also for caregivers, especially spouses (Schulz & Martire, 2004). The fluid nature of contemporary marriage and childbearing results in numerous caregiving fault lines, including the lack of a sense of responsibility and obligation, the lack of effective lines of family communication, and the lack of strong affectional ties (Ryan et al., 2012). As a result, future generations will need to be more strategic and create innovative solutions to address their caregiving needs.

Policies and Practices

There are significant opportunities to enhance health as people age. A reduction in smoking has been and continues to be important in reducing associated morbidity and early mortality. Enhancement of established public health efforts, such as vaccination programs for pneumonia, shingles, influenza, and other preventable or modifiable diseases, along with cancer screening, can further enhance health, especially among older people. To date, the CDC reports that only 25% of individuals entering late life are fully up-to-date with these programs (CDC, 2014), so there is clearly room for improvement.

Aside from these concrete public health efforts, however, very sedentary lifestyles, now typical among Americans, are strongly associated with epidemic levels of obesity, and are especially prevalent among relatively disadvantaged subgroups of the population (Lee, Andrew, Gebremariam, Lumeng, & Lee, 2014). Reductions in the risk or severity of chronic diseases will require considerable increases in physical activity, reductions in sedentary behavior, and improvements in dietary habits and nutrition. Policies that target schools and workplaces are ideally suited for programs that establish life-time healthy behaviors (Antonucci et al., 2012).

There is also great need for life-long intervention programs that target high-risk populations. Evidence suggests that intervening, even late in life, can be highly effective (Bherer, Erickson, & Liu-Ambrose, 2013). The Diabetes Prevention Program (DPP) lifestyle intervention, targeting those at high risk for diabetes, reduced the rate of developing diabetes by 58% when compared to placebo. The age group that benefitted most was the elderly, demonstrating clearly that secondary intervention is effective even at advanced ages (Tsigos et al., 2013). The National Institute of Aging has created a publicly available program, launched in 2011, called Go4Life (http://go4life.nia.nih.gov). This is an intervention program that specifically targets physical activity for the elderly by providing health information, sample exercise programs, as well as links to available support materials and partnering organizations.

Long-term care is one of the major challenges facing an aging society and will affect increasingly more families as the large Baby Boomer generation begins to age past 80 in the very near future. Unfortunately, the United States lags behind other advanced countries in responding to the need for affordable long-term services and supports, especially the lack of family incentives. A multipart strategy is necessary. This should include greater support for family and other informal caregivers, encouragement for community-based care programs as alternatives to institutionalization as well as support for the expansion of research into ways to prevent and cure the leading causes of disability in old age. We must also encourage advance planning for end-of-life decisions so that the wishes of individuals are respected.

It is clear, at this point, that we will not have anywhere near the number of gerontologically or geriatrically trained psychologists, physicians, other health care or public health professionals that we will need to offer specialized medical and preventive care to elderly people in the future (IOM, 2008). Hoge et al. (2015) have recently outlined the severity of the issue for psychologists and how it might be addressed. We need to prioritize the gerontological and geriatric training of all health care providers so that they recognize age-specific needs of younger and older people. Just as children have different health needs that require different treatments, appropriate types and dosages of medications, and respond differentially to treatment regimens, the elderly face distinct medical issues and require remedies which often are different from those appropriate for young people. One example is frailty which is more frequent among older people and alters responses to treatments and recovery. Another example is obesity which in childhood and early adulthood carries an increased risk of chronic diseases such as diabetes, hypertension, and stroke as well as increasing disability and morbidity. On the other hand, among older people carrying additional weight appears to be less harmful (Clark et al, 2014).

Ultimately, we need to discover ways to prevent or delay serious late-life disabilities. Although a century ago, many of the scientific breakthroughs came from medical science, there is an urgency now to make progress in the social sciences, particularly the science of behavioral risk modification, aimed at delaying and preventing chronic conditions. The United States has been the clear global leader in the biomedical sciences, and the caliber of American scientists continues to be superb. Serious reductions in science funding over the last decade, however, are eroding the potential of new breakthroughs in prevention and treatment of disease and disability just as population aging is rapidly unfolding. There is keen interest among biomedical scientists, for instance, in the prospect of slowing the biological processes associated with aging that increase the risk of a range of diseases and frailty. Slowing these processes could mean that some effects of aging may be avoidable and even reversible. Recent breakthroughs in stem cell biology, for example, show clear evidence that age-related changes in the hearts and brains of animals can be reversed by exposure to the circulatory systems of young animals or by treatments with proteins which circulate abundantly in young blood but are largely absent in late life (Rando & Finkel, 2013). Similarly, progress in reducing frailty by preserving muscle mass offers similar reasons for optimism (Elkina, von Haehling, Anker, & Springer, 2011; Lu et al., 2014). Goldman et al. (2013) recently reported economic analyses comparing the costs and value of interventions that delay specific diseases with the costs and values of delaying the aging process. They conclude that these broad preventive approaches would be far more cost-effective, not to mention less devastating to family, friends, and community.

Similarly, preventing or even delaying Alzheimer's disease can potentially save billions of dollars and relieve the suffering of millions of victims and their families. The decrease in funding for science across the board, however, has slowed progress in research on brain disease. In 2010 the estimates of total monetary costs of dementia were roughly $150–$200 billion annually (Hurd, Martorell, Delavande, Mullen, & Langa, 2013). Although the National Institute on Aging is investing heavily in Alzheimer's disease research and the coordination of research findings, funding shortages continue to slow the pace of new knowledge. Further, there are breakthrough insights about community-based approaches that may offer new approaches to prevention (Carlson et al., 2009) which deserve aggressive follow-up.

EDUCATION

Educational attainment influences lifestyles and, importantly, length of life (Olshansky, Beard, & Börsch-Supan, 2012). Many argue that educational attainment and its subsequent relationship to employment is at the core of social advantage and disadvantage in the United States. The level of educational attainment individuals achieve places them on starkly different life-course trajectories that subsequently influence access to jobs, partners, stable families, health care, housing, and social networks. Education predicts functional health even better than life expectancy. The strong positive correlation of education with physical health and fitness is well-established (Goldman & Smith, 2002; Jürges, Kruk, & Reinhold, 2013), with highly educated groups holding an even greater advantage in terms of healthy life expectancy than in terms of total life expectancy (Crimmins and Saito, 2000; Crimmins & Hagedorn, 2010). In short, lower levels of education are associated with more years of ill-health and fewer years in good health (Crimmins & Cambois, 2003), thereby limiting work capacity as well as engagement with families and communities.

Rather than shrinking, differences in long-term outcomes between those with and without college degrees have been widening in recent decades (Crimmins & Saito, 2000). Among white men with less than 12 years of education, life expectancy *dropped* by an average of 3 years between 1990 and 2008. Among white women, education-based gaps are even starker (Cutler, Lange, Meara, Richards-Shubik, & Ruhm, 2011). Life expectancy *declined* by 5 years between 1990 and 2008 among women with less than a high school education. When race and education are combined, the disparities are even more striking. In an article published in 2012 in *Health Affairs*, the MacArthur Research Network on an Aging Society updated estimates of the impact of race and education on past and present life expectancy. They examined trends in disparities from 1990 through 2008, and observed disparities in the context of a rapidly aging society (Olshansky, et al., 2012). To put it concretely, in 2008, white men and women with 16 years or more of schooling had life expectancies far higher than African Americans who had fewer than 12 years of education—14.2 years more for white men than black men, and 10.3 years more for white women than black women. In 2008 men and women in the United States with fewer than 12 years of education had life expectancies only slightly higher than the general US population in the 1950s and 1960s. Declines in life expectancy—especially of this magnitude—are alarming. Even though the size of the least educated subgroup in the United States is shrinking, the life experiences and lifestyles adopted by the least educated appear to be more lethal than in previous decades.

The causal pathways responsible for the association of social advantage to health and quality of life are complex. Rather than a single mechanism of influence, there are multiple pathways influencing health advantage. Social disadvantage involves environments with greater exposure to toxins, carcinogens, and violence; fewer resources (parks, libraries, supermarkets); lack of access to health care; health-damaging behaviors such as smoking, excessive alcohol use, and lack of exercise; and psychological states such as anger and low sense of control autonomy, and trust, all of which occur more frequently in socially disadvantaged populations (Adler, 2013, p. 680; see also Jackson, Knight, & Rafferty, 2010). Conversely, education appears to protect against disease, especially chronic diseases related to lifestyle, along with the ability to manage diseases, which often requires adherence to reasonably complex treatments, involving medication, diet, and self-care (Goldman & Smith, 2002). Although some controversy remains about whether education protects against the *rate* of age-related cognitive decline (Christensen et al., 2001), there is no disagreement that *level* of educational attainment is a powerful predictor of long-term outcomes.

Education is associated with greater subjective comfort and interest in learning new skills (Charness & Boot, 2009; Ellis & Allaire, 1999), as well as perceived self-efficacy (Zimmerman, 2000). Given the dramatic acceleration of technology transfer in the twentieth century—which continues today—education-based differences can be expected to become more salient in the future due to their mediating effects on technology adoption. A 2014 Pew report found that 87% of college graduates aged 65 and over were internet users, compared with only 40% of those who did not go to college. Other findings also suggest more widespread use of technology and continuing education. For example, Miller (2013) found that fully 48% of Generation Xers—people in their late 30s—reported some form of continuing education including courses, in-service training and workshops, often involving internet access. Military service, which for decades served as a vehicle for advancement among people with relatively low levels of education, now demands considerable technological skill and, according to a recent report from military leaders, low education and obesity combined exclude 75% of young Americans from military service (Christeson, Taggart, & Messner-Zidell, 2009).

Policies and Practices

For reasons noted above, education will be essential to wellbeing in the coming years. Rapid technology transfer is increasing the need for individuals to be cognitively able and motivationally inclined to adapt to new technologies. As modern economies are increasingly based on cognitive skills, a combination of limited education and a global economy marked by fast-paced changes in technology may result in substantial numbers of Americans unable to compete. All the while, college graduation rates remain stagnant.

In the past, US policies have been very successful in increasing educational attainment (Schaie, 2011). In the early twentieth century, public education greatly increased basic reading and math skills in the population. Not only did public education help to prepare young people for jobs, longitudinal studies now suggest that early educational attainment is associated with preserved cognitive performance late in life (Glymour, Kawachi, Jencks, & Berkman, 2008; Glymour & Manly, 2008). The GI Bill made college accessible to a broad segment of the population, especially after World War II given the large numbers of American veterans. The influx of veterans into colleges and universities also changed the nature of higher education, making it more practical and streamlined. The nation also invested millions of dollars in education policies, such as the National Defense Education Act, which actively targeted and recruited talented children so that the United States could maintain a scientific edge during the Cold War.

There is growing evidence that life-long investments in education pay off. Investments in public education are important in order for people to effectively prepare for knowledge-based jobs. Early childhood education improves performance in subsequent grades and may be especially beneficial for non-cognitive skills that help people work effectively with others (Heckman, 2000). We need superior higher education that can train new generations of talented young people in science and technology. It is just as clear that we need to provide ways for young people who are not college-bound to attain sufficient technological proficiencies and skills that they can secure good jobs and make viable contributions to society. Paradoxically and especially troubling are the increased threats to education as a public good, despite accumulating evidence documenting its multiple benefits for individuals and society. Longer working lives, which we turn to in the next section, also demand heavy investments in life-long education and professional training that continues throughout careers, especially in light of the increasingly fast pace of technological change.

Improving the health profiles and life expectancy of people with low levels of education is especially challenging for those who have already passed the phase in life when formal education normally occurs. Workplace education, as well as programs that allow people to return to school at regular intervals throughout adulthood, would allow people to continue to attain abilities and skills post-formal education.

Educational attainment in childhood, adolescence, and early adulthood begins a cycle that continues throughout life. Education determines access to the range of available jobs, and subsequently to work environments that differ in the degree of ongoing learning and physical safety. Highly educated workers earn more and enjoy occupations that are more cognitively demanding. They tend to participate in the workforce longer and are better prepared financially when they retire. The most educated workers become the most productive workers (at least when productivity is indexed by pay) and the most highly paid workers are the most likely to continue working into later life (Burtless, 2012).

WORK AND RETIREMENT

Work life varies enormously for Americans, largely as a function of education: from tedious jobs to dedicated careers, from activities that hold little relevance for personal identity to jobs that play prominent roles in identity and self-concept. Overall, Americans are relatively satisfied with work and older workers are the most satisfied of all age groups across income, education, gender, and race (NORC Center for Public Affairs Research, Benz, Sedensky, Tompson, & Agiesta, 2013). Of course, there is a great deal of variability in work satisfaction. Jobs that offer little in the way of identity and demand monotonous activities are far less satisfying than ones that offer autonomy and flexibility. Prospectively, engagement with work is associated with positive spillover effects on general satisfaction with life. On the other hand, job burnout predicts depressive symptoms, while depressive symptoms do not appear to be causally predictive of job burnout (Hakanen & Schaufeli, 2012). In other words, work influences psychological well-being for better or worse, depending on work practices and conditions.

The wellbeing of women, for example, is challenged by traditional work practices that put women at considerable disadvantage relative to men. Workplace structures and policies have changed relatively little since the 1950s, despite large-scale changes in workforce composition. Subsequently, the juxtaposition of work and family life now presents considerable challenges for workers, especially working families (Christensen & Schneider, 2010). Work stress in the first year of marriage has been shown to be related to marital tensions and divorce among couples 16 years later (Birditt, Wan, Orbuch, & Antonucci, 2014). Working mothers are especially affected, since they often juggle demands of home and work simultaneously. Indeed, the least satisfied workers are parents of young children. Reduced job security, job demands that extend beyond the work day, and the lack of control over schedules create considerable strain. In addition, and often unrecognized, population aging is creating new demands for workers to support older family members, and once again, these demands are falling predominantly to women (Sherman et al., 2013).

In recent years, Americans have begun to work longer (Toosi, 2012) and the trend is expected to continue (Helman, 2014). Studies that control for health and other factors that influence continued active engagement find that work in paid and volunteer positions during later adulthood contributes to physical, social, and emotional health (Bonsang et al., 2012; Carlson et al., 2009; Fratiglioni, Paillard-Borg, & Winblad, 2004; Jenkinson et al., 2013; Rohwedder & Willis, 2010), presumably due to the way such work facilitates engagement physically, cognitively, and through social integration (Börsch-Supan & Schuth, 2014; Fried, Ferruci, Williamson, & Anderson, 2004). In a comparison of countries spanning a broad range of retirement policies, older people in the countries with the least generous pension policies, who thus retired later, scored higher on tests of cognitive performance even after correcting for the fact that workers with below average cognition leave the workforce earlier (Rohwedder & Willis, 2010). These larger positive effects of working longer underscore the need for policies and practices that increase flexibility and accommodate family needs so that people who would otherwise work are not pressured into early retirement.

Workforces are not only aging, they are becoming more age diversified than ever before in history. Industrial psychology, which in the past has focused largely on ways in which personality traits and motivations of workers predict work performance (Kanfer, Wolf, Kantrowitz, & Ackerman, 2010), is beginning to study how employers can adapt to increasingly older and more age-diverse workforces (Finkelstein, Truxillo, Fraccaroli, & Kanfer, 2015). Although there is a great deal of concern about the productivity of older workers in the popular press, the small body of research addressing cognitive fitness of older workers suggests that expectations about loss of capacity are overblown. Despite evidence of a decline in processing capacity, knowledge and expertise appear to compensate well. In a recent study of German autoworkers, productivity increased up to retirement age, and though there was considerable variability in physical functioning within age groups in adulthood, the majority of people were sufficiently fit to work into their 70s (Börsch-Supan, 2013). With thoughtful changes, the melding of the expertise and strong work ethic of older workers with the speed and efficiency of younger workers could yield substantial increases in organizational productivity (Carstensen, Beals, & Deevy, 2015).

Nonetheless myths and misconceptions about older workers have pernicious effects. Employers report that they are unlikely to invest in training older workers and, once unemployed, workers over 50 are significantly less likely to find employment (Johnson & Park, 2011). There is also considerable public discussion that working longer will mean fewer opportunities for younger workers. Economists refer to beliefs about older workers taking jobs from younger workers as the "lump of labor" fallacy. At the macroeconomic level, the opposite is true: countries with greater concentrations of older people in the workforce also have lower rates of youth unemployment (Börsch-Supan, 2013; Gruber & Wise, 2008). There is no evidence that Baby Boomers are taking jobs from younger workers (Munnell & Wu, 2012).

Not surprisingly, economic preparedness influences retirement satisfaction (Bender, 2012) but concerns that retirement is associated with widespread discontent and a loss of identity have not been substantiated by research. A recent meta-analysis concluded that retirement is associated with positive effects on emotional wellbeing, related to a reduction in stress, and opportunities to spend more time with family and friends (Luhmann, Hofmann, Eid, & Lucas, 2012). The same meta-analysis revealed a slight and temporary negative effect on life evaluations, which they interpreted as anxiety or uncertainty concerning retirement. By 1 year into retirement, these negative effects were no longer observed. Although there are clearly circumstances associated with retirement that affect wellbeing negatively, such as ill health and involuntary separation from work, retirement per se appears to be favorably related to emotional wellbeing.

In part, the absence of negative effects is related to continued social engagement post-retirement. Although paid work declines as people age, volunteer activities do not (Moen & Flood, 2013). Civic engagement offers a way to harness the human capital represented in older people for communities as well as benefits for individuals. For others, retirement represents a chance to pursue "encore careers" or "second acts," where workers opt for lesser pay but greater satisfaction in social entrepreneurship (Fried et al., 2004; Freedman, 2007). In addition to the camaraderie and sense of purpose that volunteering can provide, increasingly evidence points to potential physical and psychological benefits for individuals (Fried et al., 2004). While higher levels of education are often associated with higher rates of volunteerism, in a recent study by Ajrouch, Antonucci, and Webster (2014) social networks that promote bonding through more contact and proximity were shown to substitute for the lack of human capital, such as education, to increase rates of volunteerism, thereby enhancing the probability of obtaining the positive effects on health.

From a psychological perspective, work and family life are both essential to wellbeing. Given the amount of time that people spend at work, work environments represent ideal settings for large-scale interventions in mid-life. Working longer can hold important benefits for physical and cognitive health, yet work stress can take a great toll. There is ample potential for policies and practices to improve work life.

Policies and Practices

There may be no area of life where policies are more influential than in the domain of work and retirement. Policies that encourage longer working lives can significantly change productivity trajectories and employers can help prepare people for retirement. A great many workers never enroll in financial retirement plans, and those who do often fund them inadequately. Many benefit administrators and policymakers have become alarmed, and have increasingly looked to behavioral economics research for remedies. The most effective reform in recent years is default enrollment, where employees must affirmatively "opt-out" of contributions through payroll deductions as opposed to "opt-in" (Beshears, Choi, Laibson, & Madrian, 2009). A second reform is the use of a gradually increasing contribution schedule, designed to get workers used to funding the account at low contribution levels, then allocating growing portions of future raises in order to reach more adequate contribution levels over the course of their careers (Beshears et al., 2009).

A second area for policy innovation concerns job flexibility and employer-based wellness programs. Whereas younger workers often face conflicts between childcare and work, older workers are likely to have adult family caregiving responsibilities. They often seek more optimal work/life balance. More flexible work schedules, including part-time work, 4-day work weeks, and job sharing can often extend work years. Many "retired" employees can be asked back as contingent workers to help with high-demand situations. Although there are isolated examples of attempts to accommodate older workers—for example, CVS Caremark has a snowbird program where older workers can move to warmer regions of the country during harsh winters (Sloan Center for Aging and Work, 2012) and BMW (and Ford) put comfortable chairs and larger computer monitors on assembly lines—there remains tremendous need to further investigate the advantages of age-diverse workforces (Loch, Sting, Bauer, & Mauermann, 2010).

Arguably, the most important program that influences retirement is Social Security. Today, a majority of workers claim benefits before age 63, even though benefits are reduced by 25% compared to benefits at the "normal," statutory retirement age, now 66. When Congress faced the need to strengthen the 1983 Social Security Amendments, many policymakers were determined to change the incentives related to early retirement decisions. As in many other countries, raising the statutory retirement age—even though broadly unpopular—was seen as the most effective way of doing so (Kohli & Arza, 2011). The retirement age for full benefits was raised gradually in the hopes that people would work longer. However, the continued availability of benefits at 62, even though substantially reduced, results in the great majority of workers taking early retirement in the months before turning 63. The availability of benefits at 62, albeit at lower levels, continues to trump messages about the economic virtues of working longer. This is usually short-sighted, net of health reasons, as the lower monthly benefit levels often prove grossly inadequate at older ages, when supplementation is less possible and health care costs increase. This is particularly true for older women, especially spouses who have longer life expectancies than their husbands and who may have only survivor benefits as widows.

Economic security in retirement is one of the foundational elements for late-life wellbeing. Work beyond early retirement ages, physical and mental health, healthy behaviors, prudent retirement planning, and full Social Security benefits are critical factors that support the quality of life for older Americans, today and in the future.

FAMILY LIFE

Families have historically changed and adapted in response to altered ecological conditions whether they are the result of economic transformations, technological advancements, wars, or dramatic shifts in cultural values (Antonucci & Wong, 2010; Furstenberg, 2014). These adaptations rarely come easily as they usually involve altering cherished practices.

Over the past half century, the rise of postindustrial economies throughout the world led to changes in the structure and composition of families, divisions of labor, and daily practices in all wealthy nations as they underwent what demographers refer to as the Second Demographic Transition (Lesthaeghe & van de Kaa, 1986) consisting principally of a decline in fertility below replacement levels along with an increase in life expectancy, as well as a change in societal expectations or values. When families were large and life expectancies short, the rearing and launching of children was managed mostly by relatively young adults. When older family members needed assistance, there were more younger family members available to help them. Today's families, with fewer children and growing odds of having many grandparents and great-grandparents alive at the same time, may be expected to provide support to multiple elderly relatives for extensive periods of time.

Other important societal changes contributed to evolving strains on families. As women's work moved outside the home, the demand for early childcare increased. The anticipated negative effects on children did not appear; indeed, research shows that high-quality early preschool attendance has lifelong beneficial effects on child outcomes. Strains between work and home life did appear, however, absorbed mostly by women (especially single women and poor women) who juggled demands of work and household duties simultaneously. Institutions, like work and school, continue to operate on implicit assumptions that a primary homemaker is available to care for schoolchildren mid-day and to be flexible during evenings, weekends, and holidays. Wage differentials between women and men today are accounted for primarily by relatively low wages for working mothers.

Some have argued that these transformative changes resulted in the weakening of marriage and the family as institutions. Childbearing is less likely to take place within marriage and other stable parental unions. In most wealthy nations, rates of childlessness among women are approaching one in five. Moreover, first-births are occurring later than they did in the 1950s and 1960s and are associated with smaller families—often not begun until the fourth, and even fifth, decades of life (especially late for fathers). This pattern of deferred childbearing, which increasingly begins outside of marriage, is likely to shape the family life of the elderly and their relationships with younger generations. The postponement of childbearing has taken place in wealthy countries that are rapidly aging as the large Baby Boom cohorts enter old age. This poses a significant challenge for the provision of informal care and support to the elderly at advanced ages by family members at the same time that public systems of support are being strained to breaking point. Just as the ranks of the elderly are growing and the families on whom they depend are becoming smaller, families are growing less stable (Ryan et al., 2012).

The generation in the middle, charged with caring for elderly parents while being expected to provide growing levels of support to young adult offspring, is already under considerable financial, social, and time pressures (Brody, 1981). The children of Baby Boomers, birth cohorts from the last decades of the twentieth and the first two decades of the twenty-first centuries, will be especially likely to feel enormous pressures as they enter mid-life, when they are most likely to have children living at home at the same time that their living parents begin to experience health problems and seek assistance from them. Social scientists and gerontologists refer to middle-aged parents with elderly parents as the "sandwich" generation. But the composition of the sandwich itself (i.e., the size of each of the generations) is rapidly changing, creating more crust and less filling, figuratively speaking. The middle generation enters parenthood 5–10 years later than it once did and the parenting contract has been extended, especially if young adults are more likely to seek higher education or are unable to find employment and remain in the home.

Thus, middle-aged adults between 45 and 64 are much more likely to be supporting children as their elderly parents begin to contend with serious health (and perhaps economic) issues. On the other hand, some have argued that the parent generation is likely to be healthier than previous generations. Therefore, the sandwich generation is not as pressing a problem as frequently presented in the past because most children will be out of the house and most parents will be much older by the time they require their children's assistance. Realistically, both points of view are likely to be true. Dichotomous demographic trends suggest that one will be true for affluent, well-educated families while the opposite will be true for those less fortunate.

If such scenarios were not bleak enough, several more complications often undermine the amount of support that families provide to elderly parents. The changes in family form, that is, fewer children raised by both their biological parents, heighten the risk of disconnection between the oldest generation and their descendants. Men, in particular, are likely to lose contact with some or all of their offspring through divorce or separation. A growing body of evidence reveals that fathers who experience marital breakup or who never marry, are unlikely to receive much support from their children later in life, in large part because they provided little support to their biological offspring as they grew up. In addition, divorced men often remarry, creating another potential source of support, but also conflict. As Sherman et al. (2013) have shown, remarriage is often complicated by the ambivalent feelings and uneven mix of support from children and step-children. At the same time, older never-married or formerly married older people are creating new independent support relationships, such as couples "living apart together," i.e., in separate households but committed relationships (de Jong Gierveld, 2004). These couples report valuing their partnerships as well as their independence.

As childlessness rises, elderly parents without children will be looking beyond the confines of the nuclear family for assistance. Here the literature is more encouraging: it suggests that elderly individuals who do not have children can frequently garner support from extended kin and younger friends (Kohli & Albertini, 2009). Early literature on childlessness indicates that people create synthetic families, even when younger. They become the fictive kin of people or families to whom they feel and remain close throughout their lifetime. This creates patterns of exchanges that are likely to extend into old age (Dykstra & Hagestad, 2007; Rowland, 2007). Another increasingly common, some would say new, family form for older people, is group co-housing. In these contexts people share common space, resources, chores, and some caregiving but also maintain private space (Glass, 2009; Glass & Vander Platts, 2013). It is yet to be seen, however, how strong these forms of support will be when faced with prolonged and substantial caregiving demands.

Another worrisome trend that will interact with greater variability in family forms is the growing level of inequality that has been rising for the past several decades. Both a cause and a consequence of the de-institutionalization of marriage, higher levels of inequality are creating a two-tier family system. The top-tier, roughly corresponding to college-educated families, is in a stronger position to weather the challenges of aging. They are somewhat more likely to have stable unions and children with whom they have strong interdependent relations. Second-tier families who lack the advantages of being college graduates have become less stable and more complex. Although life expectancy is lower for this group, as parents in these families reach old age, they are likely to experience relatively more stress resulting from their union instability, economic pressures, and a greater likelihood of health disabilities. In other words, the correlation between socio-economic status and social support in old age is likely to become much stronger in the middle of this century than it was in the middle of the past century. Although older people in these second-tier families tend to have more children and live in closer geographic proximity to them, due to the intergenerational transmission of accumulating life stressors such as marital instability, poorer health and occupational histories, as well as fewer economic resources, the bottom two-thirds of the population in the United States, will probably experience a severe gap between their need for assistance and the supply provided by family members.

Policies and Practices

Policies and practices concerning health, education, work and retirement, of course, fundamentally affect the family. Yet rapid changes in family structures are directly fraying the family safety net that normatively provides for young and needy family members (Cherlin & Seltzer, 2014). To the extent that families remain the primary sources of informal support, in the absence of effective policies, caregiving demands on families may escalate to untenable levels and leave many elderly people without the support that they need. These dramatic changes call for policy innovations adapted to current family structures.

Both traditional and non-traditional families will need support. Policies for children, such as Head Start, offer examples of important societal actions that improved child and family welfare. Rather than being strengthened, they are consistently underfunded and typically under political attack. Whereas many other developed nations have policies which provide such care universally, the United States has expected parents to absorb most of the cost, even in cases where costs are adjusted on sliding scales with priority given to those with more children and less income.

If we are behind in policy and practices related to children, one could argue that this is even more true of policies related to other family members. To the extent that policies help to strengthen bonds across generations, considerable benefits could accrue from their implementation. Grandparents and great-grandparents have enormous potential to, and often do, serve as sources of financial, physical and emotional support. Although most discussions about family old-age policies address the needs of older people, improved health at advanced ages means that grandparent generations can be effectively involved in their grandchildren's (and sometimes great-grandchildren's) lives well into adulthood. Making use of the additional layer of family support can be extremely valuable to children, especially in single-parent, divorced and step-family households. With high rates of divorce and remarriage, grandparents can offer essential stability to children. Policies that encourage grandparent involvement in extended families, ranging from childcare credits that later assist with homecare costs, flexible savings and education accounts, to shared housing policies could strengthen emotional bonds among family members while offsetting strains across generations.

Policies that support non-biological families are also essential in societies where 20% of women do not bear children and longer lives mean that increasingly more older people will outlive their children. As noted above, all sorts of non-traditional families exist and provide strong emotional support. Too often, however, these families are not served in the same ways as traditional families by state and federal policies.

When illness occurs, as it inevitably does, the burden falls predominantly on women, especially poor women. Short-term, acute health events are usually handled best by family members whose familiarity with frail relatives makes them uniquely suited to clearly assess and present options, help with decisions, and advocate for their relatives' needs while providing emotional and tangible support. In these cases, paid family leave, which protects wage-earners while they take time off to care for their family member would be most helpful. Long-term care presents a different set of challenges. Evidence indicates that long-term adult care can be expensive both in terms of human and economic costs. There are currently few publicly available programs to assist. As a consequence, care tends to be individual and expensive. More affluent families can, although often with difficulty, afford this personal oneonone care, but less affluent families often must call on one family member, usually a woman, to quit her job to attend to the needs of their family member. The family then has even less discretionary funds; the caregiver becomes isolated and unavailable to other family members, as does the care recipient. One might argue that the problem is not that families do not want to provide care, but that the burden they take on to provide that care is daunting.

Constant caregiving, e.g., for a family member with Alzheimer's disease, can be draining and depressing, even for the willing caregiver. It is not likely, despite the family member's most noble intentions, that she will be able to provide the best care. Care may become custodial and perfunctory without the guidance of professionals on how best to care for and prevent deterioration of the care recipient. Policies and programs should be created to provide some relief for these caregivers. Group care by professionals or even family members with professional guidance is likely to provide better care for the patient and allow the family member to complement that care while still remaining attached to their other roles and obligations such as parenting and paid employment. Long-term care of any sort is expensive and funding it is a challenge. Probably the greatest policy benefit would be to include long-term care in social insurance, so that the family does not have to impoverish themselves to receive needed help, thus relieving at least some of the financial burden. In addition to costs of caregiving is the question of where elders should live. We turn to this question briefly, below.

Housing options include aging in place; moving to different private, but perhaps better-designed, housing; subsidized independent living properties; and various forms of institutional care from assisted living to skilled nursing facilities. Housing policies are very important and yet are seriously underdeveloped. In light of the inequalities that represent an underlying theme of this chapter, we focus on community-based, affordable housing. This type of housing for seniors is minimal and decreasing in this country even though affordable housing can create safe, protective, and proactively helpful environments for older people. They have the potential to be cost-effective by providing productive environments that encourage healthy living. Older people who age-in-place, often are faced with home designs that are outdated and zoning ordinances that discriminate against multi-family living arrangements. The single family suburban home, far from centralized services, is not well suited to the needs of single parents or multi-generational households. Community living that engages the individual, younger as well as older people, improves the health and wellbeing of everyone (Webster, Ajrouch, & Antonucci, 2014). Policies could help older people modify their homes and assist families in creating multi-family dwellings; thus keeping older people engaged with their families and communities. Policies that increased availability of affordable housing, incentivized elder-friendly designs, as well as multi-generational households and communities, would be advantageous for all.

Finally, it is worth noting that current policies and restrictions concerning immigration often result in the separation of families, especially across generations. These separations have negative consequences for the family, while at the same time severing a major source of elder caregiving, both in the formal and informal sectors. Policies and practices that are supportive, rather than disruptive, of these relationships are likely to yield benefits to individuals and societies.

SUMMARY AND CONCLUSIONS

This chapter focused on four key social institutions that will fundamentally influence individuals' material and psychological success in addressing the challenges we face in light of the demographic revolution of the twenty-first century. People are living significantly longer, marital norms are changing with people marrying later, multiple times or not at all, and having fewer or no children. Normal societal structures concerning care for the elderly are less likely to be available. We highlighted the importance of a lifespan perspective to the four areas: health, education, work and retirement, and family. To successfully address these societal challenges we must enhance health and health care across the lifespan, provide life-long access to education, optimize lifetime experiences of work and retirement for people of all ages, and create innovative approaches to maintain engagement and complement or offset changes in family structure, composition, and norms. We further outlined policies and practices that have or might serve to address these challenges. Thus far, our society has been neither thoughtful nor proactive. Clearly, corrective action is necessary.

Longer life represents a tremendous social and cultural achievement. Yet, this triumph of the modern era requires changes in social norms, institutions, and behavioral practices. All demand policies that support the social fabric that provides for healthy, engaged, satisfying lives. Today, we are advantaged by considerable knowledge about the psychological and behavioral predictors of positive long-term outcomes, as well as risks for disease and disability. Strong social bonds reduce morbidity and mortality (Antonucci et al., 2011; Carstensen et al., 2011). Physical activity promotes physical and mental health; education predicts cognitive functioning in old age. The growing inequalities do not bode well for the future.

Increasingly studies show that work—whether paid or unpaid—benefits cognitive health in old age. We have amassed sufficient information about Americans 50 years of age and older that predictive modeling, such as the Future Elderly Model, can simulate a range of long-term outcomes with key inputs (Goldman et al., 2005; Zissimopoulos, Blaylock, & Tysinger, 2014), allowing sophisticated projections into the status of future generations of long-lived people. The transformation of the United States from a young into an aging society is a great challenge that also represents scores of opportunities to improve life at all ages. Fortunately, in the past, we have shown ourselves capable of stepping up to, and successfully meeting, the challenges we have faced. We will need to be committed, as a society, to create innovative, bold, and unifying solutions to successfully address the challenges of the future—much as we have in the past.

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CHAPTER

4

Sex Hormones and Cognitive Aging

Anna C. McCarrey, Melissa H. Kitner-Triolo, and Susan M. Resnick

Laboratory of Behavioral Neuroscience, National Institute on Aging, Baltimore, MD, USA

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INTRODUCTION

Sex steroid hormones influence cognition and affect at many points in life. Steroid hormones have organizational effects during the prenatal and neonatal periods. They have maturational effects during various stages of development, including activational effects at puberty, variation during the menstrual cycle and across seasons, and possibly effects at menopause and beyond. In this chapter, we will focus on hormone effects on behavior during adulthood. We begin with a discussion of menstrual cycle variation effects on cognition, affect, and neural activity. We next discuss the major focus of this chapter, that is, effects of estrogen in relation to age-related cognitive decline and risk for dementia in postmenopausal women, followed by a brief discussion of the more limited information on testosterone effects on cognition, emphasizing effects in older men. Finally, we highlight several important areas for future research.

EFFECTS OF ESTROGEN AND TESTOSTERONE IN YOUNG ADULTS

Variation in Cognition across the Menstrual Cycle

Much of the research examining the effects of hormonal fluctuations across the menstrual cycle has investigated fluctuations in verbal and spatial abilities. One reason for this emphasis is the finding that men, with naturally high levels of testosterone and relatively lower levels of estrogen and progesterone, tend to perform better on visuospatial (classically male) tasks, while women, with naturally high levels of estrogen and progesterone and lower levels of testosterone, tend to perform better on verbal (classically female) tasks (Hampson & Kimura, 1992; Maki & Resnick, 2001). This sex difference is evidenced early in life and persists to old age.

Reviews (Craig & Murphy, 2007; Gasbarri, Tavares, Rodrigues, Tomaz, & Pompili, 2012; Hampson & Kimura, 1992; Maki & Resnick, 2001) and early studies (Hampson, 1990; Hampson & Kimura, 1988; Maki, Rich, & Rosenbaum, 2002; Rosenberg & Park, 2002) examining the effects of hormonal fluctuations on cognitive processing across the menstrual cycle emphasized findings where high estrogen and progesterone levels were associated with better performance on verbal measures (verbal articulation, fluency) and fine motor skills and poorer performance on visuospatial tasks. More recent studies have yielded less consistent findings. For example, Pletzer and colleagues found higher error rates in verbal numerical processing in women during the follicular phase (low estrogen and progesterone) and higher error rates in spatial numerical processing during the luteal phase (high estrogen and progesterone) (Pletzer, Kronbichler, Ladurner, Nuerk, & Kerschbaum, 2011). Although Maki et al. (2002) found women performed better on tasks of verbal fluency and motor skills and poorer on a 3-D visuospatial task (mental rotations) during high estrogen and progesterone phases of the menstrual cycle (midluteal phase: ML) compared with low estrogen and progesterone (early follicular phase: EF), they did not find menstrual cycle effects on an explicit memory category-cued recall task. In contrast, Mordecai and colleagues found no differences on tasks of verbal fluency, verbal or visuospatial memory, 3-D visuospatial abilities or attention for EF versus ML (Mordecai, Rubin, & Maki, 2008). In other studies, estrogen and progesterone effects, based on menstrual cycle phase, were also not observed for semantic decision making, perceptual letter-matching tasks (Fernandez et al., 2003), reaction time (RT) using a decision-making monetary incentive delay task (Ossewaarde et al., 2011), spatial rotation (Rosenberg & Park, 2002) and 3-D visuospatial abilities (Schöning et al., 2007). Interestingly, practice on mental rotation tasks may impact observations of hormone associations, with one study finding associations between low estrogen and better performance during initial testing but not after repeated exposure (Courvoisier et al., 2013).

Results from studies examining working memory across the menstrual cycle have also been inconsistent. Rosenberg and Park (2002) found that higher levels of estrogen or progesterone (late follicular: LF; ovulation: OV; ML) were associated with better verbal working memory accuracy than lower estrogen and progesterone (menses: MN). In contrast, no significant differences in accuracy or RT were found on an N-back task across low (EF) and high estrogen (LF) phases, although comparison of 2-back with 0-back performance revealed an increase in errors during high-estrogen versus low-estrogen phases (Joseph, Swearingen, Corbly, Curry Jr, & Kelly, 2012).

Menstrual Cycle Fluctuations in Neural Activity

Neuroimaging studies have increased exponentially since Maki and Resnick (2001) reported the dearth of research into brain activation pattern changes across the menstrual cycle. Early studies found varying results depending on the type of behavioral tasks and neuroimaging procedure used, as well as the type of investigation (within-subject studies across the menstrual cycle, hormone-suppressing and -activating interventions) (Berman et al., 1997; Dietrich et al., 2001; Reiman, Armstrong, Matt, & Mattox, 1996; Veltman, Friston, Sanders, & Price, 2000). More recent studies using functional magnetic resonance imaging (fMRI) to investigate variation in brain function across the menstrual cycle report menstrual cycle variation in neural activation both in conjunction with performance differences and even in the absence of behavioral performance differences.

Several investigations have demonstrated menstrual cycle variation in both neural activation and task performance. For example, Derntl et al. found better facial emotional recognition performance was associated with greater amygdala activation during the follicular phase compared to the luteal phase of the menstrual cycle (Derntl et al., 2008). Investigating cortical activation with spatial and verbal numerical processing in the follicular versus the luteal phase, Pletzer et al. (2011) found higher errors rates and greater bilateral inferior parietal lobule and medial prefrontal cortex deactivation in the luteal phase for spatial versus verbal numerical processing. In addition, differential right and left frontal activation associated with working memory performance has also been associated with cyclic variation across the menstrual cycle (Joseph, Swearingen, Corbly, Curry, & Kelly, 2012).

There are also a number of studies reporting hormonal effects on neural activation in the absence of behavioral performance variability across the menstrual cycle. For example, Fernandez et al. (2003) found no estrogen-related behavioral effects in either a semantic decision-making task or perceptual letter-matching task, yet they found that higher levels of both estrogen and progesterone were associated with medial superior frontal activation and higher progesterone level was associated with bilateral superior temporal activation during the semantic task. Craig et al. found that higher estrogen was correlated with magnitude of left inferior frontal gyrus (LIFG) activation even though estrogen level was not associated with verbal recall (Craig et al., 2008c), and Schoning et al. (2007) found differences in brain activation in specific frontal, temporal and parietal regions across high- and low-estrogen phases during a 3-D mental rotation task despite the absence of menstrual cycle performance differences. In the latter study, higher estrogen during the ML phase correlated with increased bilateral activation in superior parietal, frontal gyrus, and right inferior parietal regions.

In an effort to systematically examine the effects of hormonal fluctuations on cognitive performance and brain functions, some studies have simulated menstrual cycle hormone level fluctuations using estrogen-lowering medications, specifically gonadotropin-releasing hormone agonists (GnRHa). A series of studies by Craig and colleagues (Craig et al., 2007, 2008a, 2008b) examined the effect of estrogen suppression after 8 weeks of GnRHa administered in a group of women awaiting fibroid surgery. Visual recognition accuracy using a Delayed Match to Sample task (Craig et al., 2008a) did not vary based on estrogen level (LF vs. estrogen suppression), yet recognition RT decreased across the two testing phases, and women had decreased activation during visual encoding in the middle temporal and left parahippocampal gyrus, precuneus, posterior cingulate, and paracentral lobule. In a similar study investigating verbal encoding and recognition memory, Craig et al. (2007) found no effects of 8 weeks of GnRHa administration on encoding performance but found reduced recognition discrimination after GnRHa administration. There were no activation effects during recognition, yet there were activation attenuations in the left prefrontal cortex, medial frontal gyrus and anterior cingulate during verbal encoding. Additionally, Craig et al. (2008b) found that adding back estrogen after estrogen suppression returned decreased activation in the LIFG to previous levels during encoding and reversed the decrease in verbal recognition performance to prior levels of discrimination.

Variation in Affect across the Menstrual Cycle

Early investigations (Brooks-Gunn & Warren, 1989; Warren & Brooks-Gunn, 1989) and anecdotal reports indicate that mood varies across the menstrual cycle. However, more recent results of menstrual cycle variation in affect are less evident. Maki et al. (2002) and Mordecai et al. (2008), investigated variation in affect using the Positive and Negative Affect Scale (PANAS) and depressive symptoms using the Center for Epidemiological Studies Depression Scale (CESD), and Hampson et al. employed the Profile of Mood States (POMS) (Hampson, Finestone, & Levy, 2005). No significant estrogen-related variation was observed. Additionally, Hausmann (2005) found no differences in cheerfulness, seriousness or bad mood based on hormonal fluctuations across the menstrual cycle. The detection of menstrual cycle variation in affect may be hindered by large individual differences and conditions such as pre-menstrual syndrome.

In summary, the variability in behavioral and functional activation findings across studies of menstrual cycle hormonal fluctuations may reflect differences across studies related to both assessment of hormone status and behavioral domains. Factors related to assessment of hormone status include measurement of hormone status (e.g., types of assays of estrogen and progesterone, saliva versus plasma, self-report), phases of the menstrual cycle when testing occurred, and hormonal fluctuations depending on day of testing. Similarly, results are dependent on the specific cognitive and affective domains assessed. Although menstrual cycle variation in neural activation is more consistently reported, these results also vary according to the time of testing and brain areas investigated. Future research should systematically investigate menstrual cycle variation using standardized measures of hormone status and cognitive function, and the examination of specific task-related brain regions in activation studies.

EFFECTS OF MENOPAUSE AND HORMONE LEVELS ON COGNITION IN OLDER WOMEN

Menopause is the time in a women's life in which her menstrual cycle ends, and she no longer has reproductive capacity. The timing of menopause is defined as 12 months from the final menstrual period, with a median age of 52.5 years (Gold et al., 2013). The depletion of ovarian hormones such as estrogen, progesterone, and testosterone during the menopausal transition results in a number of physiological changes, including effects on the central nervous system. Importantly, with increased longevity in recent years, women now spend more than one-third of their lives with depleted ovarian hormones. Common menopausal symptoms include hot flashes, night sweats, and urogenital problems among others (Dennerstein, Dudley, Hopper, Guthrie, & Burger, 2000; Obermeyer, Reher, & Saliba, 2007; Ribowsky, 2011). Artificially replacing hormones and boosting levels through hormone therapy (HT) alleviates many of these physiologic symptoms, and early observational and epidemiological studies suggested that HT had a number of health benefits, including decreased rate of coronary heart disease and mortality (Grodstein & Stampfer, 1995; Grodstein et al., 1997,2000; Henderson, Paganini-Hill, & Ross, 1991; Shlipak et al., 2000).

From a psychological perspective, observational studies suggested that the cumulative lifetime exposure to estrogen a women experiences impacts her cognitive functioning later in life. Factors influencing cumulative estrogen exposure include age at menses and at menopause, duration of HT in hormone users, duration of breastfeeding if child-bearing and time since menopause (Hesson, 2012). Menopause earlier in life has been linked to lower cognition in later adulthood (Hogervorst, 2012; Hogervorst, Kusdhany, & Rahardjo, 2011), as well as increased risk of overall mortality (Nelson, Walker, Zakher, & Mitchell, 2012). A number of studies report cognitive decline in women undergoing the menopausal transition (Mitchell & Woods, 2011; Schaafsma, Homewood, & Taylor, 2010; Weber, Maki, & McDermott, 2013), especially in particular cognitive domains, such as working memory and attention (Greendale et al., 2009; Keenan, Ezzat, Ginsburg, & Moore, 2001; Kimura, 2002; Wroolie et al., 2011). However, findings are mixed, and some reviews of observational studies point to no substantial changes to cognition occurring during the natural menopausal process (Henderson & Sherwin, 2007) or none of clinical relevance (Henderson, Guthrie, Dudley, Burger, & Dennerstein, 2003). Other studies describe findings whereby cognitive impairments are temporary (Greendale et al., 2009) or that only very specific cognitive domains are impacted, such as verbal fluency (Fuh, Wang, Lee, Lu, & Juang, 2006). In reviewing this literature, Henderson and Popat (2011) found no consistent links between serum estrogen levels and episodic memory or executive functions at midlife or in older naturally menopausal women. The inconsistent behavioral findings may be explained in part by the stage of menopause examined, the effects of brain aging in older women (aged 65+ years) and other covariates not considered (Shanmugan & Epperson, 2012). In addition, it is difficult to distinguish effects of menopause from age, and the menopausal transition is a time marked by greater intra- and inter-individual variability in physiology, and in cognitive and affective response to that variability.

Estrogens and Menopausal HT in Women—Observational Studies

As mentioned, in addition to relieving menopausal symptoms such as hot flashes and vaginal dryness, HT was thought to have a number of benefits to health, which included prevention of cognitive decline during the menopausal transition and beyond. Basic science investigations, including those using cell culture and animal models, indicated that estrogens, particularly estradiol, promote cholinergic activity, enhance synaptic plasticity, and offer neuroprotection against beta-amyloid-induced neurotoxicity (Brinton, Chen, Montoya, Hsieh, & Minaya, 2000; Smith, Minoshima, Kuhl, & Zubieta, 2001; Tinkler, Tobin, & Voytko, 2004; Zec & Trivedi, 2002b). Early observational studies suggested that estrogen-based HT protected against risk for Alzheimer's disease (AD), with several prospective studies suggesting more than a 50% reduction in risk in women who had used HT compared with non-users (Kawas et al., 1997; Paganini-Hill & Henderson, 1996; Zandi et al., 2002). Similarly, a number of observational studies in postmenopausal women, including those performed by our group, found that HT users performed significantly better than non-users on tests of cognition including visual memory (Resnick, Metter, & Zonderman, 1997), verbal memory (Maki, Zonderman, & Resnick, 2001), and working memory (see LeBlanc, Janowsky, Chan, & Nelson, 2001; Maki & Hogervorst, 2003; Sherwin, 2006 for reviews). Although these studies attempted to adjust for potential confounds known to impact cognitive performance, such as age, education and socioeconomic status, the "healthy user" bias remains an important confound in observational studies. Women who chose HT tended to be healthier overall, and it is likely that unadjusted confounders might still influence the results of these studies. In addition, the observational studies often included women taking different types and doses of hormone preparations at different times relative to menopause and for different durations. Furthermore, women who go through natural menopause and still have a uterus must take adjuvant progesterone to protect against estrogen-induced endometrial hyperplasia and cancer. In addition to progesterone, a variety of synthetic progestins have been used for this purpose, and the different formulations likely vary with respect to their effects on cognition and health outcomes.

Estrogens and Menopausal HT in Women—Effects of Surgical Menopause and Intervention in Younger and Older Women

Surgical menopause refers to the surgical removal of both ovaries, bilateral oophorectomy, in women still undergoing menstrual cycles. Indications for this type of procedure include malignant or benign ovarian or metastatic disease that cannot be treated medically, and ovarian or breast cancer risk reduction (Novetsky, Boyd, & Curtin, 2011; Shuster, Gostout, Grossardt, & Rocca, 2008). Unlike the natural menopausal process, where women experience a gradual decrease in ovarian hormone production over several years, surgical menopause brings about an abrupt and immediate withdrawal of these steroid hormones.

Observational results from The Mayo Clinic Cohort Study of Oophorectomy and Aging, a large-scale, long-term longitudinal study, suggested that surgical menopause in both young and old women carries an increased risk of cognitive impairment and dementia (Rocca et al., 2007; Rocca, Grossardt, & Maraganore, 2008). In another longitudinal study spanning 2 years, global cognition scores (Mini Mental State Exam) and two Wechsler Memory subscores were reduced in the surgical compared with age-, education- and weight-matched premenopausal controls (Farrag, Khedr, Abdel-Aleem, & Rageh, 2002). Moreover, these changes appeared early, at 3–6 months following surgery. Additionally, an earlier age of surgical menopause has been associated with an increased risk of cognitive dysfunction and dementia (Bove et al., 2014; Nappi et al., 1999; Phung et al., 2010; Rocca et al., 2007; Rocca, Grossardt, Shuster, & Stewart, 2012). Some researchers however, have reported negligible or no effect of surgical menopause on cognitive functioning in middle-aged (Kok et al., 2006; Vearncombe & Pachana, 2009) and older women (Bove et al., 2014; Kritz-Silverstein & Barrett-Connor, 2002).

Interest in the effects of HT on cognition was reinvigorated by a series of studies in younger surgically menopausal women conducted by Barbara Sherwin and her colleagues in the late 1980s and early 1990s. Sherwin (1988) and Phillips and Sherwin (1992) found beneficial effects of HT on cognitive function, especially verbal memory performance, in younger women who had undergone surgical menopause. Phillips and Sherwin (1992) tracked 19 women before and after bilateral oophorectomy and hysterectomy surgery, and who had been randomly assigned to estrogen-replacement therapy or a placebo group on varying memory measures. The group by time interaction was significant in that HT prevented the surgical-menopause-associated decline in immediate and delayed verbal memory. This HT effect was domain-specific as digit span scores and the immediate and delayed recall of visual material were not subject to hormonal effects. In another study examining HT use after surgical menopause, the same group reported significantly lower scores in tests of short- and long-term memory and logical reasoning for the placebo group post-surgery (Sherwin, 1988). In general, hormone treatments appeared to protect against post-surgery cognitive decline.

Observational studies have reported similar cognitive benefits for HT use after surgical menopause (Bove et al., 2014; Rocca et al., 2007). For example, Bove et al. (2014) combined the results from two longitudinal cohorts of older women (mean age 78 years), and found that HT use for at least 10 years, and within 5 years of surgery, was linked to a decreased decline in global cognitive functioning. This suggests that the length and timing of HT use may affect its neuroprotective effect in surgically induced menopause. Not all studies, however, have found such effects (Maki & Hogervorst, 2003), and there is a paucity of research studies where surgical menopause is clearly defined and objective cognitive deficits, as opposed to cognitive symptoms, are measured. Nevertheless, clinical data support the assertion that cognitive functioning may be impacted by early surgical menopause (Farrag et al., 2002; Henderson & Sherwin, 2007) and that HT may be of greater benefit to women having undergone surgical menopause.

Estrogens and Menopausal HT in Women—Intervention Studies in Older Postmenopausal Women

In contrast to the beneficial effects of estrogen therapy in younger women following surgical menopause, results of randomized controlled trials in older, naturally menopausal women have yielded more mixed results. Although some studies have reported cognitive improvements when comparing HT to placebo groups (Haskell, Richardson, & Horwitz, 1997; Sherwin, 2006; Zec & Trivedi, 2002a), the majority of recent intervention studies do not support a beneficial effect of HT in older postmenopausal women. A number of factors may contribute to mixed results, including the type of hormones used, the dosage, the timing of treatment, and the way in which the treatment was administered, including cyclic versus continuous. Additionally, results vary depending on the specific cognitive functions. Some have argued that verbal memory is the cognitive domain most affected by HT (e.g., Sherwin) whereas others have argued that working memory and prefrontal function may be more affected than delayed memory and hippocampal-dependent tasks (Krug, Born, & Rasch, 2006). This is in keeping with a study from Voytko and colleagues (2009), who found greater prefrontal effects of preserved executive functions in the form of Wisconsin Card Sorting performance and shifting visuospatial attention in a sample of menopausal monkeys administered HT.

Results from the Women's Health Initiative Memory Study (WHIMS) and the Women's Health Initiative Study of Cognitive Aging (WHISCA)

The WHIMS (Shumaker et al., 1998) and WHISCA (Resnick et al., 2004) studies have been conducted as ancillary studies to the Women's Health Initiative (WHI) randomized controlled trial of the effects of HT on health outcomes in postmenopausal women. The WHI HT trial was comprised of two parallel placebo controlled trials of conjugated equine estrogen (CEE)-based HT regimens. Enrollees were 50–79 years of age and postmenopausal. Active therapies consisted of 0.625 mg/day CEE in women post-hysterectomy and 0.625 g/day CEE combined with 2.5 mg/day medroxyprogesterone acetate (MPA) in women with a uterus. Although study medications were terminated in 2002 (women without prior hysterectomy) and 2004 (women with prior hysterectomy), women continue to be followed. The WHIMS ancillary study enrolled 7429 women 65 years of age and older to evaluate effects of HT on risk and progression of dementia. The WHISCA study enrolled women without dementia to evaluate effects of HT on memory and other cognitive abilities and was initiated on average 3 years after randomization to the HT trial. In 2008, WHI clinic visits ceased and WHIMS transitioned to an annual telephone-administered cognitive assessment battery (described below), for the WHIMS Epidemiology of Cognitive Health Outcomes (ECHO), which combines the WHIMS and WHISCA studies.

Although the choice of CEE and combined CEE + MPA interventions, rather than estradiol-based HT, has been questioned by basic and clinical scientists, it is important to remember that these preparations were the most widely used types of postmenopausal HT treatments in the United States. Until findings from the WHI in 2003, HT was widely reported in observational studies to deliver additional health benefits such as decreased risk for coronary heart disease, hip fracture (Grady et al., 1992), and dementia (Birge & Mortel, 1997; Haines, 1998; Henderson, 1997; Hogervorst, Williams, Budge, Riedel, & Jolles, 2000; LeBlanc et al., 2001; Melton, 1999; Panidis, Matalliotakis, Rousso, Kourtis, & Koumantakis, 2001; Zandi et al., 2002). The primary goal of the WHI HT trials was to test the widely held belief that postmenopausal HT would prevent heart disease in postmenopausal women (and the primary adverse event expected was increased breast cancer), a critical public health issue. The expected benefit for cardiovascular disease was not supported by the main WHI HT trial results (Anderson et al., 2004; Rossouw et al., 2002). While results varied for the CEE + MPA versus the CEE alone HT trials, CEE + MPA was associated with an increased risk of breast cancer and both treatments increased risk for stroke and blood clots in the leg and lungs.

Results of the WHIMS and WHISCA studies also yielded findings that were contrary to the predicted reduction in risk for dementia and benefit to cognitive function. Instead, both active treatment groups showed an increase in dementia risk. Randomization to combination CEE + MPA compared with placebo was associated with a significant increase in risk of dementia in women aged 65 years and older (Shumaker et al., 2003) and with poorer global cognitive function over time (Espeland et al., 2004). Randomization to CEE alone versus placebo also resulted in an increased risk for dementia, albeit not-reaching the $P = 0.05$ significance level (Shumaker et al., 2004), and was associated with significantly lower performance on a measure of global cognitive function (Espeland et al., 2004). The deleterious effects of both forms of HT on cognitive function persisted after treatment cessation (Espeland et al., 2010).

In addition to the WHIMS studies of dementia risk and global cognitive function, the WHISCA study of 2302 WHIMS participants provided information on the effects of HT on a larger battery of specific cognitive functions, including verbal, visual, and working memory, attention, verbal fluency, and spatial ability, in women without dementia. Again, contrary to expectation, Resnick et al. (2006) found that older postmenopausal women randomized to combination CEE + MPA had poorer verbal learning and memory scores over time (average 4–5 years) compared to placebo controls. However, no other cognitive functions measured were impacted. (See Singh and Su (2013) for a discussion of the neurobiological differences between endogenous progesterone and synthetic MPA that may have influenced these findings.) In women randomized to CEE alone, results from the WHISCA study showed no significant benefits or harm to age changes in specific cognitive functions (Resnick, Espeland, An et al., 2009). Neither treatment, combination CEE + MPA nor CEE alone, significantly influenced measures of affect and depressive symptoms (Resnick et al., 2006; Resnick, Espeland, An et al., 2009).

To better understand the mechanism leading to the adverse effects of these HT treatments on dementia risk and some measures of cognitive function, an MRI study of brain structure was performed in 1403 women in the WHIMS study an average of 3.0 and 1.4 years after the termination of study medications for CEE + MPA and CEE alone, respectively (Resnick, Espeland, Jaramillo et al., 2009). In view of the documented increase in risk for stroke and thromboembolic events, WHIMS investigators hypothesized that the adverse effects of HT on dementia risk and cognition might be due to an increase in vascular disease. The WHIMS-MRI study evaluated the effect of HT on ischemic lesion volumes (primary endpoint), as a measure of increased vascular disease, and total brain, frontal and hippocampal volumes (secondary endpoints), as measures of neurodegeneration. Contrary to prediction, there was no increase in MRI-assessed vascular abnormalities in HT versus placebo (Coker et al., 2009) but there was a reduction in total brain, frontal and hippocampal volumes in women previously randomized to HT versus placebo. Moreover, the adverse effects of HT on brain volumes were most pronounced in women with the lowest cognitive function at enrollment in WHI, and those with the highest white matter lesion volumes on MRI. These findings suggest that women who are less healthy may be most vulnerable to adverse effects of HT, and conversely, that HT could have different effects on a healthy brain.

Following the highly influential findings from the WHI in 2003 there ensued dramatic reduction worldwide in the use of HT after menopause (Ettinger et al., 2012). However, HT remains a highly effective treatment for relief of menopausal symptoms, including hot flashes and vaginal dryness. In addition, many investigators argued that the WHIMS results were influenced by the fact that treatment was initiated years after the cessation of menopause in women 65 years of age and older, and that treatment initiated early in menopause might yield different findings. According to this “critical period” (Resnick & Henderson, 2002) or “window of opportunity” hypothesis, the cognitive benefits of postmenopausal HT might only be observed when HT is initiated in early menopause (Henderson, 2013; Maki, 2013; Sherwin & Henry, 2008). Several observational studies offered some support for this notion. In results from the large epidemiological Cache County study, Zandi et al. (2002) found that former users (more likely to have used HT closer to menopause), especially those with more than 10 years' duration, but not current users of HT, had reduced risk for AD. In a large sample of 428 Australian women older than 60 years, benefits were found for tests of global cognition, psychomotor speed and verbal fluency in women who had initiated HT early post-menopause (MacLennan et al., 2006). Another large-scale study, where 343 postmenopausal Danish women were followed in order to assess the long-term effect of early hormonal treatment on cognitive function, found similar results (Bagger et al., 2005).

Two recent intervention studies tested the hypothesis that early initiation of menopausal HT would benefit cognition. In the WHIMS-Young (WHIMS-Y) Study, 1326 women who had been randomized to CEE with or without adjuvant MPA when aged 50–55 years were administered a validated battery of cognitive tests during a telephone interview conducted approximately 14.2 years after randomization to treatment and 7.2 years after treatment discontinuation (Espeland et al., 2013). The WHIMS-Y women were 67.2 years of age on average when tested. Given the Federal Drug Administration's recommendation of short duration/low-dose treatment when necessary for treatment of menopausal symptoms, this study provides an important test of the clinically relevant question: what happens to cognitive function years later when women receive HT during early menopause and then cease treatment? Findings from the WHIMS-Y study showed that early treatment of younger postmenopausal women resulted in neither harm nor benefit to cognitive function. From a cognitive perspective, these findings should offer some reassurance to women who find it necessary to use HT for relief of menopausal symptoms, and are consistent with earlier findings in older WHIMS participants that the healthiest women were less vulnerable to adverse effects of HT (Resnick, Espeland, Jaramillo et al., 2009).

Preliminary findings have also been reported from another randomized controlled clinical trial of HT during the early menopause (http://www.keepstudy.org/news/keeps_ceo.cfm). In the Kronos Early Estrogen Prevention Study (KEEPS), 727 women were randomized during early menopause to one of three groups: lower dose CEE (0. 45 mg/day); transdermal estradiol (50 μg/day); or placebo (Harman et al., 2005). Importantly, women on active estrogens were administered oral progesterone (200 mg), rather than the synthetic progestin used in WHI, for 12 days each month. Women were an average age of 53 years at baseline and were followed over a 4-year period. Although cardiovascular endpoints were the primary outcomes, a sub-study (KEEPS-Cog) evaluated a number of cognitive domains, including memory, in 571 of the KEEPS women (Wharton et al., 2014). The results of the cognitive study indicated that women randomized to oral CEE showed improvement in symptoms of depression and anxiety. However, similar to the WHIMS-Y results, HT in KEEPS had neither benefit nor harm to measures of memory and other cognitive functions.

Testosterone and Progesterone

While most of the literature on effects of hormones on cognitive function in older women focuses on effects of estrogens, the menopausal transition is also associated with declining levels of circulating testosterone and progesterone. Testosterone-based therapy has been used for several decades to treat low libido, however, lower levels of this hormone may also contribute to menopausal symptoms including cognitive variability (Singh & Su, 2013). For example, in a large sample of postmenopausal women not using HT, Ryan et al. (2012) reported that longitudinally, lower testosterone levels were correlated with better verbal episodic memory 2 years later, whereas higher total and free endogenous estradiol levels were associated with better semantic memory. The authors concluded that the specific testosterone/estradiol ratio affects different aspects of memory. In a mini-review article focusing on testosterone and cognition in women, Hogervorst (2012) summarized that in observational studies where a representative sample of older women over a wide age range were included (i.e., women not selected for optimal health), testosterone levels had a negative relationship with verbal memory. Conversely, studies that included very healthy older cohorts over a wide age range found that testosterone has a positive impact on verbal memory performance. Finally, in a randomized controlled trial of 200 healthy, naturally menopausal women assigned to 4 weeks of testosterone undecanoate or placebo treatment, Kocoska-Maras et al. (2011) found no effect of testosterone on verbal fluency, verbal memory, or spatial ability. In comparison to estrogen-based assessments, studies examining testosterone levels are far fewer and there is a critical need for efficacy and safety studies of testosterone or testosterone-containing treatments in older women.

As mentioned, women undergoing HT are typically prescribed progesterone or progestin (progesterone-like medication) alongside estrogen to prevent endometrial hyperplasia and decrease the risk of uterine cancer (Froom, 1991). Therefore, basic science and clinical studies have investigated effects of progesterone, as well as estrogen and testosterone. Studies examining central nervous system effects of progesterone have found neuroprotective impacts in animal models of stroke, traumatic brain injury and spinal cord injury (Singh & Su, 2013). Human studies assessing the link between progesterone and cognition indicate associations between short-term progesterone therapy and benefits on some measures of speed of processing, but not on tests of attention or verbal memory (Schüssler et al., 2008). In sum, the literature documenting the effects of sex hormones other than estrogens on cognitive outcomes in older women is limited and results are inconsistent. Testosterone has been reported as beneficial, harmful and inconsequential, whilst progesterone appears to be linked to more basic cognitive functions, such as processing speed.

Estrogens and Menopausal HT in Older Women—Associations with Brain Structure and Function

Adverse effects of estrogen-containing HT on brain volumes in older postmenopausal women in WHIMS were noted above (Resnick, Espeland, Jaramillo et al., 2009). Nevertheless, there were many reasons to believe that estrogen-containing HT would have beneficial effects on brain structure and function. Estrogen receptors in the brain are known to be clustered in structures imperative to memory and learning such as the hippocampus and the prefrontal cortex (McEwen, Akama, Spencer-Segal, Milner, & Waters, 2012). This is important given that the hippocampus is one of the first brain structures to be affected by AD, with hippocampal atrophy one of the hallmarks of the disease (Apostolova et al., 2012; Jack et al., 2000). Moreover, animal models show that estradiol influences hippocampal function and animal learning (Spencer et al., 2008).

In human brains, estrogens impact structural anatomy in some of the same brain regions. For example, hippocampal and dorsal basal ganglia gray matter volumes within young healthy women have been shown to exhibit fluctuations throughout the menstrual cycle when concentrations of endogenous estradiol vary (Protopopescu et al., 2008). However, whether higher estradiol concentrations are linked to advantageous effects on brain structure remains unclear (Wnuk, Korol, & Erickson, 2012). Some studies that investigate the connection between estrogens and brain morphology report smaller volumes (Greenberg et al., 2006) and in particular the hippocampus (Lord, Engert, Lupien, & Pruessner, 2010), including findings in older women randomized to CEE-based HT in the WHIMS study (Resnick, Espeland, Jaramillo et al., 2009). A cross-sectional finding from the Rotterdam Scan study (den Heijer et al., 2003) indicated that higher total estradiol levels were linked to lower hippocampal volumes and poorer memory performance in a large sample of older women. A follow-up study from a portion of the same sample found no association with total baseline estradiol levels and hippocampal volumes (den Heijer, van der Lijn, Niessen, & Breteler, 2009), although women in the lowest tertile at baseline had the largest decline in hippocampal volume over 3 years.

Other studies have found no association between HT and brain structure (Low et al., 2006; Sullivan, Marsh, & Pfefferbaum, 2005). Specifically, Resnick and Maki (2001) found no differences between menopausal HT users and non-users in measures of total brain volume, gray or white matter, or ventricular volumes. On the other hand, several studies that investigated the connection between estrogens and brain morphology reported *larger* volumes, especially in women receiving HT. For example, Lord, Buss, Lupien, and Pruessner (2008) found that compared to previous and non-users, current HT users had larger right hippocampal volumes, but that there was a significant negative relationship between HT duration and hippocampal volume in the current HT-users group. Larger hippocampal volumes have also been reported in HT users in other studies (Eberling et al., 2003; Erickson, Voss, Prakash, Chaddock, & Kramer, 2010; Hu et al., 2006; Yue et al., 2007). Erickson et al. (2007) reported spared gray matter prefrontal integrity and better executive control in women who received HT for up to 10 years, with both effects reversing when treatment persisted beyond this time. The same group has reported the timing of HT from menopause to be a factor, with larger hippocampal volumes reported for women who initiated treatment early postmenopause (Erickson et al., 2010). As with cognitive findings, the timing and duration of estrogen-based HT may play a role in its potential neuroprotective properties as evidenced by hippocampal and prefrontal volumes.

Sex hormones such as estrogen and progesterone may also alter functional brain networks (Mander, 2001). For example, using an fMRI visual working memory task, Berent-Spillson and colleagues showed that compared with never users, current users or women that had previously used HT exhibited increased activation in several regions critical for visual working memory including the frontal and parietal cortices and the hippocampus (Berent-Spillson et al., 2010). Additionally, a significant positive correlation between functional activation and task performance was found. Maki et al. showed that women who had undergone HT during perimenopause performed better than never-users on a verbal memory task, and that distinct patterns of hippocampal and parahippocampal activation were associated with better performance (Maki et al., 2011). Other studies have found similar increased patterns of neural activity during tasks in women receiving HT including bilateral prefrontal cortex (Persad et al., 2009; Smith et al., 2006). Taken together, these studies suggest that hormones such as estrogen can functionally alter neural systems subservient to (visual and verbal) working memory.

Using positron emission tomography (PET) scans in conjunction with HT both cross-sectionally and longitudinally over a 2-year time period, Resnick and Maki (2001) found HT-related increased patterns of brain activation in regions subservient to memory processes. Lastly, using event-related potentials (ERPs) to study HT effects in postmenopausal, age-related cognitive decline, Anderer et al. (2005) found a significant improvement of P300 latency in the HT-users group as compared with the placebo group. In sum, as with fMRI findings, PET and ERP studies suggest that hormonal treatment may modulate neural processes in postmenopausal women.

TESTOSTERONE AND COGNITIVE AGING IN MEN

Observational Studies of Circulating Levels of Testosterone and Cognitive Function

More detailed reviews of the literature on endogenous testosterone and cognitive function can be found in Yonker, Eriksson, Nilsson, and Herlitz (2006) and Thilers, Macdonald, and Herlitz (2006). Similar to studies of the associations between endogenous estradiol levels and cognitive function in women, results of studies of circulating testosterone and specific cognitive functions in both men and women yield inconsistent findings. In samples combined across younger men and women, curvilinear associations between endogenous testosterone and spatial ability have been reported. This association reflects a negative association between testosterone and spatial ability in young women in combination with a positive association in young men (Moffat & Hampson, 1996). In older men, when positive relationships are reported, they also tend to demonstrate associations between higher testosterone and higher visuospatial function, cognitive measures which often show male advantages on average. In contrast to findings with respect to visuospatial function, few positive associations have been reported for episodic memory and verbal fluency (e.g., Table 1 in Thilers et al., 2006). However, in a large population-based study (The Betula Study) of men and women aged 35–90 years, higher free (unbound and therefore metabolically active) testosterone was associated with better visuospatial abilities, verbal fluency and episodic memory in men but was negatively associated with verbal fluency in women (Thilers et al., 2006). In our earlier study in the Baltimore Longitudinal Study of Aging, which was restricted to men aged 50 years and older, free testosterone levels, measured by the free testosterone index, showed stronger associations than total testosterone with specific cognitive functions, including visuospatial abilities (Moffat et al., 2002). In addition, higher free testosterone levels were associated with a decreased risk for AD (Moffat et al., 2004). However, in the Florey Adelaide Male Ageing Study of 1046 men aged 35–80 years, higher total and free testosterone levels were associated with poorer verbal memory and executive function but faster psychomotor speed (Martin, Wittert, Burns, Haren, & Sugarman, 2007). In a smaller study of 96 men, aged 38–69 years, Martin et al. found no overall main effect of free testosterone levels on spatial abilities or other cognitive measures in the sample as a whole (Martin, Wittert, Burns, & McPherson, 2008). However, in men over age 50 years, higher total and free testosterone were associated with poorer processing speed and executive function. In a large sample of 3369 men aged 40–79 years, from the European Male Ageing Study, Lee et al. found no significant relationships between testosterone and performance on the Rey-Osterrieth Complex Figure, Digit Symbol Substitution Test, and a recognition memory test after adjusting for covariates (Lee et al., 2010). Similarly, there was no relationship between circulating testosterone and global cognition or executive function after adjustment for important covariates in 1602 men participating in The Osteoporotic Fractures in Men Study (MrOS) study (LeBlanc et al., 2010). The lack of consistent findings may reflect variation in study samples, both with respect to age and sex, specific cognitive abilities evaluated, and methods of measuring both free and total testosterone.

Intervention Studies of Testosterone Supplementation

In contrast to the more abrupt changes in ovarian steroid hormone levels experienced by postmenopausal women, men show gradual declines in testosterone from age 20 years and older (Harman, Metter, Tobin, Pearson, & Blackman, 2001). Compared to young men, 30% of men over age 70 years have low total testosterone and 70% have low free testosterone concentrations that would be considered hypogonadal. Thus, there has been substantial interest in the use of testosterone supplements in older men to improve sexual function, motor function, energy, memory, and other cognitive functions. Marketing and use of testosterone supplements are widespread in the United States. Although improvement in bone density, muscle mass, sexual and motor function, as well as energy, has been demonstrated in young hypogonadal men (Snyder et al., 2000), the efficacy of testosterone supplementation in older men is unclear. It is also important to note that effects of testosterone supplementation may reflect changes in estrogens as well as androgens. In addition to effects mediated through the androgen receptor, testosterone is also aromatized to estradiol and can have estrogen-mediated effects.

A number of small randomized trials in young and older men suggest that testosterone may improve memory in older men, though not all studies find such benefits (see Driscoll & Resnick, 2007 for a review). However, in a carefully designed series of studies, Cherrier and colleagues found beneficial effects of testosterone supplementation in eugonadal young and older men with normal cognition. These studies used intramuscular injections of testosterone enanthate (weekly intramuscular injections of 100 mg) in young men aged 21–46 years (Cherrier et al., 2002) and older men aged 50–80 years (Cherrier et al., 2001, 2004, 2005). In young men, co-administration of testosterone restored the reduced verbal memory performance associated with suppression of gonadotropin and testosterone secretion. In older men, men receiving 6–8 weeks of testosterone treatment showed greater improvement on tests of verbal memory, spatial memory and spatial ability compared with placebo. Beneficial effects of weekly testosterone enanthate were also evident in hypogonadal men (Cherrier, Craft, & Matsumoto, 2003) and men with cognitive impairment (Cherrier et al., 2005). Importantly, in a separate intervention study using three doses, the beneficial effects of testosterone were evident only at moderate doses and were not evident at low- or high-dose treatments (Cherrier et al., 2007). This finding may shed light on the negative effect of testosterone enanthate (200 mg/biweekly for 90 days) on verbal memory in eugonadal older men who received cognitive testing when circulating testosterone was high (Maki et al., 2007). One small study of testosterone gel supplementation showed no benefit of treatment for cognitive function in men with cognitive impairment or normal memory functioning (Lu et al., 2006), and a second small study of testosterone gel in combination with gonadotrophin and testosterone suppression showed no acute effects on cognitive function in young and older individuals with normal cognition (Young, Neiss, Samuels, Roselli, & Janowsky, 2010). Lastly, in the largest study of testosterone treatment to date, 237 men between the ages of 60 and 80 years with low-normal testosterone levels were randomized to receive 80 mg of testosterone undecenoate or matching placebo twice daily for 6 months. Although lean body mass increased and fat mass decreased, there were no significant effects of treatment on functional mobility, bone mineral density or cognitive function, including measures of verbal memory, spatial ability, and executive function (Emmelot-Vonk et al., 2008). Variation across studies may reflect the type and dose of testosterone treatment, as well as timing of cognitive assessment relative to the timing of administration in the case of non-gel formulations.

As the majority of prior intervention trials have involved small study samples or have not included clearly hypogonadal men, the potential of testosterone supplementation to improve health outcomes, including cognitive function, in older men remains uncertain. A large-scale multi-site study of the efficacy of testosterone gel in improving health outcomes in hypogonadal symptomatic men is ongoing (Snyder et al., 2014). The Testosterone Trials are a coordinated series of seven trials of the effects of 1% testosterone gel, titrated with a target range of 500–800 ng/dL, for 1 year on motor function, sexual function, vitality, cognition, anemia, bone, and cardiovascular outcomes and enrolled 789 men at 12 clinical sites. All study participants receive a brief cognitive battery at baseline, 6 months and 12 months, assessing memory complaints, verbal and visual memory, attention and executive function, and spatial ability. In addition, global cognitive function is assessed at baseline and at 12 months. All participants have been enrolled and study results are expected in 2015.

CONCLUSIONS AND AREAS FOR FUTURE RESEARCH

In this chapter, we provide an update of the literature investigating the relationship between sex steroid hormones and cognitive functioning, emphasizing the state of knowledge with respect to the influence of hormonal changes on cognitive aging in older adults. Although there is great interest in the potential of hormone treatments to prevent or reverse age-related cognitive decline, there is limited evidence in support of benefits in well-controlled clinical trials to date. With respect to estrogen treatment in older women, the WHIMS and its related studies have demonstrated that hormone treatment should not be initiated in older postmenopausal women aged 65 years and older. In older postmenopausal women, CEE-based treatments increased risk for dementia (Shumaker et al., 2004), had detrimental effects on global cognition (Rapp et al., 2003), and had adverse effects on brain volumes measured by MRI (Resnick et al., 2009b). Although hormone treatment may benefit younger women undergoing surgical menopause, studies of middle-aged women treated close to the menopausal transition showed neither harm nor benefit based on recent results from the WHIMS-Y and KEEPS-Cog studies. These findings in combination provide some reassurance that short-term use of HT for treatment of menopausal symptoms poses little risk to cognitive function.

In contrast to studies of estrogens and cognitive function in older women, there is comparatively less information from clinical trials of the cognitive effects of testosterone supplements in older men. Trials conducted to date have involved small samples of men with normal testosterone levels and have included a variety of testosterone regimens administered over different timeframes. The Testosterone Trials, which will conclude by Fall 2014, will provide important information on a sample of more than 789 hypogonadal older men administered testosterone gel over a 1-year period. Should efficacy, including cognitive benefit, be established in this trial, long-term follow-up studies will be necessary to better establish the safety profile of this treatment. Testosterone treatment is known to increase prostate-specific antigen and thus, may lead to more biopsies and detection of prostate cancers. Testosterone also may have other adverse health effects, with several recent studies suggesting potential cardiovascular risks (Basaria et al., 2010; Finkle et al., 2014).

In conclusion, there are many inconsistent findings from investigations of the contributions of age-related declines in sex steroid levels to cognitive aging. However, findings from recent clinical trials are beginning to inform clinical practice with respect to cognitive function as well as other aspects of physical and behavioral health. There is much to learn from future studies that can be guided by the wealth of information in the basic sciences to inform the types and timing of treatments that should be tested in future studies.

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CHAPTER

5

The Aging Mind in Transition: Amyloid Deposition and Progression toward Alzheimer's Disease

Denise C. Park and Michelle E. Farrell

Center for Vital Longevity, School of Behavioral and Brain Sciences, University of Texas at Dallas, Richardson, TX, USA

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INTRODUCTION

Alzheimer's disease is a progressive neurologic disorder that is initially manifested as memory loss resulting from damage to mediotemporal regions in the brain, particularly the entorhinal cortex and hippocampus (Kaye et al., 1997). The disease progresses over time from memory dysfunction to inability to recognize even close family members, to loss of bodily functions, and ultimately death. The greatest risk factor for Alzheimer's disease (AD) is old age, with recent data indicating that 44% of 80-year-olds in the United States have Alzheimer's disease (Alzheimer's Association, 2015). At present, there is no cure for Alzheimer's disease. The loss of identity and dignity that AD causes, as well as the dependence it creates, has made it one of the most feared outcomes of a long life by adults of all ages. Moreover, the extended disability associated with Alzheimer's disease strains both the health care system and the loved ones of the afflicted.

Until relatively recently, the risk factors for AD were not very clear, and even now, diagnosis of AD can be quite difficult, particularly in its early stages. If an older individual is evaluated by a neurologist or neuropsychologist for memory complaints and shows below-average memory performance, the individual will receive further testing to look for the underlying cause. Possibilities include a range of neurological diseases, including AD, psychiatric disorders, and endocrine or vascular disease. The individual would likely receive a brain scan with an MRI (magnetic resonance imaging) scanner that would provide a relatively detailed image of the structure of the brain. However, the image would not have sufficient clarity to permit a diagnosis of AD. In fact, the only way to get a definitive diagnosis of AD is after death via autopsy. At autopsy, neuropathologists can diagnose Alzheimer's disease through detection of the hallmark characteristics of AD: microscopic amyloid plaques and neurofibrillary tangles in the gray matter of the brain—characteristics discovered by Aloysius Alzheimer over 100 years ago.

Diagnosis of AD in the living person has typically been one of exclusion of other disorders because it is only at autopsy that tissue can be examined microscopically for the plaques and tangles. Thus, if, after a work-up, no specific cause is isolated for the poor memory function that has been documented, the affected individual will most likely be labeled as suffering from mild cognitive impairment (MCI), and will be told that there is about a 50% chance they are in the early phases of AD. They will learn that the only way to have more confidence in a diagnosis of AD is to observe symptom progression over a period of time, possibly years, and to "wait and see." They may be offered a drug that might improve memory symptoms temporarily, although most physicians will wait until they see symptom progression and are more confident that the MCI patient is indeed afflicted with AD.

The picture presented above, however, is changing. Very recently, new imaging techniques have been developed that, for the first time in human history, provide in vivo images of the amyloid plaques (Klunk et al., 2004) and tau tangles (Villemagne, Fodero-Tavoletti, Masters, & Rowe, 2015) associated with Alzheimer's disease. Besides providing diagnostic evidence about AD, the ability to see amyloid and tau deposits in vivo, particularly when combined with other neuroimaging techniques, is providing scientists with the remarkable opportunity to understand the transition from healthy cognitive function to the earliest stages of Alzheimer's disease. The focus of this chapter is to provide an overview of what has been learned about the development of AD, beginning with older adults who are initially cognitively normal and who show no hint of any latent pathology, but who ultimately move toward a diagnosis of AD.

We first will provide a brief overview of the techniques used to measure AD pathology in healthy older adults. We will follow with two models of how individuals transition toward AD. We first will discuss the Scaffolding Model of Aging and Cognition (Park & Reuter-Lorenz, 2009; Reuter-Lorenz & Park, 2014), which provides a flexible model for understanding how both subtle and frank neuropathology with age may affect cognitive function and transition an individual toward AD. Then we will present the Preclinical Model of AD (Jack et al., 2010; Sperling et al., 2011), which provides a specific sequence of detectable stages from healthy function to AD-related dementia based on underlying pathology. The latter half of the chapter will discuss what we have learned so far about the transition from healthy aging to dementia due to Alzheimer's disease, based on the above models. Finally, we will discuss factors that moderate the transition toward full-blown AD and we close with a series of critical issues and questions about cognitive aging and AD that require future study.

AMYLOID IMAGING

Great progress has been made in understanding the brain changes that lead to AD as a result of the newly found ability to image amyloid deposition in vivo. Amyloid comes from a protein found in the neurons of normal healthy brain called amyloid-precursor protein or APP (Hardy & Selkoe, 2002). In Alzheimer's disease, a piece of the APP molecule gets cleaved off. It is this protein fragment (now called amyloid) that ends up aggregating into clumps or plaques that have been a hallmark of AD since its discovery over 100 years ago. The imaging process for detecting amyloid involves injecting a radiotracer substance intravenously that travels to the brain and binds with amyloid. The radiotracer emits a signal captured by a PET scanner. The PET scanner localizes the signal to a 2 mm^3 voxel in 3D space, so that the produced image shows where in the brain amyloid is detected and in what quantity. Amyloid deposition is fairly widespread throughout the brain (except in primary sensory regions), but the areas with the highest concentration are typically the precuneus and the anterior and posterior cingulate cortex (Rodrigue et al., 2012). The original amyloid radiotracer was invented at the University of Pittsburgh by Bill Klunk and Chester Mathis (Klunk et al., 2004) and was named "Pittsburgh Compound B," commonly referred to as "PiB." This ligand has a limited half-life of only 20 min and can only be made on-site in a cyclotron and then must be injected immediately, thus limiting its use to a few research sites. Later, other compounds were developed with longer half-lives including F-18 florbetapir (Avid Radiopharmaceuticals/Eli Lilly; Wong et al., 2010), florbetaben (Bayer; Barthel & Sabri, 2011) and flutemetamol (GE Healthcare; Nelissen et al., 2009), that has resulted in more widespread use. The F-18 ligands were all recently approved by the FDA for diagnostic use, but only in clinical populations. It should be noted that research in fatally ill patients who underwent PET shortly before passing away confirms by autopsy that the scans accurately measure amyloid deposits (Clark et al., 2011).

It is also worth noting that it is possible to measure amyloid levels in spinal fluid retrieved during a lumbar puncture. Due to the invasiveness of this procedure, as well as the lack of information about where in the brain the amyloid has deposited, amyloid PET imaging is utilized much more heavily than lumbar puncture. Another new and potentially important development that has the potential to enhance our understanding of AD considerably is the availability of a radiotracer that binds to tau. Like amyloid, tau is a hallmark of AD, and a requirement for the definitive diagnosis of AD at autopsy. In a normal healthy brain, tau is important for the stability of axons. In Alzheimer's disease and many other dementias, tau becomes misfolded and clumps together into tangles inside a neuron (unlike amyloid, which floats freely in the brain) (Price & Morris, 1999; Spillantini & Goedert, 2013). The tangles kill neurons (Spillantini & Goedert, 2013). The radiotracers that allow in vivo measures of tau have been developed and currently have limited availability for research. In the coming years, tau radiotracer ligands should provide a new wave of insight into AD pathology and the transition from healthy to demented (Villemagne et al., 2015). However, because of the scarcity of data on tau and the wealth of data on amyloid, the present chapter will focus primarily on what we have learned from amyloid.

MODELS OF COGNITIVE TRANSITIONS

To understand the progression from cognitive health to AD, it is useful to think of cognitive decline as having multiple causes. Broadly speaking, causality can be attributed to two major sources: normal aging and neuropathology. Below we focus on two models that are useful theoretical guides for understanding the causal factors that control the transition from a healthy mind to AD.

Scaffolding Theory of Aging and Cognition

The Scaffolding Theory of Aging and Cognition (STAC) model (Park & Reuter-Lorenz, 2009) was designed to integrate structural and functional neuroimaging data on aging with cognitive aging findings in an effort to provide a relatively complete view of how age-related changes in brain structure and function affect cognition. Importantly, the paths depicted in the model provide concrete, testable hypotheses that can be supported or disproven as relevant data become available. The original STAC model was revised recently (Reuter-Lorenz & Park, 2014) and this newer STAC-r model is shown in Figure 5.1. The model shows series constructs that are predictors of both the level of cognitive performance as well as the rate of age-related cognitive decline and individual experiences over time. Both the original model and STAC-r relate the process of biological aging directly to deterioration in brain structure and brain function, as shown by the path in Figure 5.1. Examples of biologically based, age-related declines in brain structure include dopamine depletion (Li, Lindenberger, & Sikstrom, 2001), volumetric shrinkage (Raz et al., 2005), white matter lesions (Wen & Sachdev, 2004), and cortical thinning (Salat et al., 2004). The model also shows that biological aging affects brain function, with exemplars of this including findings that show age-related decreases in hippocampal activity (Gutchess et al., 2005; Park & Gutchess, 2005), and less specialization of neural activity with age ("dedifferentiation," Park et al., 2004, 2012). The STAC-r model shown in Figure 5.1 posits that brain structure and brain function are directly related to both level of cognitive function as well as rate of cognitive change. The other important element depicted in Figure 5.1 is that STAC-r is designed to encompass the life course (depicted by the leftmost circle) in accounting for cognitive function and cognitive change. The model integrates the role of both life experiences and genetic variables that operate to enrich (e.g., exercise thickens brain tissue, Cotman & Berchtold, 2002) or deplete (e.g., obesity relates to decreased brain function, Bischof & Park, 2015) brain structure and function. Finally, both the original model and STAC-r included pathways that allow for the deleterious effects of functional and structural changes in the brain on cognition to be muted by "compensatory scaffolding," that is, as structures decline with age, an increase in neural activity is observed, primarily in frontoparietal regions of the brain (Cabeza, 2002).

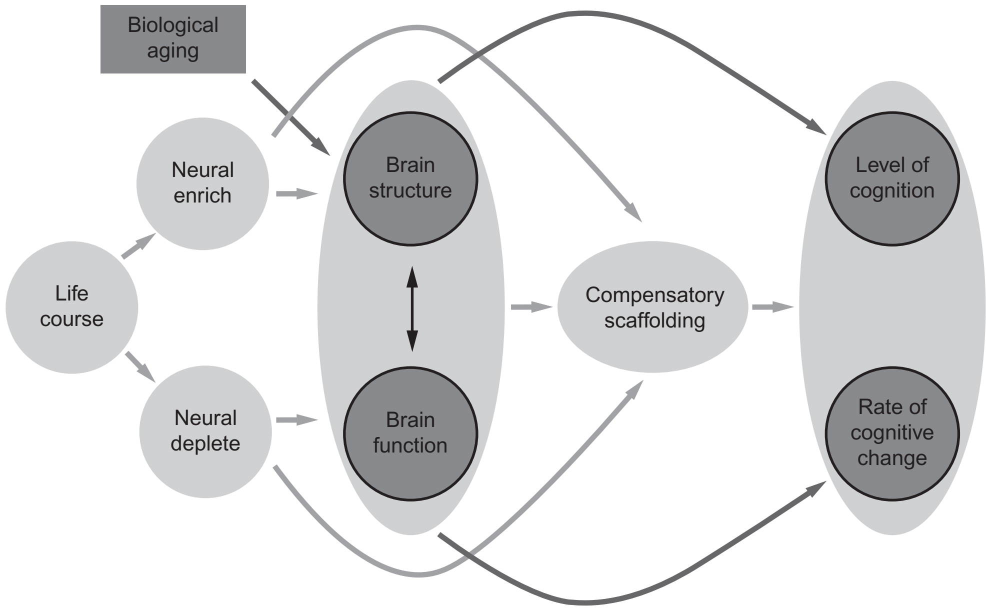

FIGURE 5.1 A schematic diagram of the Scaffolding Theory of Aging and Cognition-Revised (STAC-r). The model outlines general factors that influence adult cognition and cognitive change. Various life course events (e.g., education, physical fitness, vascular health) promote neural enrichment or neural depletion, which, along with biological aging, affect brain structure, brain function, and compensatory scaffolding. The confluence of these factors is theorized to influence one's current cognitive ability and one's rate of cognitive change. *Source: Adapted from Reuter-Lorenz and Park (2014).*

In other words, compensatory scaffolding is developed in an attempt to maintain healthy cognition in the face of a host of age-associated neural insults. There is widespread evidence that older adults recruit more neural circuitry than young on a broad range of tasks, including memory encoding (Cabeza et al., 1997; Grady, McIntosh, Rajah, Beig, & Craik, 1999), working memory (Reuter-Lorenz et al., 2000), and inhibition tasks (Huang, Polk, Goh, & Park, 2012). Finally, an important aspect of STAC and STAC-r is that the models encompass both normal aging as well as pathological aging. A normally aging individual would experience modest decreases in brain structure and function with age and evidence some compensatory scaffolding that would help maintain cognition. In contrast, a person on the path to AD would have much greater aggregation of amyloid and pronounced hippocampal shrinkage, and accordingly, would show a strong path from brain structure and function to rate of cognitive change.

One impetus for developing the STAC model and its revision was the surprising finding that many healthy older adults had no symptoms of cognitive impairment during life but had substantial amyloid deposition in their brains at autopsy (Bennett et al., 2006; Braak & Braak, 1996; Thal, Capetillo-Zarate, Del Tredici, & Braak, 2006). In fact, the autopsy data indicated that about 25–30% of deceased older adults who evidenced normal cognitive function had as much amyloid as individuals with Alzheimer's disease symptoms (Katzman et al., 1988). The constructs of both neural enrichment via experience and compensatory scaffolding provide mechanisms to explain the preservation of cognitive function in the context of declining structural integrity of the brain with aging.

A Model of Preclinical AD

The availability of amyloid imaging has greatly increased our understanding of the development of AD over time. It is known from in vitro studies and studies in rats that amyloid is neurotoxic to synapses and results in synaptic dysfunction (Cleary et al., 2005; Shankar et al., 2007; Walsh et al., 2002). The presence of amyloid in many apparently healthy individuals, including those in middle age, has resulted in the hypothesis that amyloid deposition may be one of the earliest markers of AD. This has led to the idea that AD pathology may slowly accrue over many years before cognitive symptoms are manifested. Amyloid is thought to be an initiating event that starts a cascade of neurodegeneration that eventually leads to cognitive decline and dementia (Hardy & Selkoe, 2002; Jack et al., 2010). In recent years, researchers proposed the use of various neuroimaging techniques and biomarkers to test the amyloid cascade hypothesis (Jack et al., 2010; Sperling et al., 2011).

To understand the possibility that AD pathology could be silent for many years with no manifestation of behavioral symptoms, the National Institute of Aging, in collaboration with the Alzheimer's Association, commissioned a report on the asymptomatic phase of AD. The report termed this silent phase to be "preclinical AD" (Sperling et al., 2011). Sperling et al. (2011) outlined a detailed staging of preclinical AD, relying heavily on the amyloid cascade hypothesis (Hardy and Selkoe, 2002; Jack et al., 2010). The stages of the Preclinical Model of AD proposed by Sperling et al. (2011) are described below (also see Figure 5.2):

Stage 0. No AD pathology and a healthy brain.
Stage 1. Amyloid starts to deposit.
Stage 2. Amyloid continues to accrue and evidence of neurodegeneration begins to be detectable.
Stage 3. Amyloid continues to deposit and neurodegeneration spreads, but now cognitive decline is also evident.

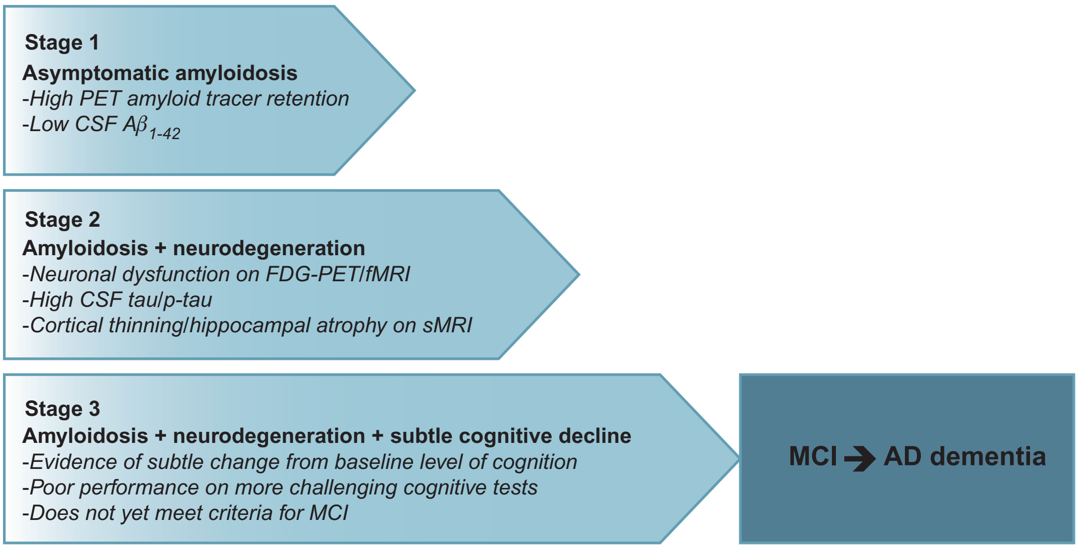

FIGURE 5.2 The Preclinical Model of Alzheimer' Disease. The above model lays out the stages of preclinical AD and the markers associated with each stage, from Stage 1 (amyloid only) to Stage 2 (amyloid + neurodegeneration) to Stage 3 (amyloid + neurodegeneration + cognitive) to MCI and finally dementia. *Source: Reproduced from Sperling et al. (2011).*

The first two stages of the model require little explanation. Stages 2 and 3 however require considerably more explication. The hypothesis is that the spread of amyloid in Stage 2 results in specific damage to neural function which then leads to neuronal loss. Then, by Stage 3, sufficient neuronal loss and damage have occurred that it results in clinical symptoms of memory decline that are detectable. Since the publication of Sperling et al. (2011), new research has been published on preclinical AD. Below, we raise three questions of critical importance to understanding the characteristic course and mechanisms underlying preclinical AD.

WHAT IS THE RELATIONSHIP BETWEEN AMYLOID DEPOSITION AND NEURODEGENERATION?

As mentioned above, the preclinical AD model predicts that amyloid deposition in healthy adults will result in a detectable relationship between amyloid burden and measures of neurodegeneration. The model suggests that amyloid deposition affects both synaptic dysfunction and neuronal loss, and we discuss each type of neurodegeneration in turn.

Neuronal Dysfunction

Studies of the link between amyloid and neuronal dysfunction have not used direct measures of neuronal activity. Rather the studies have primarily relied on how amyloid deposition affects fMRI BOLD activity in specific brain regions and metabolic activity in the brain that is measured by FDG-PET imaging. Studies have consistently demonstrated that amyloid deposition disrupts network circuitry in the brain, particularly in the default network, a network which is active at rest and suppressed at periods of high cognitive challenge (Drzezga et al., 2011; Elman et al., 2014; Mormino et al., 2011; Sheline et al., 2010). In addition to disrupting the integrity of the network, amyloid deposition also decreases the ability to modulate or control brain networks in response to task demands associated with episodic memory (Hedden et al., 2009; Huijbers et al., 2014; Kennedy et al., 2012; Sperling et al., 2009; Vannini et al., 2012, 2013). Additional evidence that amyloid may be related to dysfunction of neuronal activity can be found from FDG-PET studies. Unlike fMRI, FDG-PET does not directly measure brain activity at a specific moment in time, but rather provides an overall measure of how metabolically active different regions are by measuring how much glucose the regions are utilizing for energy. Interestingly, high amyloid burden has been associated with lower metabolic activity in temporoparietal brain regions known to be impaired in AD patients (Knopman et al., 2014; Lowe et al., 2014). In sum, fMRI and FDG-PET studies provide evidence that amyloid is related to lower brain activity in specific regions associated with AD and poorer connectivity among regions within networks. Longitudinal studies are needed to properly address cause and effect, but this supports the idea that individuals transition from healthy to demented by first depositing amyloid and then exhibiting signs of neuronal dysfunction. Based on the preclinical AD model, the next step involves detecting actual neurodegeneration in the form of losses in brain structure.

In order to fully understand the relationship between amyloid and brain function, long-term longitudinal studies are necessary, and such studies are underway. A critical question that only longitudinal studies can answer is how long individuals can show evidence of amyloid deposition before exhibiting signs of neurodegeneration and whether there are variables that hasten or slow that transition. Similar questions are relevant to tau tangles as well, but much more research is needed. Answers to these questions will unquestionably be forthcoming. It is clear from initial reports that the damage from amyloid most likely occurs over several years, making detection difficult in the shorter 1–2-year studies completed thus far. The degradation of the brain associated with amyloid does not appear to occur rapidly.

Neuronal Loss

The second type of neurodegeneration that has been hypothesized to be related to amyloid deposition is neuronal loss. The primary measures utilized to examine neuronal loss as individuals transitions toward AD are decreases in cortical thickness across many brain regions and a specific decline in hippocampal volume. Hippocampal atrophy has long been associated with progression from healthy aging to dementia (Kaye et al., 1997), so amyloid imaging researchers quite logically have attempted to demonstrate a link between amyloid and hippocampal volume. Results have shown that, in fact, high amyloid burden has been related to lower hippocampal volume (Hedden et al., 2009; Mormino et al., 2009; Rowe et al., 2010; Storandt, Mintun, Head, & Morris, 2009), while others have failed to find a relationship (Bourgeat et al., 2010; Dickerson et al., 2009). Several studies have also found that amyloid is associated with reduced gray matter thickness in the same regions that show thinning with Alzheimer's disease (Becker et al., 2011; Dickerson et al., 2009; Dore et al., 2013; Mormino et al., 2009; Rowe et al., 2010; Storandt et al., 2009). While some studies have cast doubt that there is a consistent neuroanatomical signature associated with amyloid burden and preclinical AD (Whitwell et al., 2013; Wirth et al., 2013), it is generally accepted that amyloid is associated with cortical thinning.

Some of the inconsistent findings may be due to more individuals in studies with negative findings being in Preclinical Stage 1 (amyloid only) and positive findings occur when more participants are in Preclinical Stage 2 (amyloid + neurodegeneration).

Overall, while correlations between amyloid and measures of neuronal loss are not detected as consistently across studies as measures of synaptic dysfunction, it is likely a reflection of the more indirect relationship between amyloid and neuronal loss. Unfortunately, we are not aware of any studies to date that explicitly test the sequence from neuronal dysfunction to neuronal loss. Further research, especially longitudinal work, is necessary to establish a clearer picture of how precisely individuals transition from amyloid to synaptic dysfunction to neuronal loss.

Another important issue to consider in a discussion of neurodegeneration in the preclinical AD model is the role of tau tangles. Tau tangles literally kill neurons, so that tau deposition should be a particularly potent marker of neurodegeneration. Amyloid is known to induce the formation of tau tangles in rats (Bolmont et al., 2007), however, due to the limited data on in vivo tau in humans, little is known about the interaction of tau with amyloid and the resultant effects on neurodegeneration. While a small amount of tau is present in the medial temporal lobe in healthy adults before amyloid deposition, it is hypothesized that amyloid induces the spread of tau (and thus neurodegeneration) throughout the neocortex (Price & Morris, 1999). It is clear that tau plays a very important role in the preclinical model of AD. However, until very recently, it was only possible to measure the gross level of tau burden indirectly through CSF obtained from lumbar punctures. The very recent availability of new tracers will hopefully allow PET imaging of tau in the same way amyloid is imaged. In the coming years, tau imaging is likely to provide new insights into the transition from amyloid alone (Stage 1) to amyloid + neurodegeneration (Stage 2). It is notable that CSF studies have revealed that tau is much more predictive than amyloid of cognitive decline (Fagan et al., 2007). Thus tau imaging studies will also play an important role in understanding the transition from Stage 2 to

Stage 3, when cognitive decline becomes apparent, and from there to dementia.

DOES AMYLOID DEPOSITION INVARIABLY LEAD TO COGNITIVE DECLINE?

While the preclinical model of AD predicts that amyloid initiates a cascade that leads eventually to cognitive decline (via neurodegeneration), many early amyloid imaging studies (completed before the model was developed) sought to examine the amyloid and cognition relationship directly. In this section, we will first review the early amyloid–cognition findings, before discussing more recent studies that relate amyloid, neurodegeneration, and cognitive decline altogether, in the sequence predicted by the preclinical model of AD.

Amyloid and Episodic Memory

Due to the well-known relationship of memory dysfunction as an early symptom of Alzheimer's disease, many studies have sought to find a link between amyloid burden and episodic memory. While some cross-sectional studies have found a relationship between amyloid burden and decreased episodic memory performance (Aizenstein et al., 2008; see Hedden, Oh, Younger, & Patel, 2013 for review; Pike et al., 2011; Resnick et al., 2010; Sperling et al., 2013), others have failed to find a significant effect (Ewers et al., 2012; Rodrigue et al., 2012; Storandt et al., 2009; Tolboom et al., 2009).

One issue with these cross-sectional studies is that they attempted to relate amyloid burden to cognitive performance at a single time point, rather than to relate amyloid accumulation to cognitive decline. One way in which studies managed to get around the expense of longitudinal testing was through the use of questionnaires that collected subjective memory reports. Participants were asked to report whether they felt their memory had declined in recent years. Interestingly, greater subjective memory complaints were associated with higher amyloid burden (Amariglio et al., 2012), even in the absence of memory dysfunction.

Unlike cross-sectional studies, longitudinal studies have the potential to establish a causal relationship between amyloid deposition and cognitive decline. Importantly, initial amyloid status is predictive of future progression to MCI and dementia (Villemagne et al., 2011). While there have been few longitudinal amyloid–cognition studies to date, some studies have demonstrated that initial amyloid burden is predictive of decline in episodic memory (Ellis et al., 2013; Lim et al., 2013; Resnick et al., 2010), but others have failed to find a relationship in healthy older adults (Villemagne et al., 2011).

Impact of Amyloid on Other Cognitive Domains

Overall, results from both cross-sectional and longitudinal studies seeking to find a direct link between amyloid and episodic memory have been inconsistent. While fewer studies have evaluated the effects of amyloid on non-memory domains, the findings are just as inconsistent as the studies on episodic memory. While some cross-sectional studies find null results (Lim et al., 2012; Oh, Madison, Haight, Markley, & Jagust, 2012), others have found associations between amyloid and executive function/reasoning (Resnick et al., 2010; Rodrigue et al., 2012; Schott, Bartlett, Fox, Barnes, & Alzheimer's Disease Neuroimaging Initiative, 2010), working memory (Rentz et al., 2010; Rodrigue et al., 2012; Rolstad et al., 2011), processing speed (Rodrigue et al., 2012; Stomrud et al., 2010), and visuospatial function (Pike et al., 2011; Rentz et al., 2010). Likewise, some longitudinal studies have found a correlation between initial amyloid burden and subsequent decline in non-memory domains (Snitz et al., 2013; Wirth et al., 2013), while others have failed to find a significant relationship (Ellis et al., 2013; Lim et al., 2014; Villemagne et al., 2011).

While some of the null findings in the amyloid–cognition literature may simply reflect insufficient power (many of the early studies had very small sample sizes), these inconsistencies may actually be explained by the preclinical model of AD. It is plausible that the inconsistencies across studies were caused by differences in how advanced the neurodegeneration was is in each study sample, with studies including subjects more advanced in amyloid deposition evidencing a relationship to cognitive function. In support of this point, Rodrigue et al. (2012) selected only the highest amyloid participants (n = 18) from a pool of 137 participants. They then treated amyloid as a continuous variable and correlated it with cognitive performance. The higher the amyloid level, the more likely subjects were in later stages of preclinical AD, and indeed, under these circumstances, increasing amyloid level was a strong predictor of decreasing performance on the speed of processing, working memory, and reasoning.

Amyloid, Neurodegeneration, and Cognitive Decline

By including measures of both amyloid and neurodegeneration, researchers can better assess predictions of the preclinical model of AD. It is expected that in order to observe cognitive decline in amyloid-positive older adults, neurodegeneration must first be present. In concordance with this, Mormino et al. (2009) demonstrated that the effect of amyloid deposition on episodic memory was fully mediated by hippocampal volume. Additionally, Mormino, Betensky, Hedden, Schultz, Amariglio, et al. (2014) demonstrated in a recent 2-year longitudinal study that only those cognitively normal adults with both amyloid and neurodegeneration at baseline exhibited cognitive decline. Thus, these studies that incorporate both amyloid and neurodegeneration support the preclinical AD model and the idea the cognitive decline is a result of a cascade from amyloid to neurodegeneration to cognitive impairment. Lastly, in another recent longitudinal study, Vos et al. (2013) reported that over 5 years the conversion rate to symptomatic Alzheimer's disease was 2% for individuals with no initial pathology (stage 0), 11% for those with amyloid only at baseline (Stage 1), 26% for those both amyloid- and neurodegeneration-positive (Stage 2), and 56% for those previously exhibiting amyloid, neurodegeneration, and cognitive decline (Stage 3). The increasing probability of conversion to dementia in later stages of the preclinical AD model provides confidence that it is an appropriate and useful heuristic for understanding how individuals transition from healthy aging to dementia.

In summary, research on the relationships among amyloid, neurodegeneration, and cognitive decline supports the preclinical model of AD. More longitudinal research, as well as research incorporating tau imaging, is needed to confirm this sequence of events.

MODIFIERS OF TRANSITION TO AD: ENRICHMENT AND DEPLETION FACTORS

Although the preclinical model does an excellent job in describing order and symptoms of a transition from cognitive health to AD, it does not address factors that speed up or slow down the rate of cognitive decline. The role of life course experiences and other individual difference variables that potentially affect brain structure and function is a key element in the STAC-r model shown in Figure 5.1. The STAC-r model distinguishes between brain enrichment and depletion factors that can result from lifecourse experiences (such as education) or that are biologically based (e.g., a genetic marker that enhances risk). Below we consider enrichment and depletion factors that are likely to affect the speed at which the transition to AD occurs.

Depletion Factors

There are a broad range of variables that enhance AD risk and may speed the transitions through preclinical stages. One of the highest risk factors, as noted earlier, is age itself. It has been long established from autopsy studies that amyloid plaque deposition increases with age (Braak & Braak, 1991; Braak, Thal, Ghebremedhin, & Del Tredici, 2011). Similarly, amyloid imaging studies have confirmed age as a primary risk factor for amyloid deposition (Mielke et al., 2012; Morris et al., 2010; Rowe et al., 2010). Typically, an examination of the distribution of amyloid across age reveals that most of the population is amyloid-negative, but starting around age 60 amyloid deposition reaches a sufficiently high level that a subpopulation of amyloid-positive individuals begins to appear. Interestingly, a recent study by Rodrigue et al. (2012) showed that even after removing the individuals identified as amyloid-positive from a sample of 30–89-year-olds, there was still an increase in amyloid with age. This suggests that even within the group that appears amyloid-negative, there is some sub-threshold level of amyloid that becomes increasingly common as individuals age.

Another depletion factor is the possession of the ε4 allele of the APOE gene. In comparison with other APOE alleles, the APOE ε4 allele markedly increases the risk of AD and decreases the age of onset (Corder et al., 1993). While it has been known for decades that APOE ε4 carriers transition to dementia at earlier age than non-carriers, only recently have we started to understand what this means in the context of preclinical AD. About 19% of the population in the US is APOE ε4 carriers (Strittmatter & Roses, 1996). APOE ε4 carriers are disproportionately represented in adults who are carrying amyloid (Rowe et al., 2010). Recent evidence suggests this APOE ε4-related risk is associated with impaired clearance of soluble amyloid from the brain, resulting in more rapid amyloid accumulation and deposition (Castellano et al., 2011; Deane et al., 2008). This implication of a direct relationship between APOE ε4 and amyloid deposition is supported by evidence that APOE ε4 carriers have greater amyloid deposition than non-carriers in cognitively normal older adults (Morris et al., 2010; Reiman et al., 2009; Rowe et al., 2008). Furthermore, APOE ε4 has also been associated with earlier onset of amyloid positivity (Fleisher et al., 2013), as well as an increased rate of amyloid deposition across age (Morris et al., 2010) in a dose-dependent manner. In a recent longitudinal study, Mormino, Betensky, Hedden, Schultz, Ward, et al. (2014) demonstrated that APOE ε4 carriers who were also amyloid-positive exhibited greater cognitive decline over 1.5 years than amyloid-positive APOE ε4 non-carriers, as well as amyloid-negative APOE ε4 carriers and non-carriers. Thus, these findings indicate that the APOE ε4 allele is a depleting factor that not only shifts the transition to dementia earlier in the lifespan, but also causes individuals to advance more quickly from healthy to demented.

Lifestyle variables are another particularly important depletion factor because they are potentially modifiable and thus possible targets for interventions. Greater amyloid burden has been associated with lower lifetime cognitive engagement (Landau et al., 2012), hypertension (Langbaum et al., 2012), and less physical exercise (Liang et al., 2010). Interestingly, further study has shown the impact of all of these factors is modified by the APOE ε4 allele. For example, Head et al. (2012) found that APOE ε4 carriers who engaged in low levels of exercise had greater amyloid than more physically active APOE ε4 carriers, but that in non-carriers there was no effect of exercise. Similarly, Wirth, Haase, Villeneuve, Vogel, and Jagust (2014) found being less cognitively engaged throughout the lifespan was related to greater amyloid deposition than those who were more cognitively engaged throughout their lives, but only for APOE ε4 carriers. Rodrigue et al. (2013) reported that in

APOE ε4 carriers, significantly greater amyloid burden was detected in those with uncontrolled hypertension, whereas the presence of APOE had no impact on those with controlled hypertension or without hypertension. Taken together, these studies suggest a gene–environment interaction, such that APOE ε4 carriers, while at greater risk for amyloid deposition, are also uniquely suited to intervention. Exercise, cognitive engagement, and controlling hypertension all may reduce amyloid deposition and thus delay transition to dementia.

Enrichment Factors

There is an increasingly large AD literature indicating that higher levels of education and sustained engagement in intellectually challenging activities delay the age of onset of AD (for review, see Stern, 2002). The effect of such enriching activities has also been studied with respect to levels of amyloid deposition in healthy adults (Rentz et al., 2010; Roe et al., 2008; Vemuri et al., 2011). It has been suggested that enriching experiences result in a build-up of cognitive reserve that is protective and allows individuals to withstand negative effects of pathology (Stern, 2002). In line with this argument, using education and IQ on the American National Adult Reading Test as measures of reserve (Rentz et al. (2010), demonstrated that individuals with lower cognitive reserve exhibited worse memory with increasing amyloid burden, while memory in those with higher cognitive reserve appeared to be unaffected by increasing amyloid burden. This provides evidence that enriching experiences may delay the transition from healthy aging to dementia.

It is important to recognize that the impact of these variables can be very significant. For example, research done by the Alzheimer's Association (2014) has indicated that delaying the diagnosis of AD by 5 years would reduce the number of cases diagnosed by over 40%. One also need only consider what it would mean to an AD sufferer and their family to have 5 more years of independence and vitality available to them to recognize the significance of factors that delay the transition to AD.

Conclusion and New Directions

The development of in vivo imaging of the amyloid plaques and tau tangles associated with AD is a breakthrough technology that will allow us to understand the sequence of transformations both brain and behavior undergo on what is very often a long and slow progression to the dementia associated with AD. The Preclinical Model of AD (Sperling et al., 2011) has proven to be a useful heuristic for understanding transitions. The STAC-r model of neurocognition is proving, as well, to be a flexible model that encompasses both pathological and healthy aging trajectories and allows for the integration of experiences and individual differences into our understanding of AD.

As this chapter clearly illustrates, we have much to learn about the earliest phases of AD. It is exciting to recognize that new tools are available that will provide information about causality and help isolate the most plausible timing for interventions. Key questions that remain to be answered that in our view are of pressing importance are as follows:

- More attention needs to be devoted to the study of middle age. Is it possible to isolate a neurocognitive footprint decades before symptoms of AD appear? This issue is of critical importance with respect to timing of interventions.
- What is the temporal relationship between detectable levels of amyloid and onset of cognitive symptoms? If the interval spans a decade or more, is an amyloid-positive PET scan useful information to provide to afflicted individuals? Related to this, what speeds up or slows down progression

through preclinical stages? Can we provide reliable scenarios to patients about their status and future?

- Longitudinal studies are essential to understand causal relationships and transitions. It might be useful to speed up information acquisition to develop 15-year hybrid designs where perhaps three samples were simultaneously initiated with different ages at entry (e.g., 45-, 55-, and 65-year-olds). Such a design would minimize cohort effects but provide fairly complete information regarding the lifespan from ages 45 to 80 in only 15 years.
- The study of tau is of tremendous interest and is likely to provide a significant number of missing pieces to the puzzle of AD.
- Finally, AD occurs in the context of many other disorders. Assessing total neural burden (e.g., white matter lesions, dopamine depletion, etc.) would provide critical information about how AD pathology interacts with other conditions and may be a strong predictor of rapid transitions.

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CHAPTER

6

Research on Human Plasticity in Adulthood: A Lifespan Agenda

Simone Kühn[1] *and Ulman Lindenberger*[1,2]

[1]**Center for Lifespan Psychology, Max Planck Institute for Human Development, Berlin, Germany**

[2]**Max Planck University College London Centre for Computational Psychiatry and Ageing Research, Berlin, Germany**

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PLASTICITY AND STABILITY IN LIFESPAN DEVELOPMENT

For a long time, instances of *plasticity*, defined as long-lasting alterations in the brain's chemistry, gray matter, and structural connectivity in support of behavior, were assumed to be restricted to early periods of development. However, recent research has shown that plasticity is present throughout the lifespan, albeit to different degrees (Churchill et al., 2002; Hensch, 2005; Kempermann, 2006). Hence, the brain's potential for plasticity needs to be constantly held in check by mechanisms sustaining *stability* (Hensch, 2005). Recent research has begun to identify molecular mechanisms that promote either stability or plasticity. The dynamic interplay of these mechanisms organizes behavioral development into alternating, sequentially structured periods of plasticity and stability that permit the hierarchical organization of cerebral function and higher-order cognition. The canonical example is the sequence of sensitive periods that drives sensory and cognitive development from infancy to adolescence. According to Hensch (2005) and Takesian and Hensch (2013), plasticity in later periods of life, including adulthood and old age, is likely to be governed by similar molecular mechanisms as those regulating the opening and closing of sensitive periods during early ontogeny.

During periods of stability, behavior is far from immutable. In addition to plasticity, there is *flexibility*, defined as the adaptive reconfiguration of the existing behavioral repertoire in the absence of macroscopic structural change (cf. Lövdén, Bäckman, Lindenberger, Schaefer, & Schmiedek, 2010). At the behavioral level of analysis, the distinction between plasticity and flexibility can be traced back to Jean Piaget. In 1980, Piaget argued that cognitive development alternates between phases of structural change, in which new structures and relations are created, and phases of elaboration, in which the implications of these structures and relations are explored and instantiated.

In summary, the evolving brain strikes a balance between plasticity and stability that supports the construction, modification, and maintenance of behavioral repertoires from early ontogeny to late adulthood. We assume that the set point of the plasticity/stability equilibrium follows an overall lifespan trend from a greater relative emphasis on plasticity to a greater relative emphasis on stability. In particular, and for reasons outlined below, the transition from childhood to adulthood results in a strengthening of mechanisms that actively suppress plasticity and promote stability.

THE SUPPLY–DEMAND MISMATCH MODEL OF PLASTICITY

Lövdén, Bäckman et al. (2010) proposed the economic metaphor of neural supplies and experiential demands to further clarify the difference between plasticity and flexibility (Figure 6.1). Whereas flexibility *makes use* of existing neural supplies, plasticity *changes* them. According to Lövdén, Bäckman et al. (2010), it would be functionally maladaptive and metabolically costly if a system would always and instantaneously respond to supply–demand mismatches with plastic (structural) changes, rather than with the utilization of the range of function supported by flexibility. A central nervous system under permanent renovation would not develop a coordinated scheme of habits and skills, and would constantly consume large amounts of energy. Hence, the supply–demand mismatch has to surpass some degree of intensity to trade the goal of stability for that of plasticity. The degree of sluggishness of plastic responses to mismatch differs among various manifestations of plasticity, probably in part as a function of the metabolic cost of their implementation. For example, whereas gliogenesis and growth of capillaries may develop over

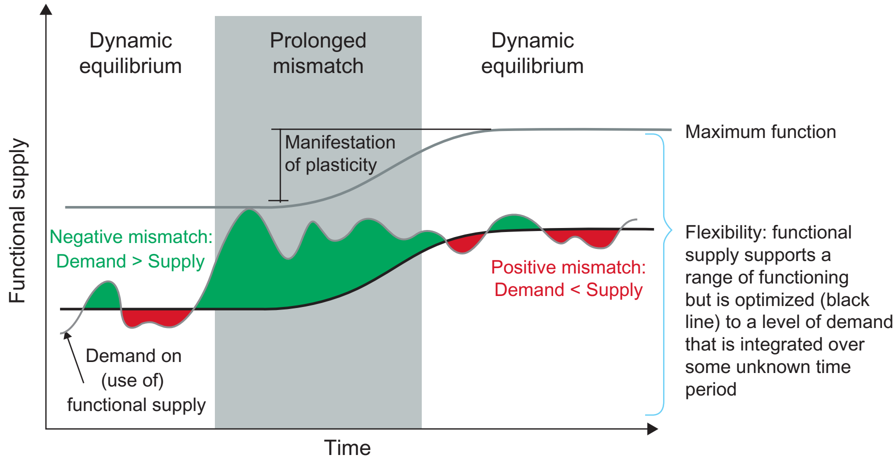

FIGURE 6.1 *The supply–demand mismatch model of plasticity*. The mismatch between functional supply and experienced environmental demands can be caused by primary changes in demand (shown here), or by primary changes in functional supply (not shown). *Functional supply* denotes structural constraints imposed by the brain on function and performance, and permits a given range of performance and functioning. *Flexibility* denotes the capacity to optimize the brain's performance within this range. Deviations in *functional demand* that are within the available range of functional supply constitute the impetus for plasticity. Mismatches between supply and demand need to be present for some period of time to overcome the system's tendency towards stability (sluggishness), and to push the system away from its current dynamic equilibrium. *Adapted from* Lövdén, Bäckman et al. (2010).

months, synaptogenesis and structural changes associated with long-term potentiation (LTP) may develop over hours, minutes, or seconds.

How does the sluggishness of plastic responses change from early ontogeny to adulthood? In the course of their lives, adults have acquired a rich model of the world that enables the flexible deployment of established behavioral repertoires. For this reason alone, the number of situations requiring a plastic response is likely to decrease with advancing adult age. In addition, putting a premium on stability also favors continuity of social structures, which in turn may facilitate the deployment of plastic potential in the next generation (cf. Lindenberger, 2014). Finally, bringing about plastic changes is metabolically costly (Kuzawa et al., 2014), and these costs are likely to be exacerbated in systems that have accumulated damage, reflecting evolved limitations in somatic maintenance, as is the case for brains in later adulthood. Primarily for these reasons, we assume that the brains of older adults are both less able and less in need of reaction to a supply–demand mismatch with a plastic response, relative to the brains of normally developing children and adolescents.

The preceding considerations motivate a set of three propositions, which we elaborate on in the remainder of this chapter:

1. *Plasticity decreases from childhood to old age.*
2. *Flexibility increases from childhood to middle adulthood, and declines thereafter.*
3. *Relative to childhood, plasticity in adulthood and old age is more associated with maintenance, and less with growth.*

Figure 6.2 illustrates these propositions. In the following, we will expand on them, with empirical examples drawn primarily from cognitive intervention studies and animal models. We then compare the

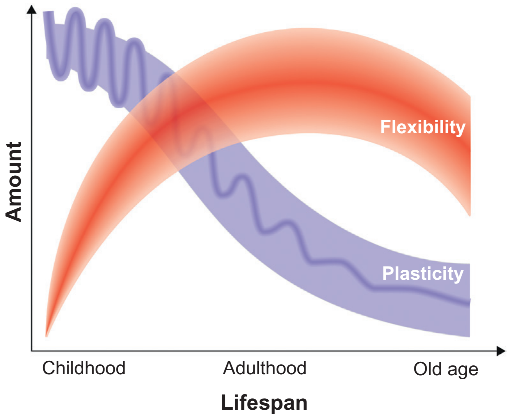

FIGURE 6.2 *Plasticity and flexibility across the lifespan.* Plasticity refers to long-lasting alterations in the brain's chemistry, gray matter, and structural connectivity in support of behavior. Flexibility denotes the capacity to optimize performance within the limits of the current functional supply. The dynamic interplay of mechanisms promoting plasticity versus stability, illustrated by the oscillating pattern of the plasticity trajectory, organizes behavioral development into alternating, sequentially structured periods that permit the hierarchical organization of cerebral function and higher-order cognition. The range of the functions at any given age denotes between-person differences and within-person modifiability.

stability–flexibility–plasticity framework to the theory of crystallized versus fluid intelligence (*Gf–Gc theory*; Cattell, 1971; Horn, 1989), and conclude by suggesting avenues for future research.

PROPOSITION #1: PLASTICITY DECREASES FROM CHILDHOOD TO OLD AGE

Early in life, children's brains are highly malleable by experience, both inside and outside the uterus (Karmiloff-Smith, 1995). In the mid-1900s, it was discovered that depriving an organism of certain experiences at an early age compromises brain function later on. In a seminal series of studies on kittens, Hubel and Wiesel (1959) surgically closed one of their eyes soon after birth. When the deprived eye was reopened a few months later, it appeared normal, but most of the nerve cells in the visual cortex no longer responded to visual input from that eye. These findings demonstrate the importance of sensitive periods, defined as developmental windows in which experience has a particularly strong effect on brain structure. Mice show similar responses to visual deprivation. The discovery of sensitive periods has led to the quest for the factors that influence their opening and closure. In particular, the inhibitory neurotransmitter gamma-aminobutyric acid (GABA) has been found to be involved in the onset of sensitive periods (Hensch, 2005).

Both the initial overproduction of synapses and the subsequent stimulus-dependent pruning of dendritic arborization are thought to play a key role in cortical ontogeny. Early neural plasticity does not happen synchronously in all brain regions, but rather progresses like a "wave," beginning in primary sensory and motor regions and subsequently moving towards secondary association areas, parietal cortex, and finally to frontal brain regions. To explore this progression computationally, Shrager and Johnson (1996) modeled a simplified cortical array, and showed that a corticotrophic wave, in combination with a pruning mechanism, results in cortical structures with hierarchically organized representations. The model nicely illustrates that temporally and spatially structured periods of plasticity facilitate the emergence of hierarchical brain organization. The simulation provides a compelling reason why brain development within and across sensory modalities does not consist of one single period of generalized plasticity, but of an orderly sequence of sensitive periods.

Neural and behavioral evidence clearly indicates that plasticity declines with age. One kind of behavioral evidence in humans is provided by training studies, in which children, younger adults, and older adults practice the

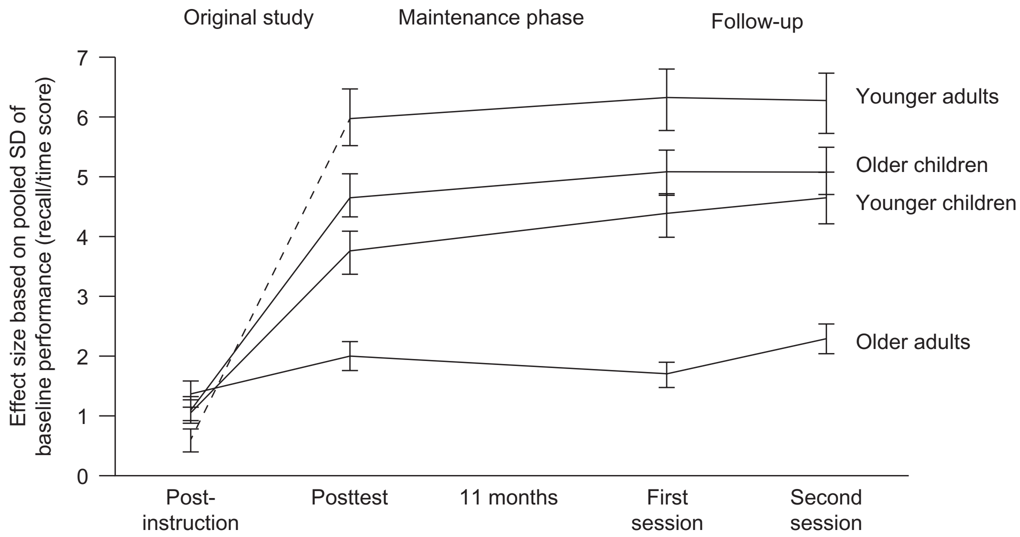

FIGURE 6.3 *Plasticity in memory performance across the lifespan.* The left part of the figure summarizes the results of a training study by Brehmer et al. (2007), whereas the right part summarizes the results of a follow-up study conducted 11 months later (Brehmer et al., 2008). In line with the trajectories shown in Figure 6.2, children profited more from mnemonic practice and reached higher levels of performance at the end of training. Younger and older adults' average performance levels were stable across the 11-month no-contact interval. In contrast, children's memory performance improved beyond originally attained levels, presumably reflecting maturational changes in the brain's functional supply. Levels of memory performance refer to the number of words recalled over log encoding times (recall/time scores) and are expressed in pooled pretest standard deviation units. For younger adults (dashed line), the post-instruction scores of the training study cannot be interpreted because of ceiling effects; all other scores are interpretable. Error bars indicate standard errors of the mean.

same cognitive skill (Shing & Lindenberger, 2011). For instance, Brehmer, Li, Müller, von Oertzen, and Lindenberger (2007) and Brehmer et al. (2008) asked participants of different ages to acquire and practice an imagery-based memory technique. Children benefited more from the intervention and reached higher levels of asymptotic performance than older adults (Brehmer et al., 2007), reflecting the reduction of plastic potential in older age. Younger and older adults' performance levels were found to be stable in a follow-up session after 11 months (Brehmer et al., 2008), suggesting that the ability to maintain acquired skills is relatively well preserved in adulthood. In contrast, children even improved their performance from posttest to follow-up session, presumably because task-relevant brain structure had matured in the meantime (Figure 6.3).

Another observation from Brehmer et al. (2007) is that younger adults showed larger performance gains than children, suggesting, at first sight, that plasticity is greater in early adulthood than in childhood. In our view, this observation points to the general difficulty of disentangling plasticity and flexibility at the behavioral level of analysis (see section on plasticity and flexibility in relation to *Gf–Gc* theory). Given the expansion of the behavioral repertoire from childhood to adulthood, the acquisition of a new mnemonic skill may depend less upon plasticity with increasing age, and more on the reconfiguration of already-existing strategies and skills. This hypothetical difference in

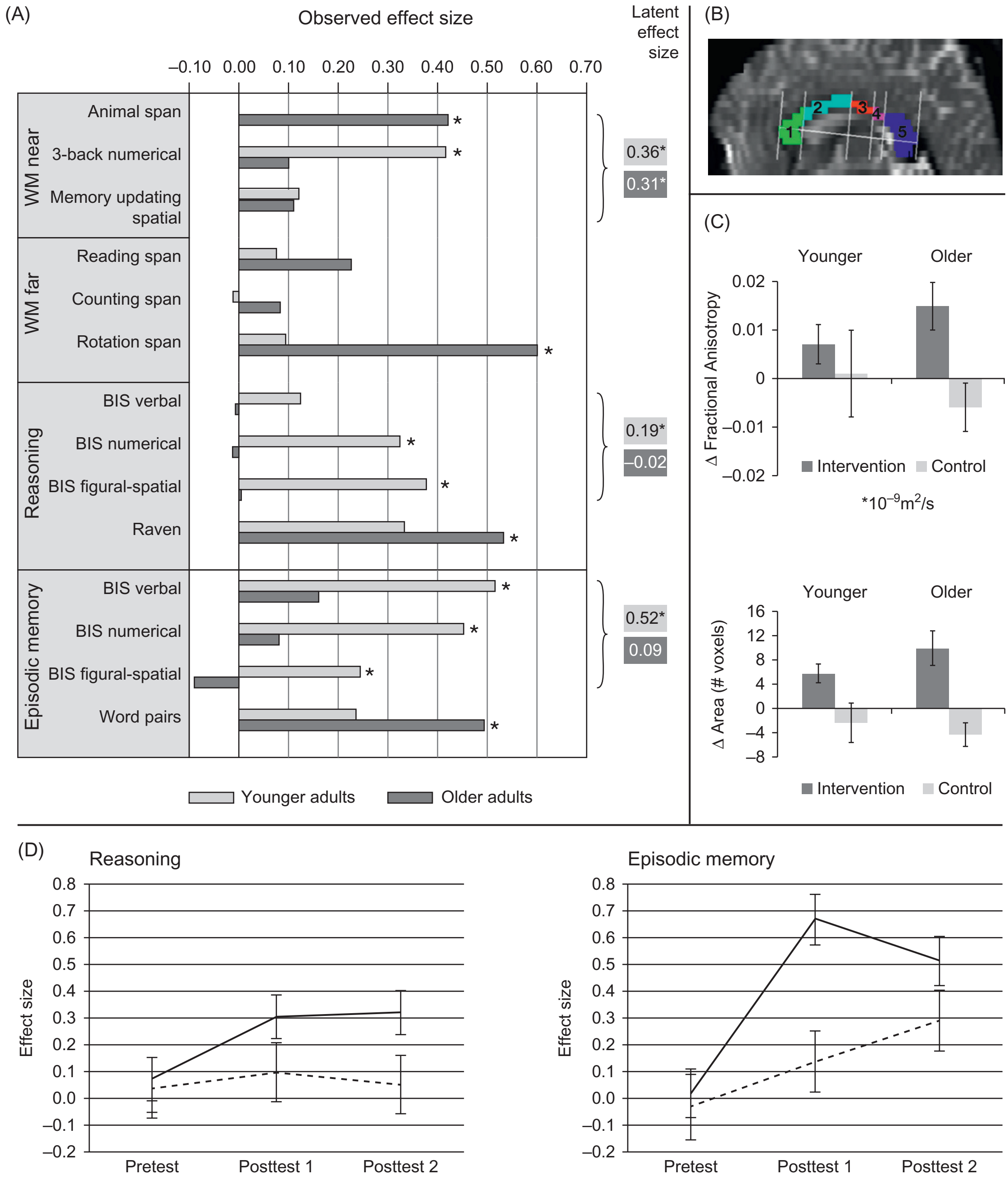

FIGURE 6.4 *Plasticity of intellectual abilities in younger and older adults.* In the COGITO study (Schmiedek et al., 2010), 101 younger and 103 older adults practiced six tests of perceptual speed, three tests of working memory, and three tests of episodic memory over a period of 6 months for 101 daily 1-h sessions. Unpracticed cognitive tests were administered before and after training to examine whether performance improvements generalize to the level of cognitive abilities (transfer).

the relative importance of plasticity and flexibility in the production of training gains would lead one to predict that transfer of training, as an indicator of plasticity, would be more prominent in children than in adults. To our knowledge, this prediction has not yet been tested directly.

Other studies have focused on age differences in plasticity within the adult age range (for a review, see Lövdén, Wenger, Mårtensson, Lindenberger, & Bäckman, 2013). In one very extensive training study (Schmiedek, Lövdén, & Lindenberger, 2010), older and younger adults practiced three working memory, three episodic memory, and six perceptual speed tasks for 100 1-h sessions (Figure 6.4). Immediately after training, both older and younger adults showed near transfer of training to working memory, and younger adults showed additional transfer to episodic memory and reasoning. Neural data obtained for subsamples of younger and older adults revealed an increase in white matter integrity in the genu of the corpus callosum in both younger and older adults (Lövdén, Bodammer, & Kühn, 2010). In younger adults, transfer effects in reasoning and episodic memory were maintained over a period of 2 years (Schmiedek, Lövdén, & Lindenberger, 2014).

Among the various regions of the brain, the hippocampus is both particularly plastic and vulnerable to risk factors (Raz, 2007). While hippocampal neurogenesis persists throughout adulthood, animal data indicate that the rate at which new neurons are generated dramatically declines with increasing age (Bizon & Gallagher, 2003; Kuhn, Dickinson-Anson, & Gage, 1996; Lee, Clemenson, & Gage, 2012). Older animals show significantly less neural progenitor proliferation, neuronal differentiation, and neural survival than younger animals (Ben Abdallah et al., 2010; Heine, Maslam, Joëls, & Lucassen, 2004). In mice, the age-related decline of neural progenitor cells begins at 1–2 months of age and progressively decreases each month thereafter, until it is barely present in aged mice (Bondolfi, Ermini, Long, Ingram, & Jucker, 2004).

Animal evidence from post-lesion plasticity after stroke shows that the expression pattern of growth-promoting genes parallels the evolution of neuritic sprouting. In contrast, in aged animals, the expression of such genes is dampened or delayed, which may account for the age-dependent decline in compensatory responses (Li et al., 2010). Several growth inhibitors are up-regulated after stroke in the aged brain, but not in the juvenile brain (Li & Carmichael, 2006). These findings fit well to the assumption that the brain strikes a balance between plasticity and stability. During the transition from childhood to adulthood, the set point of equilibrium is shifting away from plasticity towards stability, presumably reflecting the operation of molecular mechanisms that actively suppress plasticity.

FIGURE 6.4 (Continued) (A) Effect sizes (ES; standardized changes in the experimental group minus standardized changes in the control group), separately for younger adults (gray bars) and older adults (black bars). Statistically significant ES correspond to reliable interactions (*$P<0.05$) between group (experimental vs. control) and occasion (pretest vs. posttest). Observed ES refer to individual tests, latent ES to cognitive abilities estimated with structural equation modeling. At the level of cognitive abilities, younger and older adults show transfer of training to working memory (WM); in addition, younger adults also show transfer to reasoning and episodic memory. (B) A midsagittal slice of a mean diffusivity data set, with the corpus callosum segmented into five different regions. The first region refers to the genu, which connects the prefrontal cortices. (C) Changes in fractional anisotropy and area of the genu assessed in subsamples of younger and older COGITO participants. Changes differ reliably between intervention and control groups, but not by adult age (Lövdén, Bodammer et al., 2010). (D) Younger adults maintain transfer of training effects in reasoning and episodic memory over 2 years (Schmiedek et al., 2014).

The age-related average decrease in plasticity takes place in the presence of sizeable individual differences in plasticity at any given age, and these differences seem to increase rather than decrease with advancing age. Individual differences in older rats' ability to learn novel information are a particularly striking example. Some older animals' capacity to learn is just as great as that of younger animals (Bizon & Gallagher, 2003; Bizon, Lee, & Gallagher, 2004). Likewise, Kempermann and colleagues have repeatedly shown that enriched environments promote neurogenesis and learning in mice (Kempermann, Kuhn, & Gage, 1997), and enhance individual differences in plasticity (Freund et al., 2013; see also Bergmann & Frisén, 2013).

PROPOSITION #2: FLEXIBILITY INCREASES FROM CHILDHOOD TO MIDDLE ADULTHOOD, AND DECLINES THEREAFTER

As noted above, flexibility differs from plasticity, and denotes individuals' use of their currently available brain resources, or their "functional cerebral space" (Kinsbourne & Hicks, 1978). The available evidence indicates that flexibility increases from childhood to middle adulthood, reflecting the vast increase in knowledge, habits, and skills, but gradually declines during later stages of life, due to senescent changes in the brain's chemistry, anatomy, and function (for a summary, see Lindenberger, 2014). This decline is likely to occur for at least two reasons. First, the behavioral repertoire itself is shrinking (selection), reflecting the decline in functional supply associated with normal aging (for a summary, see Lindenberger, 2014); second, the goal-directed, top-down implementation of the remaining set of behaviorally relevant brain states becomes increasingly inefficient (Lindenberger & Mayr, 2014). For instance, adaptively switching from one task set to another becomes increasingly difficult with advancing age, presumably as a reflection of senescent changes in prefrontal circuitry and dopaminergic neuromodulation (Gazzaley, 2013).

In addition to the sheer size of the behavioral repertoire, which corresponds to the brain's functional supply, flexibility is aided by cognitive control, or the ability to adaptively switch among different task sets (Mayr, Kuhns, & Hubbard, 2014). Cognitive control increases from childhood onwards, and declines in the course of normal aging (De Luca et al., 2003). Confirmatory factor analyses suggest that the structure of executive functions progresses from unity to diversity during middle childhood and adolescence, indicating a higher differentiation over the course of development (Shing, Lindenberger, Diamond, Li, & Davidson, 2010; Span, Ridderinkhof, & van der Molen, 2004; F. Xu et al., 2013). Global switch costs, which reflect the load associated with working on more than one task set, are more pronounced in older adults than in younger adults (Kray & Lindenberger, 2000; Verhaeghen & Cerella, 2002; Wasylyshyn, Verhaeghen, & Sliwinski, 2011). Global switch costs are typically derived by comparing reaction times in single-task blocks with blocks of trials that contain two or more tasks. In line with pronounced adult age differences in global switch costs, performance in dual-task situations, where two tasks have to be accomplished in parallel, also show pronounced adult age differences (Verhaeghen & Cerella, 2002).

Lindenberger and Mayr (2014) have recently suggested that older adults rely more strongly on environmental external information than younger adults do, in part because they have difficulties in internally triggering and maintaining cognitive representations. Similar accounts have previously been proposed in the domain of memory. It has been shown that adult age differences in memory performance tend to be exacerbated when retrieval depends on self-generated cues, whereas age differences are smaller when retrieval cues are provided by the environment (Craik, 1983, 2006).

The decline of task switching and dual-tasking as well as the increased reliance on environmental support with advancing age support the claim that flexibility declines during later periods of adulthood because the cognitive system is gradually losing cognitive, "top-down" control, or the capability to impose its goal structure upon a complex or distracting environment. For instance, Passow et al. (2012) examined adult age differences in the interplay between perceptual saliency and attentional control over auditory processing in a dichotic listening task. Perceptual saliency was manipulated by decreasing the intensity of either the right- or the left-ear input in 5-dB steps until a maximum difference of 20 dB between ears was reached. The 0-dB difference condition served as the baseline intensity and was adapted to each participant's individual hearing threshold. Twelve different dichotic syllable pairs were presented twice for each of the nine interaural intensity conditions. Attentional focus was manipulated by instructing the participants to focus on the right ear, on the left ear, or on both ears (neutral focus). When the stimulus of the attended ear is louder, then attention is facilitated by saliency; however, when the stimulus of the attended ear is softer, then attention has to overcome the saliency advantage of stimuli presented to the unattended ear. Across all interaural intensity conditions, younger adults were capable of flexibly focusing their attention on auditory inputs from either the right or left ear (see Figure 6.5A). In stark contrast to younger adults, the performance of older adults was driven almost exclusively by perceptual saliency, with attentional focus having little effect on performance (see Figure 6.5B).

Cognitive control has been linked to the integrity of the prefrontal cortex (Alvarez & Emory, 2006), and a recent meta-analysis has reported an association between executive task performance and volume of the prefrontal cortex, showing that "bigger is better" (Yuan & Raz, 2014). The prefrontal cortex is known to be among one of the last brain regions to mature during childhood (Giedd et al., 1999) and to substantially decline as humans reach older ages (Raz, 2000). Hence, the aspect of flexibility related to the pliable and goal-adequate use of existing knowledge, skills, and habits, rather than to their sheer amount, may closely follow the ontogenetic trajectory of prefrontal areas.

Senescent changes in cognitive control among animals seem to resemble those of humans. For instance, aged rats show decrements in a set-shifting task performance as compared to young rats (Beas, Setlow, & Bizon, 2013). Interestingly, the variability among older rats was considerably higher than the variability among younger rats, and some of the older rats performed at the level of the young. Relative to young monkeys, aged monkeys are impaired in learning a set-shifting task, and show a greater number of perseverative responses (Moore, Killiany, Herndon, Rosene, & Moss, 2003). Perseverative behavior has also been observed in aged mice in cases in which they are required to overcome a previously learned response (Matzel et al., 2011). The latter study also showed that the observed impairments in flexibility are not entirely immutable, as the older mice seemed to benefit from a cognitive exercise regimen.

PROPOSITION #3: RELATIVE TO CHILDHOOD, PLASTICITY IN ADULTHOOD AND OLD AGE IS MORE OFTEN ASSOCIATED WITH MAINTENANCE, AND LESS OFTEN WITH GROWTH

Several studies have found that the brains of older adults show fewer signs of growth in response to an intervention than the brains of younger adults. In a juggling training

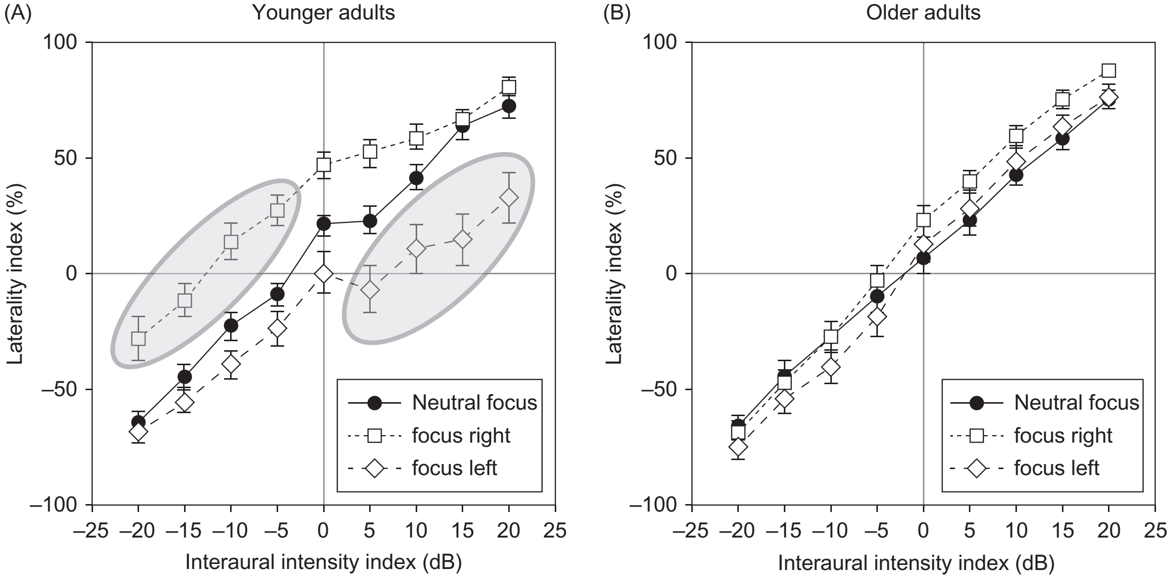

FIGURE 6.5 *Adult age differences in flexibility.* In a dichotic listening task, Passow et al. (2012) presented participants with dichotic pairs of voiced versus unvoiced syllables (e.g., /ba/ vs. /pa/), and asked them to report the syllable they heard. Perceptual saliency, shown on the *X*-axis, was manipulated by decreasing the intensity of either the right- or the left-ear input in 5-dB steps until a maximum difference of 20 dB between ears was reached. Negative values represent conditions in which left-ear stimuli were louder than right-ear stimuli, and positive values represent conditions in which right-ear stimuli were louder than left-ear stimuli. Attentional focus was manipulated by instructing participants to focus on the right ear, on the left ear, or on both ears (neutral focus). Reports are quantified by the laterality index, shown on the *Y*-axis, which expresses the amount of right-ear reports in relation to left-ear reports (i.e., [(right ear − left ear)/(right ear + left ear)] × 100). The laterality index ranges from −100% to +100%, with positive values indicating a right-ear advantage, and negative values indicating a left-ear advantage. When the stimulus of the attended ear is louder, then attention is facilitated by saliency; when the stimulus of the attended ear is softer, then the saliency advantage of the stimuli presented to the unattended ear has to be overcome by top-down attentional control. In contrast to younger adults (A), who were capable of flexibly focusing their attention on auditory inputs from either the right or left ear, performance in older adults was driven almost exclusively by perceptual saliency (B). In particular, the distance between the data highlighted and the data point from the neutral-focus condition underscore younger adults' ability to use top-down modulation to overcome conflicts between perceptual saliency and attentional focus; the overlap between the corresponding conditions among older adults indicates that this ability is severely impaired in old age. *Figure adapted from Passow et al. (2012) with permission.*

study (Boyke, Driemeyer, Gaser, Büchel, & May, 2008), older adults showed training-induced gray-matter increases in task-related brain regions, but these changes were less pronounced than those found in younger adults (Draganski et al., 2004). Lövdén et al. (2012) found that spatial navigation training was associated with maintenance of hippocampal volumes in both younger and older adults relative to younger and older adults in the control group, who showed age-related volume shrinkage. However, reliable training-induced increases in cortical thickness of the precuneus and the paracentral lobule were restricted to the group of younger adults (Wenger et al., 2012).

In line with general tenets of lifespan psychology (Baltes, 1987; Baltes, Lindenberger, & Staudinger, 2006), these findings mandate an age-comparative look at neural and behavioral manifestations of plasticity in adulthood. In adulthood, and especially in old age, the positive effects of cognitive interventions on cognitive development may not exclusively, and perhaps not even primarily, consist in growing new tissue, or acquiring new skills. Instead, such interventions may trigger positive deviations from the modal path of cognitive aging by preventing the structural, functional, and behavioral decline that would have occurred otherwise. In this vein, Nyberg, Lövdén, Riklund, Lindenberger, and Bäckman (2012) as well as Lindenberger, Burzynska, and Nagel (2013) have proposed that the *maintenance* of brain structure and function over time may function as a key meta-mechanism of successful cognitive aging. From this point of view, effective cognitive interventions may preserve the volume of relevant brain areas during a time period in which non-trained individuals show reductions in volume.

In animals, age-related synapse loss has been shown to be reversible, for instance, in response to the administration of nicotine (Picciotto & Zoli, 2002) or estrogen (Morrison, Brinton, Schmidt & Gore, 2006), and in response to neurotrophin gene transfer in rhesus monkeys (Smith, Roberts, Gage & Tuszynski, 1999). Similarly, environmental enrichment (Darmopil, Petanjek, Mohammed, & Bogdanović, 2009) and exercise have been shown to attenuate neural and behavioral losses in older animals (Kempermann, 2008; Kronenberg et al., 2006).

PLASTICITY AND FLEXIBILITY IN RELATION TO *GF–GC* THEORY

It is instructive to compare the postulated lifespan gradients of plasticity and flexibility, as shown in Figure 6.2, with the gradients postulated by existing two-component theories of cognitive lifespan development (Baltes, 1987; Cattell, 1971; Horn, 1989; for a summary, see Lindenberger, 2001). These theories make two basic assumptions. First, they posit that cognitive development across the lifespan reflects the operation of two intertwined components, one biological and the other cultural. The biological component is construed as an expression of the neurophysiological architecture of the mind as it evolved during biological evolution and unfolds during ontogeny. The cultural component refers to bodies of knowledge available from and mediated through culture. Second, potential related to the biological component is *invested into* various cultural domains, thereby leading to the acquisition of culturally transmitted bodies of knowledge. A good example is the acquisition of reading and writing skills. Hence, at any point in time during development, two types of cognitive capacities can be distinguished: the capacity to invest (i.e., to acquire new knowledge of various sorts); and the capacity to think and act on the basis of acquired knowledge.

Arguably the most influential two-component theory of cognitive lifespan development is the theory of *fluid* versus *crystallized* intelligence (*Gf*–*Gc* theory) introduced by Raymond B. Cattell (Cattell, 1971) and modified by John Horn (Horn, 1989). Fluid intelligence represents the biological component; it is called fluid because it can be invested into various cultural domains. In contrast, crystallized intelligence represents the cultural component; it is called crystallized because it has solidified into knowledge.

In light of these assumptions, one may gain the impression that the *Gf*–*Gc* distinction is virtually identical to the distinction between plasticity and flexibility proposed in this chapter. And, indeed, the hypothesized lifespan trajectories for flexibility and *Gc* are identical (Figure 6.2). However, the trajectories for plasticity and *Gf* deviate from each other: whereas overall plasticity, on average, is assumed to decline across the lifespan, *Gf* shows a sharp increase up to late adolescence and early adulthood, followed by accelerated decline during adulthood and old age. In fact, the trajectories postulated by *Gf*–*Gc* theory summarize a vast amount of psychometric evidence obtained through standardized behavioral testing and factor analysis (Jones & Conrad, 1933). Abilities subsumed under *Gf*, such as reasoning, memory, spatial orientation, and perceptual speed, generally show a sharp increase in childhood and adolescence, followed by roughly linear decline during adulthood, and accelerated decline in very old age. In contrast, abilities subsumed under *Gc*, such as verbal knowledge and certain facets of numerical ability, remain stable or increase up to the sixth or seventh decades of life, and evince some decline in advanced old age.

In our view, the discrepancy between plasticity and *Gf* points to the hybrid nature of measured *Gf*. In contrast to theoretical assumptions, the empirical indicators used to assess *Gf* are not, as postulated, a pure expression of biological potential; if they were, the lifespan trajectory for *Gf* would, in fact, coincide with the trajectory postulated for plasticity. Instead, indicators of *Gf* represent a mixture of plastic potential and flexibility (e.g., invested plasticity), and this hybrid nature of *Gf* places its trajectory in an intermediate position between plasticity and flexibility. This reinterpretation of *Gf* helps to explain the massive performance gains on IQ tests across historical time, also known as the "Flynn effect" (Flynn, 1987). This gain is more likely to reflect secular changes in the realization of plastic potential, or gene–environment correlations, than changes in the potential itself (for a similar line of reasoning, see Beam & Turkheimer, 2013; Dickens & Flynn, 2001).

OPEN QUESTIONS AND FUTURE RESEARCH DIRECTIONS

We end this chapter by highlighting three open research questions, and suggesting future directions in the study of human adult plasticity.

Investigating Age Differences in the Sequential Progression of Plasticity

Developmental findings, animal models, and conceptual considerations indicate that plasticity-induced gray matter changes take an inverse quadratic course (Lövdén et al., 2013). For example, in-vivo microscopic imaging of dendritic spines in mice reveals new spines after a few hours of motor training in mice (T. Xu et al., 2009), which is followed by selective stabilization of new and partial elimination of old spines (see Fu & Zuo, 2011, for review). Learning-related cortical map expansion has also been shown to occur quite rapidly, such as within a few days, and then renormalize during further training despite stable performance (Molina-Luna, Hertler, Buitrago, & Luft, 2008; Reed et al., 2011). It has been proposed that an initial "overshoot" may increase the pool of neural resources from which the most efficient wiring can then be selected (Reed et al., 2011). At an ontogenetic timescale, Changeux and Dehaene have suggested that brain plasticity during early ontogeny goes through cycles that are marked by an initial increase in the number of synapses followed by experience-dependent selective stabilization of behaviorally relevant connections (Changeux & Dehaene, 1989; see also Edelman, 1987). Based on these findings and concepts, Lövdén et al. (2013) recently proposed that expansion followed by partial renormalization may be a common principle that unites different manifestations of plasticity.

From a design perspective, one may argue that an expansion–renormalization process is presumably a more efficient way for the brain to reorganize and adjust than a constant growth process. In stark contrast to this conjecture, available evidence on macroscopic manifestations of plasticity in humans is generally restricted to pretest–posttest designs, with one scan taken before and another taken after the termination of the intervention. Such designs do not discriminate between monotonic and non-monotonic manifestations of plasticity. In a recent study, Wenger et al. (submitted) acquired up to 16 magnetic resonance images during a 7-week period in which 15 right-handed young men practiced left-hand writing and drawing. After 4 weeks of training, the authors observed increases in gray matter of both left and right primary motor cortices relative to a control group; 3 weeks later, these differences were no longer reliable. Gray matter in the primary motor cortices expanded during the first 4 weeks, and then partially renormalized, in particular in the right hemisphere, despite continued practice and further performance improvements. Based on these promising findings, it seems highly desirable to compare the time course of intervention-induced plastic changes across different age groups to gain a more dynamic view of age-graded changes in plasticity.

Scrutinizing “Ribot’s Law” and the “Dark Side of Plasticity”

For a long time, researchers have speculated that senescent changes in the mammalian brain late in life are a mirror-image of maturational changes early in life. The general idea was introduced by the French philosopher Théodule Ribot, who noted that episodic memory loss in old age progresses from newly acquired memories to older memories (Ribot, 1881). Transferring this observation to the neural level of analysis, Ribot postulated that senescent brain changes would follow the reverse order of maturational changes during development. According to this hypothesis, brain regions that would develop late—during ontogeny and possibly also during phylogeny—would be those that degenerate early (Hill et al., 2010), following a “last in, first out” rule (Raz, 2000).

In line with Ribot’s law, Raz (2000) noted that regional differences in volume shrinkage are inversely related to the order in which intracortical fibers of different brain regions myelinate during early ontogeny. Using lifespan cross-sectional data and VBM-based analyses, Douaud et al. (2014) recently reported a set of brain regions that show signs of late maturation and early senescence in an inverted-U-shape relationship between structural variation and age. The regions following this mirror-image pattern were transmodal regions including heteromodal cortex as well as limbic and paralimbic regions; in particular, lateral prefrontal cortex, frontal eye field, intraparietal sulcus, superior temporal sulcus, posterior cingulate cortex, and the medial temporal lobe. Based on separate analyses, the authors discovered that the very same brain regions that matured late and senesced early also showed a heightened vulnerability to clinical disorders such as schizophrenia and Alzheimer’s disease.

Based on the notion that ontogeny is characterized by temporally ordered, hierarchically nested cycles of plasticity (Shrager & Johnson, 1996), one may speculate whether late-maturing brain regions are more susceptible to the detrimental effects of aging exactly because their construction and operation builds on earlier cycles of plasticity. In this context, it is interesting to note that brain regions with greater plastic potential in adulthood tend to show greater age-related decline, and to be particularly vulnerable to vascular and metabolic risk factors. One such region is the hippocampus, which is critically involved in spatial orientation, and in many forms of learning and memory. The hippocampus is both particularly plastic and highly susceptible to risk factors such as stress, vascular conditions, and metabolic syndrome, suggesting that plasticity comes at a price (Raz, 2001, 2007).

To further explore the association between regional differences in plasticity and regional differences in age-related decline, we conducted a quantitative meta-analysis, using methods that are described in detailed in Eickhoff et al. (2009). The meta-analysis was based on 27 studies for which training-induced gray matter changes have been observed (Lövdén et al., 2013). Despite large variation in the skills that were trained, we observed considerable concordance across studies in right occipital cortex (27, −84, −3), left precentral gyrus (−37, −21, 58), left cerebellum (−27, −41, −46), right cuneus (19, −84, 28), right postcentral gyrus (41, −27, 39), left inferior parietal lobe (−54, −32, 27), left parahippocampal gyrus (−17, −10, −16), left superior frontal gyrus (−22, 52, 20), right thalamus (23, −38, 8), right superior temporal gyrus (58, 6, −12) and left insula (−42, −8, 16) (P<0.05 FDR corrected, cluster > 200 mm^3). Age-related atrophy of brain areas has consistently been reported for prefrontal cortex, insula, caudate nucleus, thalamus, and sensorimotor cortex in a meta-analysis (Di, Rypma, & Biswal, 2014) as well as hippocampus, cerebellum, and parietal cortex (Raz, 2004; Raz, Ghisletta, Rodrigue, Kennedy, & Lindenberger, 2010). When focusing on the overlap between the two sets of brain regions, 8 of the 11 brain areas showing structural plasticity across training studies were located within brain regions that have been reported to show pronounced age-related decline in volume. If this association between plasticity and vulnerability holds true, it would call for interventions that target brain regions showing large, rather than little, age-related decline (Raz, 2009).

In this context, the issue of excessive plasticity needs to be addressed as well. There are indications that plasticity can disrupt neural representations and behavior. A particularly compelling case is focal dystonia, a neurological condition associated with involuntary muscular contractions in particular parts of the body. Focal dystonia is commonly characterized by prevailing facilitation of synaptic potentiation, and a loss of synaptic inhibitory processes (Quartarone & Pisani, 2011). Accordingly, highly trained musicians are disproportionately affected by focal dystonia (Altenmüller & Jabusch, 2010). Though the motto, "use it or lose it," aptly summarizes the positive association between active lifestyles and cognitive functioning in old age (Hertzog, Kramer, Wilson, & Lindenberger, 2008), focal dystonia and related conditions remind us that plasticity itself may be a risk factor for behavioral development.

Towards a Molecular Understanding of Plasticity Dynamics in Human Adults

Human ontogeny is structured by a progressive sequence of sensitive periods (Michel & Tyler, 2005). These periods are not confined to basic aspects of sensory development but extend to higher-order cognitive functions, such as language (Werker & Tees, 2005) and music (Bailey & Penhune, 2012; Penhune, 2011). Inhibitory GABA neural circuits have been identified as drivers of the onset of sensitive periods (Hensch, 2005). At the same time, plasticity is constrained by two main classes of "brakes." First, the resulting structures, such as myelin and perineuronal nets, limit further plasticity. Second, the balance between excitatory and inhibitory transmitter release put constraints on plasticity (Bavelier, Levi, Li, Dan, & Hensch, 2010). A case illustrating the active suppression of plasticity comes from individuals who suffer from amblyopia. These individuals' eyes appear normal, but one eye's vision is impaired because it was not stimulated properly and did not develop its full visual potential during the sensitive period. When amblyopic patients lose vision in the normally functioning eye, the amblyopic eye sometimes improves spontaneously (Bavelier, Achtman, Mani, & Föcker, 2012; Rahi et al., 2002). This observation is consistent with the notion that the connections from the amblyopic eye are actively suppressed rather than destroyed entirely, so that the loss of vision in the other eye may reactivate existing connections.

Conceptually and empirically, it is highly attractive to apply the molecular insights gained from the study of sensitive (also called critical) periods in animals and humans to the study of adult plasticity (cf. Bavelier et al., 2010). In particular, it is intriguing to examine whether sensitive periods can be reopened or prolonged in adult humans. Attempts to reopen windows of plasticity in adulthood may combine behavioral interventions (Lövdén et al., 2013) with targeted pharmacological manipulations (Gervain, Vines, Chen, & Seo, 2013) or with stimulation of relevant brain areas (Ferreri & Rossini, 2013).

One question that will accompany this work is whether mechanisms of plasticity change with age and experience. For instance, one may wonder about age-graded differences in the mechanisms and meaning of neurogenesis in the hippocampus. Once hippocampal circuits have been formed, the need for cellular plasticity may decrease (Couillard-Despres, Iglseder, & Aigner, 2011). Upon exposure to new stimuli, younger (or un-experienced) individuals may require more neurogenesis to improve the circuitry than older (or more experienced) animals. Based on this example, one may speculate that the degree of plasticity required for meeting new environmental demands is inversely related to previous exposures to similar challenges (cf. Schaie, 1962). In line with this speculation, long-term adaptive changes in dendritic spines have been found to be abundant in young animals, but virtually absent in adult animals (Grutzendler, Kasthuri, & Gan, 2002). This difference may be related to age differences in transfer of training. In younger individuals, plasticity may operate on a wide scale, and more easily transfer to untrained skills. In older individuals, plasticity may operate at a more local level, with little evidence of transfer to untrained skills. Clearly, age-comparative intervention studies are needed to validate these claims.

To conclude, the molecular mechanisms that regulate plasticity during adulthood may be more or less similar to the mechanisms that regulate sensitive periods in early ontogeny. Delineating these commonalities and differences may turn out to be the most important research question in the study of human adult plasticity for the next decade.

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CHAPTER

7

Cognitive and Physical Aging: Genetic Influences and Gene–Environment Interplay

Chandra A. Reynolds[1] *and Deborah G. Finkel*[2]

[1]Department of Psychology, University of California – Riverside, Riverside, CA, USA [2]Department of Psychology, Indiana University Southeast, New Albany, IN, USA

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INTRODUCTION

Maintaining or stimulating cognitive functioning while offsetting the extent and timing of cognitive decline (Salthouse, 2012; Schaie, 1989), particularly reducing dementia risk, has become of principal importance to the research community and to the related industries that have emerged with respect to brain training and other health-promoting activities. Past

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research has attempted to distinguish normative cognitive change from dementia-related loss, yet, the new criteria for Alzheimer's disease (AD) recognize a potentially long preclinical period (10 years or longer) under which physiological changes occur before clear clinical signs are manifest (Sperling et al., 2011). This stance implies: (i) that the etiologies underlying normative cognitive change and dementia risk may be partly shared, and (ii) that physiological changes occurring before clinical signs of dementia may indicate a shared etiology or even dynamic relationships between physical and cognitive functioning. Thus, in this chapter while we are focusing on relevant research in normative cognitive aging, we must also consider the associated etiologies of dementia and physical aging. Building on earlier *Handbook* chapters (Kremen & Lyons, 2011), we highlight newer directions in cross-domain work with physical aging traits (e.g., body mass index (BMI), pulmonary functioning, blood pressure (BP), heart rate variability, grip strength, functional ability), measured genetic and environmental influences, and biological markers of gene–environment interplay processes.

COGNITIVE FUNCTION

After decades of research, characterization of age changes in cognition has achieved a certain level of precision. Understanding and identifying the influences of neurobiological and psychosocial factors on cognitive aging, however, is an ongoing process. Behavior genetic approaches provide methods for examining the relative impact of genetic and environmental influences and their interplay, and the accumulating results have been summarized in several recent reviews of the literature (Finkel & Reynolds, 2009; Johnson, McGue, & Deary, 2014). Moreover, several twin studies of adult development and aging have recently combined forces both to increase power to detect subtle genetic and environmental effects and to resolve any conflicting results reported by individual studies (Pedersen et al., 2013).

General Cognitive Ability

We know that on average general cognitive ability tends to decline throughout adulthood; however, genetic and environmental influences on cognitive aging manifest an intriguing and perhaps unexpected pattern. Initial meta-analyses demonstrated that the heritability of IQ is about 50% in young adulthood (Bouchard & McGue, 1981). As twin studies of adulthood accumulated longitudinal waves of data, it became clear that heritability continues to increase throughout the first half of the adult lifespan, reaching estimates as high as 80% in middle adulthood (Pedersen, Plomin, Nesselroade, & McClearn, 1992). There is some debate about how genetic and environmental variances change in the second half of the lifespan, as cognitive aging accelerates and a lifetime of accumulating environmental influences begins to overwhelm the system. A recent review of longitudinal twin studies of aging reports declines in heritability in late adulthood with associated increases in environmental variance (Finkel & Reynolds, 2009). In contrast, others report stable heritability estimates for cognitive function in late adulthood (McGue & Christensen, 2013). Recent cross-sectional analyses using over 14,000 twins from nine twin studies representing three countries suggests relative stability in heritability estimates for some cognitive domains, but changes in heritability for other domains (Pahlen et al., 2014). However, even this analysis has a limited sample over age 80, the age at which some studies suggest heritability may decline (McClearn et al., 1997; Reynolds et al., 2005); therefore, the issue remains unresolved.

Specific Cognitive Abilities

As with investigations of mean cognitive aging trajectories, behavior genetic analyses have focused on specific cognitive abilities for increased precision in the understanding of influences on cognitive change. In general, heritability estimates within specific domains tend to be somewhat lower than estimates for general cognitive ability, with estimates ranging from 50% to 70% (Finkel & Reynolds, 2009). In addition to focusing on changes or stability in heritability, longitudinal twin data allows us to estimate the genetic and environmental influences on change in cognitive function, per se. In other words, latent growth models provide estimates of heritability of average functioning at various ages (intercept) and genetic influences on changes in functioning over time (slope). Behavior genetic decomposition of latent growth models suggests generally high heritability for intercepts across cognitive domains, little or no heritability for linear slope estimates across cognitive domains, and small to large effects for quadratic estimates that tap accelerating change with age (McArdle, Prescott, Hamagami, & Horn, 1998; McGue & Christensen, 2002; Reynolds et al., 2005). For example, heritability of intercept of the growth curve for a verbal ability factor was 79%, heritability of both linear and quadratic rates of change was 0%, indicating that change in verbal ability with age resulted entirely from unique environmental factors (Finkel, Reynolds, McArdle, & Pedersen, 2005). When the individual tests that comprise the verbal factor were examined, however, the results indicated that genetic influences on quadratic decline varied from 9% to 42% across tests. Results for the processing speed factor and component tests tended to be more consistent: heritability for both intercept and quadratic rates of change were 80%, suggesting a strong neurobiological basis for age changes in processing speed. However, recent multivariate behavior genetic analysis of growth models demonstrates that most of the genetic influences on change are shared across domains, with specific genetic variance on change for memory and spatial ability, only (Tucker-Drob, Reynolds, Finkel, & Pedersen, 2014). In other words, regardless of the different abilities tapped by each domain, the genetic influences on cognitive change appear to be more global than specific.

Recent advances in brain imaging allow researchers to identify other relevant components of cognitive functioning central to the aging process, beyond the traditional domains of verbal, spatial, memory, and speed. For example, some of the largest age-related changes in brain structures are associated with changes in executive function and working memory. Working memory can be tapped by measures of memory span that require participants to both store and process information. Backwards digit span, measures of letter-number span, and spatial span tend to be moderately heritable in middle and late adulthood (Karlsgodt et al., 2010; Kremen et al., 2007; Posthuma et al., 2003). Executive function is a complex phenotype comprised of inhibitory control and set-shifting in addition to working memory. Multivariate behavior genetic analyses tend to find both a common genetic factor and genetic influences specific to the individual executive function components (for a review see Kremen, Moore, Franz, Panizzon, & Lyons, 2014). However, most of this research has concentrated on young and middle-adulthood twins, and more investigation of working memory and other executive function components in the second half of the lifespan is needed.

Environmental Influences

In addition to investigating genetic influences on cognitive abilities, behavior genetic approaches also provide a mechanism for identifying environmental factors that influence functioning, both shared rearing environment and nonshared environmental factors unique to each individual. Results of twin studies of aging indicate that environmental influences on cognitive aging generally take the form of unique nonshared factors that lead to differences among individuals from the same family; thus the rearing environment has little impact on cognitive function in the second half of the lifespan. Environmental factors that influence both mean cognitive performance and rates of decline include education and socioeconomic status, occupational complexity (Andel, Vigen, Mack, Clark, & Gatz, 2006; Finkel, Andel, Gatz, & Pedersen, 2009), lung function (Emery, Finkel, & Pedersen, 2012), and leisure activities, including social participation (Lövdén, Ghisletta, & Lindenberger, 2005). It is important to note that many of these ostensibly environmental variables are themselves influenced by genetic factors. Twin studies provide a methodology for disentangling shared genetic and environmental variance between cognitive function and "environmental" measures. For example, latent growth curve analyses of cognitive ability traits suggest that education shares genetic variance with performance levels, but environmental variance with rates of change (Reynolds, Gatz, & Pedersen, 2002). This outcome is generally consistent with related findings suggesting that environmental factors underlie associations between education and dementia risk (Gatz et al., 2007), even as levels of cognitive performance and functioning show patterns of partial genetic overlap with education (Pedersen, Reynolds, & Gatz, 1996). Lung function, which likely taps environmental factors such as smoking, exercise, and environmental exposures, shares both genetic and environmental variance with declines in fluid intelligence (Finkel, Reynolds, Emery, & Pedersen, 2013). Thus, phenotypic approaches can identify candidate environmental influences on cognitive decline, but behavior genetic methods are required to determine the exact nature of the relationship.

PHYSICAL FUNCTION

To fully understand the mechanisms of cognitive aging, it is important to consider the physical context in which that aging occurs. Although it is difficult to discuss various physical systems in isolation, we will consider more physiological aspects of physical function first, then more behavioral components. For the purposes of this summary, *physiological functioning* includes obesity, cardiovascular health, and lung function whereas *behavioral physical functioning* includes muscle strength and functional ability.

Physiological Functioning

Extensive research has documented that having a normal body mass index (BMI = 19–25 kg/m^2) in midlife is related to better health and survival; however, slightly elevated BMI (25–30) in late adulthood is associated with better health prognoses than normal BMI (Dahl, Lopponen, Isoaho, Berg, & Kivela, 2008; Romero-Corral et al., 2006). This "obesity paradox" is likely driven by disease processes that cause weight loss, emphasizing the role of BMI as a marker of general health. Mean BMI increases somewhat with age, but heritability estimates remain fairly constant at 70% throughout the second half of the lifespan (Nan et al., 2012; Silventoinen & Kaprio, 2009).

Of the several indices of cardiovascular health that have been included in twin studies of aging, BP is the most common. Behavioral genetics investigations suggest moderate genetic influences on BP: heritability near 45% for systolic BP and 34% for diastolic BP (Hong, de Faire, Heller, McClearn, & Pedersen, 1994; Vinck, Fagard, Loos, & Vlietinck, 2001). Some studies suggest decreasing genetic influences on BP with increasing age (Finkel et al., 2003; Hong et al., 1994; Tambs et al., 1993). In contrast, heritability estimates for elevated BP (hypertension) are higher, ranging from 46% to 63% (Kupper et al., 2005; McCaffery, Papandonatos, Lyons, & Niaura, 2008). Recent investigations of cardiovascular health have focused on measures that require more sophisticated technology. Heart period variation, respiratory sinus arrhythmia, and other heart rate variability (HRV) indices from ECG are predictive of cardiac events and mortality. These ECG-based measures tend to be moderately to strongly heritable (30–55%), depending on the testing context: at rest versus experimentally induced stress conditions (De Geus, Boomsma, & Snieder, 2003; Kupper et al., 2004; Li et al., 2009; Snieder, van Doornen, Boomsma, & Thayer, 2007; Uusitalo et al., 2007). Environmental influences on cardiovascular health tend to be unique to the individual and include caffeine, smoking, BMI, and medications (Uusitalo et al., 2007). Investigations of serum lipids, primarily cholesterol and triglycerides, also provide insight into the nature of genetic and environmental influences on cardiovascular health. Heritability estimates are moderate to strong across serum lipid and lipoprotein traits, typically between 30% and 80% (Beekman et al., 2002; Goode, Cherny, Christian, Jarvik, & de Andrade, 2007; Nilsson, Read, Berg, & Johansson, 2009). After age 50, results for heritability of serum lipids are mixed, with reports indicating decreases, stability, or even small increases, depending on study design (cross-sectional or longitudinal) and lipid or lipoprotein constituent (Goode et al., 2007; Heller, de Faire, Pedersen, Dahlen, & McClearn, 1993). However, longitudinal studies suggest unique (new) genetic influences may emerge by midlife (Middelberg, Martin, & Whitfield, 2006) with possible amplification of heritable influences in late life (Goode et al., 2007).

Lung function is clearly related to cardiovascular health, but it is also associated with general functioning in several domains, including functional ability and cognition (Emery et al., 2012; Singh-Manoux et al., 2011). Lung function is moderately heritable in late adulthood, with estimates ranging from 30% to 50% (Hukkinen et al., 2011; Vasilopoulos et al., 2010; Whitfield, Wiggins, Belue, & Brandon, 2004). In particular, heritability varies based on the type of spirometric data (e.g., forced expiratory volume vs. full vital capacity). Behavior genetic analyses that differentiate genetic variance common to multiple measures and unique to each measure indicated primarily unique genetic variance for measures of lung function (Vasilopoulos et al., 2013). Thus even variables assumed to assess the same general domain of functioning can reveal complex etiologies.

Behavioral Physical Functioning

Heritability estimates for physical strength in adulthood range from 30% to 60% for both measures of upper body strength such as hand grip and measures of lower body strength such as knee extension (Finkel et al., 2003; Frederiksen et al., 2002; Tiainen et al., 2004, 2005). In addition, heritability of these measures of physical strength appears to be stable across adulthood (McGue & Christensen, 2013). Beyond simple strength, physical *function* measures tasks that generally have more ecological validity, such as Activities of Daily Living (ADL) or behaviors such as walking, balance, and chair stands. Unlike the results for physical strength, however, heritability estimates for physical functioning tend to be mixed, with evidence for significant age and gender effects (Christensen, Frederiksen, Vaupel, & McGue, 2003; Christensen, Gaist, Vaupel, & McGue, 2002; Finkel, Pedersen, & Harris, 2000; Finkel et al., 2003). As variability in functional measures increases with age, heritability estimates also increase, but heritability tends to be higher for women than for men (Christensen et al., 2003; Finkel, Ernsth-Bravell, & Pedersen, 2013). This gender difference likely reflects both different susceptibility to chronic disabling conditions and differential life experiences.

CROSS-DOMAIN INVESTIGATIONS

As we have seen, aging in both cognitive and physical domains results in part from genetic influences. The vital question, then, is to determine the extent to which the genetic factors that influence aging in one domain are also acting in other domains. In other words, it is possible that a single set of genes is having pleiotropic effects on the aging process, impacting aging in several domains. Research in this area has focused on the interrelationships between genetic and environmental influences on cognitive and physical function, as well as evidence for direct associations between brain structure and cognitive function in adulthood.

Interrelationships Between Cognitive and Physical Aging

As longitudinal twin studies of aging have continued to amass data, we have witnessed significant growth in behavior genetic investigations into the nature of the interrelationships between cognitive and physical aging. Some of the earliest work focused on the relationship between lung function and cognition, and accumulating evidence indicates a strong relationship between genetic influences on lung function and genetic influences on measures of fluid ability. For example, genetic variance in lung function at baseline was correlated with genetic variance in cognitive function 6 years later (Emery, Pedersen, Svartengren, & McClearn, 1998). Moreover, an analysis incorporating 19 years of longitudinal data for both lung and cognitive function indicated that genetic variance associated with lung function was in fact a primary contributor to subsequent change in fluid ability suggesting that the directional relationship from decreased pulmonary function to decreased cognitive function arises from genetic factors (Finkel, Reynolds et al., 2013).

More recent twin analyses have incorporated additional physiological measures of health. In a sample of Finnish twins, researchers found that the correlation between BMI at midlife and cognitive scores in late life was primarily genetically mediated. Additionally, indices of cardiovascular disease at midlife explained a portion of the difference in cognitive scores in discordant twin pairs (Laitala et al., 2011). In fact, evidence suggests that heritability estimates for measures of spatial ability and memory were significantly lower in a sample of untreated hypertensives, as compared with non-hypertensive and medicated hypertensive middle-aged men, absent any mean differences between the groups (Vasilopoulos et al., 2011). Thus, untreated hypertension may disrupt genetic influences underlying cognitive functioning, such as maintenance of brain structures and vasculature, even before cognitive deficits appear. Moreover, autonomic functioning, i.e., very low frequency HRV, may be implicated in verbal but not spatial memory performance in middle–age men without post-traumatic stress disorder (PTSD) based on between- and within-twin pair analyses (Shah et al., 2011); effects were apparent even when controlling for familial factors and hence implicating a role for (nonshared) environmental pathways (Shah et al., 2011).

In a cross-sectional twin analyses, the speed with which participants completed various functional ability tasks shared genetic variance with cognitive functioning in middle age but not later in adulthood, when processing speed explained most of the genetic variance in cognition (Finkel et al., 2000). Longitudinal twin analyses indicated significant shared genetic variance between functional ability and cognition. Three possible explanations for this relationship were supported by model-fitting: physical illness impacts subsequent cognitive function (e.g., hypertension), cognitive function as a contributor to the ability to maintain good health and lifestyle habits, and a biological process of aging that affects both (Johnson, Deary, McGue, & Christensen, 2009). Future studies may help unpack these competing explanations.

Brain Structures

The recent integration of various methods of brain imaging into twin studies of aging has resulted in the proliferation of research into the genetic and environmental influences on the association between specific brain structures and specific cognitive functions. Although experience clearly shapes the brain, genetic influences account for 40–95% of individual differences in brain structures and function (Chavarría-Siles, Fernández, & Posthuma, 2014). Similar to results from longitudinal twin studies of cognitive abilities; genetic influences on change in brain volume over time appear to be minimal (Lessov-Schlaggar et al., 2012). Nevertheless, the associations between brain structures and cognitive functioning tend to be primarily genetically mediated. For example, Posthuma and colleagues reported that although the correlations between gray-matter volume and white-matter volume and intelligence tend to be modest ($r=0.25$), the correlations reflect shared genetic variance only (Posthuma et al., 2002). Similarly, specific brain regions and structures (such as gray matter thickness and white matter hyperintensities) have been shown to share genetic variance with general intelligence and specific abilities such as working memory (Blokland et al., 2011; Hulshoff Pol et al., 2006; Joshi et al., 2011). Two concerns about this emerging field exist. First, most of the twin research is conducted on younger adults; few studies of middle-aged and older twins have incorporated brain imaging measures. The Vietnam Era Twin Study of Aging (VETSA) includes brain imaging (Kremen, Franz, & Lyons, 2013) and the National Heart, Lung, and Blood Institute (NHLBI) twin study reports that in a sample of older male twins, associations between white matter hyperintensities and cognitive function resulted for the most part from shared genetic variance (Carmelli, Reed, & DeCarli, 2002). Second, a variety of cognitive tasks may engage a particular brain region; hence, it is improbable that a designated region is "mapped" or central to a specific cognitive ability. Rather, knowledge of a region's functions should be evaluated against any newly observed relationships with task performance measures, as well as with related traits (Kanai & Rees, 2011).

Specific Genes Important to Cognitive and Physical Aging

The aforementioned studies indicate an important role for genetic influences on cognitive aging, physical functioning, and the relationships between the two domains. Indeed increases in genetic variance or heritability are typical at least through late adulthood even as nonshared environmental factors accumulate across the adult lifespan into old–old age. The search for genes that may potentiate or moderate normative cognitive aging, and the extent to which these overlap with physical functioning, are important issues to evaluate. Moreover, the extent to which measured environmental factors interact with genetic factors to moderate cognitive aging is receiving greater attention.

Association and linkage approaches are the two primary methods used in the identification of genes important to traits such as cognitive decline (Plomin, DeFries, Knopik, & Neiderhiser, 2013). Association studies evaluate correlational relationships between a variant of a particular gene, i.e., an allele, and cognitive change traits. While traditional association studies were conducted based on theoretical or biological evidence, millions of variants, primarily single nucleotide polymorphisms (SNPs), that appear frequently in populations (5% or higher) have been evaluated in genome-wide association studies (GWASs). Most recently, researchers have turned to whole-genome sequencing to evaluate rare variants as many of the GWASs have explained a limited amount of variation in traits (Plomin et al., 2013). Linkage strategies trace the extent to which a genetic marker or mutation co-occurs with a disorder or trait, within families, and are useful to localize genes of interest (Plomin et al., 2013).

Cognitive Aging

For over 20 years, the gene encoding apolipoprotein E (*APOE*) has stood out as the primary genetic susceptibility factor for late-onset AD (Corder et al., 1993; Strittmatter et al., 1993), and more recently for non-pathological (normative) cognitive aging (Davies et al., 2014; Reynolds et al., 2006). GWASs of AD risk conducted over the last decade have revealed about 20 additional gene candidates and pathways (Lambert et al., 2013; Schellenberg & Montine, 2012), although a number of these have yet to be evaluated for normative cognitive aging. These gene pathways include: (i) cholesterol and lipid metabolism (e.g., *APOE*, *ABCA7*, *CLU*, *SORL1*), (ii) cellular endocytosis or adhesion which play a role in protein absorption (*BIN1*, *CD2AP*, *FERMT2*, *PICALM*), (iii) immune/inflammatory response (e.g., *CR1*, *HLA-DRB5*–*DRB1* region, *INPP5D*, *MEF2C*, *MS4A4E/MS4A6A*), (iv) cell-signaling or synaptic functioning processes in hippocampal regions (e.g., *MEF2C*, *PTK2B*, *SLC24A4*), and (v) neural development (e.g., cell migration, *PTK2B*).

APOE and *SORL1* play a role in the lipid metabolism pathway and have been implicated in normative cognitive aging (Davies et al., 2014; Reynolds et al., 2006, 2013). *APOE*, although expressed in the periphery, is the primary transporter of cholesterol in the brain (Lambert et al., 2013; Schellenberg & Montine, 2012). The risk allele, *APOE* ε4, is associated with increased beta-amyloid (Aβ) protein deposition, a hallmark neuropathology observed in those with AD, but also observed at autopsy among aged individuals with no prior clinical signs of dementia (Caselli, Walker, Sue, Sabbagh, & Beach, 2010). The *SORL1* gene encoding sortilin receptor 1 (SorL1) plays a dual role: protein sorting and binding to the low-density lipoprotein (LDL) (http://www.ncbi.nlm.nih.gov/gene/6653). Moreover, SorL1 participates in the transport of the amyloid precursor (*APP)* protein, a precursor of Aβ (Gustafsen et al., 2013). Numerous common and rare *SORL1* SNPs and haplotypes have been associated with increased risk of AD (Jin et al., 2013; Reitz, Brayne, & Mayeux, 2011) and recently *SORL1* variants and risk scores (capturing multiple variants) were shown to predict differential accelerations in normative cognitive decline (Reynolds et al., 2013).

GWASs evaluating cognitive decline have not as yet extended findings beyond *APOE* for the above-noted AD-risk genes (Davies et al., 2014; De Jager et al., 2012). For example, cumulative impacts of susceptibility loci previously identified for cardiovascular disease, diabetes, or inflammatory/immune processes are not significantly associated with cognitive trajectories although the sample sizes may be a limiting factor (De Jager et al., 2012). In older adulthood, there appear to be numerous but small cumulative effects of common gene variants for fluid and crystalized intelligence performance (Davies et al., 2011), where, for example, as much as 51% of the variance in spatial performance was accounted for by thousands of SNPs; however, cognitive change was not evaluated. It may be that a focus on changes within specific cognitive domains will be more fruitful than global measures of cognitive change (Kremen et al., 2014). For example, recent findings for *SORL1* suggest a relatively greater number of associations with rate of cognitive change versus performance levels, particularly for spatial as well as episodic memory and verbal ability domains (Reynolds et al., 2013). Moreover, a focus on rarer variants via sequencing efforts may provide greater clarity on the impact of particular genes. Finally, a focus on multiple gene variants, gene sets or gene pathways rather than specific gene variants (e.g., SNPs) may prove more illuminating as to mechanisms that underlie variability in maintenance of cognitive abilities into older age. Additionally, such efforts may point to the relative involvement of particular pathways and importantly the exclusion of other pathways (Lips et al., 2012; Ruano et al., 2010). Emerging work on older adult samples is now appearing that considers multiple genes. For example, a genome-scanning approach evaluated regional association of DNA variants and cognitive aging outcomes in three Scottish birth cohorts, providing suggestive evidence that a region on chromosome 5 containing the *PRRC1* gene may be important to fluid ability performance in late adulthood (ages 65–79 years) (Rowe et al., 2013). However, this region was not statistically associated with the residual-based cognitive change outcome (cognitive performance in late life residualized for age 11 cognitive ability). Promisingly, altered *PRRC1* expression was observed in the temporal cortical region (based on gene methylation assessments) and suggests follow-up work is warranted. Gene set analyses, considering multiple genes presumed to be related to the cognitive outcome trait, have been conducted using these three Scottish samples plus two English samples from the CAGES consortium (Hill et al., 2014). Here, researchers considered over 1400 genes that regulate postsynaptic density via the receptor complexes NMDA/MAGUK (*N*-methyl-D-aspartate/membrane-associated guanylate kinase), AMPA (α-amino-3-hydroxy-5-methyl-4-isoxazolepropionic acid), and mGlu5 (metabotropic glutamate receptor 5). Results suggested genes regulating NMDA/MAGUK receptor complexes may be important to fluid ability performance. Replication was achieved in samples from Norway and Australia, with ages 18–79 and 15–30 years, respectively. Thus, specificity to late-life cognitive change is unclear. Extensive pathway-based searches have yet to be undertaken for cognitive change outcomes, especially cognitive trajectories. However, promising competitive pathway methods that compare a focal pathway against "control" pathways have been applied to IQ among adults with schizophrenia, where three synaptic gene pathways were identified, i.e., intracellular signal transduction, excitability, and cell adhesion and trans-synaptic signaling (Lips et al., 2012).

Physical Aging

Meta-analyses of *GWAS* focusing on BMI and related obesity traits have identified a number of genetic variants (Speliotes et al., 2010). In particular, the *Fat Mass and Obesity Associated* (*FTO*) gene candidate appears to show strengthening associations with BMI across childhood (Haworth et al., 2008) and into early adulthood but may lessen in impact into older adulthood (Graff et al., 2013). Additionally, the gene responsible for encoding brain-derived neurotrophic factor (*BDNF*) has been implicated in BMI (Speliotes et al., 2010). Analysis of an obesity genetic risk score incorporating information from a total of 32 single nucleotide polymorphisms identified in the meta-analysis (Speliotes et al., 2010) suggested prediction of adult BMI trajectories up to age 65 but not after (Dahl, Reynolds, Fall, Magnusson, & Pedersen, 2014).

A number of genes may regulate BP traits across a number of populations (e.g., *ATP2B1, CNNM2-NT5C2, FGF5, CASZ1, CSK-ULK3, MTHFR*) although others may be selective, e.g., in East Asian populations a *RPN6-PTPN11* gene variant has been implicated which is in proximity to the *ALDH2* gene involved in alcohol metabolism (Kato et al., 2011). Interestingly, a recent study revealed that the risk variant C677T in *MTHFR*, a gene which regulates plasma homocystine (folate) levels, may be associated with accelerating atrophy of white matter over time in those with mild cognitive impairment (MCI), replicating findings in two samples (Rajagopalan et al., 2012). Other studies find equivocal evidence for genetic variants in *MTHFR* and association with cognitive aging or impairment (Ford et al., 2012; Moorthy et al., 2012), even while serum levels of homocysteine or vitamins B-12 and B-6 may be correlated with impaired cognitive performance (Ford et al., 2012; Moorthy et al., 2012).

APOE is associated with serum lipid profiles (Bennet et al., 2007), where carriers of *APOE* ε4 have poorer lipid profiles than those with the most common haplotype *APOE* ε3/ε3, while carriers of the rarer *APOE* ε2 have more positive lipid profiles on the whole, except for triglycerides (Bennet et al., 2007). Indeed, over 95 genes achieved significance at the genome-wide level in a GWAS of cholesterol, remarkably explaining between 25% and 30% of the genetic variance for serum lipids traits (Teslovich et al., 2010). As discussed above *APOE* figures prominently in cognitive aging and risk of AD.

GWASs for heart rate measures have identified a number of gene candidates (Deo et al., 2013). Two genes are associated with resting heart rate across populations: (i) *GJA1* encoding connexin 43 (the primary protein constituent in the myocardial gap junction), and (ii) *MYH6* that codes for a heavy-chain subunit of cardiac muscle myosin (Deo et al., 2013). Neither of these genes has been specifically implicated in GWAS efforts for AD or cognitive aging. The complexity of findings for HRV, i.e., population-specific gene variants coupled with environmental factors that may partly drive associations of HRV with verbal memory performance at midlife (Shah et al., 2011), suggest a multifaceted set of genetic and environmental influences that need further characterization.

A meta-analysis of GWAS studies on lung functioning of over 48,000 individuals of European ancestry, reported a total of 16 associated gene loci (Soler Artigas et al., 2011). Of the 16 loci, some genes are in lipid/cholesterol (e.g., *LRP1*) and immune pathways (e.g., *TGFB2*), pathways implicated for AD; however, the 16 specific candidates have not been identified in the largest GWAS meta-analysis of AD to date (Lambert et al., 2013).

Gene Pathways Underlying Cognition-Physical Functioning Dynamics

The lipid pathway, particularly typified by genes such as *APOE* and *SORL1*, may be an important pathway underlying associations between cognition and physical functioning traits. A predictive relationship between serum lipids and lipoprotein values on cognitive change exists and changes in serum lipids have been observed in those with MCI versus healthy elderly (Reynolds, Gatz, Prince, Berg, & Pedersen, 2010; Tukiainen et al., 2012). Moreover, further explorations of the protein sorting pathway that *SORL1* also participates in, i.e., vacuolar protein sorting 10 (VPS10) domain-containing receptor protein family, suggests that additional genes in this family are associated with AD (Reitz et al., 2013) and deserves further attention in evaluations of normative cognitive aging.

We also highlight synaptic plasticity pathways, and the *BDNF* gene as an exemplar. Brain-derived neurotropic factor (bdnf) is expressed in the prefrontal cortex and hippocampal regions, and is implicated in synaptic plasticity processes that occur during memory formation and the persistence of memories (Kambeitz et al., 2012). Curiously, variants in the *BDNF* gene have not been identified in GWAS of cognitive aging nor of AD risk, although *BDNF* has been identified in GWASs of BMI (Speliotes et al., 2010). Hence, there are reasons to re-consider *BDNF* with respect to cognitive aging, especially as it may partly underlie links between physical and cognitive functioning (Gomez-Pinilla & Hillman, 2013; Hotting & Roder, 2013). According to meta-analytic work, the val^{66}met BDNF polymorphism may be important to hippocampal-dependent memory formation based on animal and human studies (Kambeitz et al., 2012). Specifically, the met allele is correlated with small decrements in declarative memory performance relative to val carriers (Kambeitz et al., 2012), perhaps due to decreased bdnf availability (Dincheva, Glatt, & Lee, 2012). Additionally, earlier meta-analysis work suggests significant heterogeneity in effect sizes for executive functioning traits (Mandelman & Grigorenko, 2012), which may deserve additional examinations. *BDNF* may predict late life cognitive change (Harris et al., 2006), perhaps in females specifically (Fukumoto et al., 2010; Komulainen et al., 2008; Laing et al., 2012). Most recently, additional *BDNF* variants have been associated with declines in cognitive functioning (i.e., 1-year change in ADAS-cog scores) as well as hippocampal and whole-brain atrophy across 2 years but not AD risk (Honea et al., 2013). Potential moderators of bdnf levels include exercise (higher: Erickson, Miller, Weinstein, Akl, & Banducci, 2012), gender (female lower: Lommatzsch et al., 2005), and age (older lower: Lommatzsch et al., 2005), among others.

GENETIC INFLUENCES ON ENVIRONMENTAL SENSITIVITY

Behavioral genetic methods allow us to investigate not just genes or environmental influences in isolation, but how they interact to impact cognitive and physical aging (Pedersen, et al., 2013; Reynolds, Finkel, & Zavala, 2014). Accumulating evidence suggests genetic (G), environmental (E), and G × E processes change over the life course in importance and make-up (Bell et al., 2012; Deary et al., 2012; McClearn, 2006; Reynolds, et al., 2005; Reynolds, Gatz, Berg, & Pedersen, 2007). Genetic effects may become increasingly stronger due to amplification of gene influences already in effect, while new gene influences may emerge to impact cognitive change at least until young-old age (Deary et al., 2012; Reynolds et al., 2005). In tandem, person-specific environmental factors may accelerate in importance—a potential signal of the presence of gene–environment interplay (Reynolds et al., 2005, 2007). Indeed, environmental contexts may have differential impacts on memory trajectories dependent on particular genotypes (Reynolds et al., 2007). For example, a within-pair analysis of monozygotic (MZ) pairs suggested that non-carriers of the *APOE* e4 risk allele and those homozygous for the major allele for estrogen receptor 1 alpha gene (*ESR1a*) variant rs1801132 showed greater disparities in semantic memory change versus those carrying respective risk alleles (i.e., *APOE* ε4, minor allele in rs1801132). Moreover, within-pair differences in memory trajectories correlated significantly with within-pair differences in depressive symptoms only among pairs who were *non-carriers* of these risk alleles. Hence, for those not already at high genetic risk for cognitive decline, environmental contexts stemming from experiencing lower or higher depressive symptoms may moderate memory trajectories. Indeed, dementia research suggests that perhaps due to already elevated risk, *APOE* ε4 carriers may be generally less responsive to environmental factors than non-ε4 individuals (Gatz, 2007). In contrast, other research suggests that those carrying *APOE*-ε4 may show greater responsiveness to particular dietary (e.g., altered triglycerides, C-reactive protein (CRP) levels) (Carvalho-Wells, Jackson, Lockyer, Lovegrove, & Minihane, 2012) or exercise/activity interventions (Erickson et al., 2012), as illustrated below, although additional work is needed.

Two models of genetic influences on environmental sensitivity have been increasingly contrasted in recent developmental psychopathology literature, i.e., the well-known diathesis-stress model versus the differential susceptibility model (Belsky, Pluess, & Widaman, 2013). The diathesis-stress model suggests that environmental influences may be more impactful for some individuals than others (Zuckerman, 1999). For example, those who carry the *APOE* ε4 allele may be negatively impacted to a greater degree by exposures to low economic resources (Sachs-Ericsson, Corsentino, Collins, Sawyer, & Blazer, 2010) or alcohol consumption (Downer, Zanjani, & Fardo, 2014) than non-carriers. The differential susceptibility model suggests a cross-over effect; i.e., those with a risk genotype may, in deleterious environments, be more negatively affected but otherwise thrive in positive environments compared to those without the risk genotype who hold relatively steady regardless of the environment (Belsky, 1997, 2005; Belsky et al., 2009). Examples that approach an expected cross-over are: (i) in the context of a low physical activity environment, those with the *APOE* ε4 allele may show lower engagement of neural networks activated in semantic memory processing, but in a high activity context those with the ε4 allele show comparable activation to those not at risk (Smith et al., 2011); (ii) likewise, particularly detrimental effects of low exercise to those with ε4 may also be conferred with respect to higher β-amyloid deposition, while engagement in exercise may alleviate this enhanced risk (Head et al., 2012). While in these recent empirical examples higher physical activity did not lead *APOE* ε4 individuals to surpass non-ε4 individuals in positive outcomes, the mitigation of risk via physical activity was notable. In the literature at large, however, the direction of effects as to exercise/physical activity, *APOE* genotype, and cognitive performance benefits is not clear, suggesting additional work is necessary (Erickson et al., 2012).

The differential susceptibility model can be seen conceptually as a variant of the concept of antagonist pleiotropy wherein benefits of particular genotypes (to reproductive success) may be seen in earlier development but pose detrimental effects in late life (see Fabian & Flatt, 2011, for review). For example, young adult carriers of *APOE* ε4 may show enhanced memory performance comparative to non-ε4 individuals but any benefits may dissipate and ultimately reverse in late life (Jochemsen, Muller, van der Graaf, & Geerlings, 2012; Mondadori et al., 2007; Moreau et al., 2013; but see Bunce et al., 2013). In addition to these models, a number of additional models of gene–environment interplay have been proposed that may likewise explain possible synergies among genetic and environmental influences on cognitive and physical aging (Reynolds et al., 2014). Such models are essential to place into context a variety of complex empirical findings that are emerging as well as to evaluate competing models when designing new studies. Importantly, it will be necessary to take a life course approach to shifting dynamics of genes and environments in evaluating pathways to optimal or less optimal pathways to maintaining or improving cognitive functioning into late life (Reynolds et al., 2014).

Biomarkers of GE Interplay

Directly measureable evidence of gene–environment interplay is essentially feasible due to recent advances in the measurement of biomarkers such as methylation and telomere lengths. In the context of life course studies of cognitive aging, the addition of epigenetic biomarker measurement may lead to the uncovering of pathways that promote accelerating cognitive declines, and equally important, to those pathways that promote maintenance or improvements in cognitive functioning into old age. Epigenetic modifications that alter gene expression occur due to a variety of mechanisms including direct methylation of DNA (Day & Sweatt, 2012; Rakyan, Down, Balding, & Beck, 2011). Characteristically, the process of DNA methylation takes place with the addition of a methyl group to the DNA base cytosine within cytosine-guanine dinucleotides (CpGs), leading to long-term alterations in gene expression. Of specific interest are CpG-rich regions that occur within or in the proximity of gene promoter regions such as CpG "islands" or "island shores" (Rakyan, Down, Balding, & Beck, 2011). Methylation has been measured in human brain, muscle, and leukocyte tissues (Fernandez et al., 2012). Moreover, methylation levels correlate with age, change in health traits, as well as dementia-associated neuropathology and neurological disorders (Bell et al., 2012; Boks et al., 2009; Fernandez et al., 2012). Recently, a methylation site in the vicinity of *PRRC1* (cg04431054) on chromosome 5 that altered expression in the temporal cortex predicted fluid ability scores (Wang et al., 2012).

DNA methylation occurs due to *nongenetic* (i.e., epigenetic) processes proposed to result from prenatal or early life exposures and at later points in the lifespan (Gottesman & Hanson, 2005). For example, it may be that low education and other life events lead to particular environmental exposures (Gatz et al., 2006) that elicit epigenetic modifications (Tehranifar et al., 2013). Although such links have yet to be empirically shown for cognitive aging, one may speculate that effects of epigenetic changes may accelerate or accumulate over time and lead to less optimal aging outcomes such as cognitive decline.

While DNA sequence variation and epigenetic processes are distinct by definition, evidence of significant twin concordance for methylation levels is apparent, suggesting genomic regulation of methylation (Coolen et al., 2011). In addition, heritability of DNA methylation may vary across particular genes (Bell et al., 2012; Boks et al., 2009). Moreover, whether epigenetic alterations facilitate or are outcomes of disease or aging, such as cognitive aging or dementia, is not understood (Chouliaras et al., 2010). To disentangle causal versus consequential sequences of events, longitudinal assessments of both cognitive performance and DNA methylation will be necessary. In addition, the extent to which methylation in non-brain matter (e.g., leukocytes) is relevant to cognitive aging is also a concern. Given that in vivo measurements in human brain matter are not yet possible, methods to identify the relevance of peripheral tissue methylation as markers of functionally relevant alterations in the CNS are important (Wang et al., 2012).

Telomere Length

Telomeres, i.e., DNA segments that cap the ends of chromosomes, have become of interest as a biomarker that may index aging and indeed environmentally mediated processes. Moreover, as discussed further below, recent work on telomeric influence on gene expression (telomere position effect, TPE) (Stadler et al., 2013) suggests the possible interplay between aging/environmental exposures and gene expression via telomere lengths. Telomeres shorten with each cell division and predict cell functioning and eventual senescence (Shawi & Autexier, 2008); for example, telomeric loss may be associated with increased risk of somatic mutation and damage during cellular division (Aubert & Lansdorp, 2008). Shorter telomere lengths are predicted by increasing age (Steenstrup et al., 2013), low education (Adler et al., 2013; Steptoe et al., 2011), psychosocial stress and adversity (Price, Kao, Burgers, Carpenter, & Tyrka, 2013), and illness (Fyhrquist & Saijonmaa, 2012; Kong, Lee, & Wang, 2013).

Telomere lengths are heritable based on studies of twins (Bakaysa et al., 2007; Broer et al., 2013), yet twin pair differences in telomere lengths predict pair differences in cognitive performance suggesting possible environmental mechanisms. Longer telomere lengths correlate with higher working and episodic memory performance (Valdes et al., 2008) while within-pair comparisons suggest that twins with shorter telomere lengths performed more poorly relative to their cotwins (Valdes et al., 2008). However, the full picture across studies suggests that the association between telomere lengths and cognitive decline and dementia risk remains unclear (Devore, Prescott, De Vivo, & Grodstein, 2011; Hochstrasser, Marksteiner, & Humpel, 2012; Ma et al., 2013; Moverare-Skrtic et al., 2012; Zekry et al., 2010). Longitudinal studies are lacking yet they are needed to clarify temporal causality (Mather, Jorm, Parslow, & Christensen, 2010). Moreover, variations across tissue types sampled must be considered (e.g., buccal cells, leukocytes, brain tissues) (Thomas, O'Callaghan, & Fenech, 2008) as well as moderation by genotypes such as *APOE* (Wikgren et al., 2010).

Telomeres may influence gene expression even for those genes that sit relatively far from the telomeric region (100 kilobases), and hence pose implications for models of gene–environment interplay and aging. According to a study of the age-dependent disorder human facioscapulohumeral muscular dystrophy (FSHD) (Stadler et al., 2013), telomere shortening may lead to increased *DUX4* gene expression and hence to increased FSHD risk (Stadler et al., 2013). Although much work remains to be conducted, it may be speculated from this work that telomere shortening occurring as a consequence of age or due to environmental exposures may alter gene expression that could impact cognitive trajectories into late life.

SUMMARY AND FUTURE DIRECTIONS

Quantitative behavioral genetic studies suggest substantial genetic influences on cognitive performance across domains, albeit higher for processing speed and lower for memory traits. Meanwhile substantial genetic variation contributes to change in spatial and perceptual speed processes, but is less important or variable for change in traits in the verbal and memory domains. Across domains, person-specific environments tend to increase with age in their importance to cognitive aging. Together these patterns signal changing and perhaps dynamic gene–environment influences. Similar conclusions can be drawn for aging of physical traits. The extent of genetic and environmental influences on aging varies by physical trait, with evidence for increasing unique environmental influences but also for the possible onset of new gene expression in late adulthood. Sex differences in genetic and environmental variance for physical aging reflect gender differences in life experiences and exposures. These complicated physical aging trajectories provide a rich tapestry of potential influences on cognitive aging. Molecular studies, particularly those using GWAS methods, highlight the complexity of the search for specific genes for cognitive aging, although key variants identified for cognitive aging, particularly *APOE* or *SORL1* as well as *BDNF* (among other BMI-related genes) suggest interrelationships among etiologies contributing to cognitive and physical aging, or pleiotropic effects.

Additional lifespan research is necessary to evaluate the changing dynamics of genetic and environmental influences on cognitive aging, including shared and unique dynamics with physical aging traits. As described above, lipid and synaptic plasticity pathways are promising to consider, among others. Multiple studies indicate that both *APOE* and *SORL1* are associated with pathological and non-pathological cognitive aging and decline. Additional behavioral work is necessary to evaluate a role for *APOE* and *SORL1*, indeed the lipid pathway at large, on aspects of cognitive growth and decline patterns.

Indeed, complex sex- plus age-dependent effects may be evident over the entire life course. For example, recent work in the lipid pathway suggests that men's and women's cognitive trajectories may be differentially influenced by serum cholesterol and lipoprotein traits in periods of late adulthood (Reynolds et al., 2010) and likewise *SORL1* may have sex-dependent effects on cognitive trajectory features (Reynolds et al., 2013). Moreover, men may be more likely to be diagnosed with MCI (Petersen et al., 2010; Roberts et al., 2012) and women with AD, including a greater risk conferred by carrying the *APOE* e4 allele (Genin et al., 2011). However, little evidence has emerged from quantitative behavioral genetic studies of qualitatively different heritable or environmental impacts on cognitive change (Finkel, Reynolds, Berg, & Pedersen, 2006). Work on motor functioning, however, suggests that important gender differences in life experiences for the cohorts in question can result in significant sex differences in genetic and environmental contributions to the aging process (Finkel, Ernsth-Bravell et al., 2014). Finally, further consideration of historical and emerging contexts is needed. For example, the extent to which cohort advances in education and other pervasive (positive and negative) environmental contexts might impact fundamental etiological processes underlying cognitive change is unclear. Hence, a greater understanding of complex life course or competing pathways to cognitive health in late life is warranted.

In sum, both quantitative genetic and molecular genetic approaches will remain necessary to achieve a fuller understanding of cognitive aging. Echoing an earlier *Handbook* chapter (Kremen & Lyons, 2011), we expect that future longitudinal behavioral genetic work, including examinations of biomarkers of gene–environment interplay across the life course, may provide a clearer picture of the contributions and dynamics of specific environmental and genetic factors that contribute to the diversity of cognitive aging outcomes. Fundamentally, cognitive aging *is* physical aging; therefore, future research will need to continue to incorporate the physical context of cognitive changes.

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CHAPTER

8

Memory: Behavior and Neural Basis

Cindy Lustig and Ziyong Lin

University of Michigan, Ann Arbor, MI, USA

OUTLINE

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WHAT IS MEMORY, AND WHAT IS AGING?

A Martian attempting to understand the human condition might be rather baffled to discover that we use the same term—"memory"—to describe the processes that allow us to ride a bicycle, know that the sound "bahy-si-kuhl" refers to that contraption, recount the story of our last ride, and successfully meet our friends at the correct time and place for the next journey. Likewise, as discussed in Chapters 1–3, "aging" is a complex, multidimensional term that varies in both its theoretical scope and in how it is operationally defined across studies (e.g., healthy vs. normal vs. preclinical; cross-sectional vs. longitudinal; chronological age as time from birth vs. time to death).

Despite these complexities, a review of some of the major meta-analyses of different aspects of memory and aging (Bopp & Verhaeghen, 2005; Fleischman & Gabrieli, 1998; Henry, MacLeod, Phillips, & Crawford, 2004; Old & Naveh-Benjamin, 2008; Spencer & Raz, 1995;

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Uttl, 2011; Verhaeghen, Steitz, Sliwinski, & Cerella, 2003) reveals several consistent themes. From a task perspective, major factors influencing the presence and size of negative age differences include demands on controlled versus automatic processing, demands for associative versus item processing, and the opportunity for use of environmental support or compensation. Age-related declines are not uniform in size, nor are they universal—especially in the domains of prospective memory and emotional memory there is an increasing emphasis on findings indicating preserved or even better performance by older adults. As research increases on genetic and lifestyle influences on aging, as well as on interventions to preserve and improve the performance of older adults, there is a corresponding emphasis on understanding the component processes and biological mechanisms that underlie memory performance and individual differences in their efficiency and use.

Below we start with a brief discussion of the major findings on age-related memory preservation and decline and how they may be related to different brain structures. This discussion starts from the traditional systems' view of different types of memory that has guided much of this research. Such views provide an easy introductory framework, but upon closer examination quickly prove inadequate for describing the complexity of findings. In recent years, the field has increasingly moved to a consideration of how different processes that may be implicated in a variety of memory tasks are affected by age as well as situation factors.

BRAIN AGING AND MEMORY: A COMPLEX AND DYNAMIC RELATIONSHIP

At a broad level, patterns of structural brain change follow a "front to back" or "last in, first out" pattern (Raz, 2000). That is, the prefrontal areas that are among the last to reach full maturity are also those that show the earliest age-related decline, whereas posterior sensory regions that reach mature states within the first few years of life show relatively little decline in healthy aging. Studies of the hippocampus and medial temporal regions most strongly associated with episodic memory have yielded mixed results, with the head and body more likely to show age differences than the tail (Gordon, Blazey, Benzinger, & Head, 2013).

These patterns fit well with a broad view of age differences in memory. Working memory tasks that require the executive functions supported by prefrontal cortex show large age-related declines, whereas declines in sensory memory and passive short-term storage, which rely primarily on the activation and maintenance of representations in posterior cortex, are relatively small. In episodic memory, simple item recognition shows only minor declines, with the size of age-related declines increasing with demands for prefrontal control processes (e.g., free recall) and association processes that depend on the hippocampus and other medial temporal lobe structures. In contrast, semantic memory is preserved and may even increase until the final decades of life, consistent with the relatively preserved volume of the anterior temporal lobes (Taki et al., 2011).

However, the picture quickly becomes more complicated when looking at a finer grain of detail. For example, although the word retrieval might be considered an index of semantic memory, tip-of-the-tongue errors are a common complaint for older adults, and appear to be linked to age-related declines both in regions involved in phonological processing—which may increase the likelihood of such errors—and prefrontal regions involved in the selection and inhibition processes needed to resolve them (Galdo-Alvarez, Lindin, & Diaz, 2009; Shafto, Burke, Stamatakis, Tam, & Tyler, 2007). There is also substantial regional heterogeneity in the patterns of age-related volume differences and change. For example, Raz, Ghisletta, Rodrigue, Kennedy, and Lindenberger (2010) found that lateral prefrontal cortex showed substantial cross-sectional age differences but little longitudinal change, whereas orbitofrontal cortex had the opposite pattern. Of course, gray matter volume changes are only one aspect of brain aging; changes in white matter volume, integrity, and connectivity and in neurotransmitter function also play important roles (see Chapter 6 on plasticity).

Rather than a simple mapping of types of memory task (e.g., working memory, episodic memory, semantic memory) to specific brain systems, a neurocognitive approach to age effects on memory considers that any memory task requires multiple processing components (Cabeza & Moscovitch, 2013) and that young and older adults often differ not only in the efficiency of specific components but also the degree to which they rely on them. Not surprisingly, these differences are reflected in measures of brain function, and one of neuroimaging's most compelling contributions to research on aging is the rejection of a simple "lesion" model in which older adults' brains are characterized by reduced activity, especially in prefrontal regions associated with cognitive control.

Instead, especially in memory tasks (working memory tasks with exceptionally high executive demands may be an exception), older adults often show more activation, especially of prefrontal regions, and this is often associated with better performance within the older adult group (Cabeza et al., 2002; Reuter-Lorenz, Stnczak & Miller 1999; Rosen et al., 2002; see Eyler, Sherzai, Kaup, & Jeste, 2011, for a review)—though some longitudinal studies suggest that this pattern may be driven by a subset of participants (Nyberg et al., 2010) or even reflect impending decline (Persson et al., 2006). There are a number of frameworks describing age-related differences in activation and their links to behavior, some emphasizing specific spatial or temporal patterns (e.g., HAROLD (Hemispheric Asymmetry Reduction in the Old), Cabeza, 2002; PASA (Posterior to Anterior Shift in Aging), Davis, Dennis, Daselaar, Fleck, & Cabeza, 2008; ELSA (Early to Late Shift in Aging), Dew, Buchler, Dobbins, & Cabeza, 2012), and others the interactions between external task demands and internal processing and activations (e.g., CRUNCH (Compensated Related Utilization of Neural Circuits Hypothesis), Reuter-Lorenz & Cappell, 2008; STAC (Scaffolding Theory of Aging and Cognition), Park & Reuter-Lorenz, 2009; GOLDEN (Growing of Lifelong Differences Explains Normal aging), Fabiani, 2012).

CONTROL AND ASSOCIATION: MAJOR INFLUENCES ON AGE DIFFERENCES IN MEMORY

Despite these complexities, it is possible to derive consistencies in the interactions between memory and aging—especially when one takes the perspective of examining components that may play into multiple memory systems, as described above. Here we summarize some of the major themes driving research on memory and aging. In some cases age differences in neural structure and function have a fairly straightforward relationship to differences in memory performance, but in others they suggest that age differences in memory processing may be quite a bit more complex than suggested by typical central-tendency measures of accuracy or response time.

The Controlled Processing Paradox: Important and Impaired

At a heuristic level, older adults often perform as well as young adults on memory tasks that rely largely on automatic processing, and the young-adult advantage increases with demands on controlled processing (Jennings

& Jacoby, 1993; Spencer & Raz, 1995). In addition to having reduced cognitive control, older adults are often more reliant on top-down control at earlier stages of processing and lower levels of task difficulty, possibly in partial compensation for sensorimotor deficits (Carp, Park, Hebrank, Park, & Polk, 2011; Fabiani & Gratton, 2005; Fabiani, Low, Wee, Sable, & Gratton, 2006; Gazzaley et al., 2008).

Repetition priming (facilitated or biased processing as a result of prior exposure) is a prototypical example of automatic processing: It occurs even if the participant is not consciously aware of the connection between the prior exposure and current task. As expected, it is largely preserved in aging, but even here there is some variance in control demands and age differences: simple identification and decision priming tasks (e.g., faster perceptual or semantic decisions for repeated than novel stimuli) rarely show declines in healthy adults, and it has been suggested that when impairments are found, they indicate subclinical or impending dementia (Fleischman, 2007). In contrast, age differences are more frequently found on tasks that require more controlled processes such as production or selection among competing alternatives (e.g., category exemplar production or word stem completion where the stems have multiple potential completions in addition to the target). As is also the case on explicit memory tasks, older adults are more impaired by interference from such competing alternatives (Ikier, Yang, & Hasher, 2008; Lustig & Hasher, 2001).

As in behavioral studies, age differences in priming-related neural activity reductions are influenced by control demands. Furthermore, stimulus repetition can have independent effects on different brain regions and networks (Wig, Buckner, & Schacter, 2009), not all of which contribute to behavioral priming effects. For example, Lustig and Buckner (2004) reported that older adults had similar repetition-related reductions in left inferior frontal cortex during a semantic decision task, and that these activity reductions correlated with response-time reductions, indicating functional significance. This basic finding replicates across studies that use similar tasks (Ballesteros, Bischof, Goh, & Park, 2013; Bergerbest et al., 2009; Gold, Andersen, Jicha, & Smith, 2009; Soldan, Gazes, Hilton, & Stern, 2008), although some of these have found age differences in other areas, especially right prefrontal and inferior temporal regions that may have reflected engagement and repetition-related change in compensatory processing. Such compensatory processing may be especially prevalent in studies that used relatively simple (e.g., MMSE score cutoffs) rather than extensive screens for subclinical dementia (see discussion by Fleischman, 2007). As noted earlier, tasks such as word stem completion that require selection among competing alternatives are more likely to show behavioral differences, and they likewise are associated with age differences in the neural correlates of priming (Bäckman et al., 1997; Daselaar, Veltman, Rombouts, Raaijmakers, & Jonker, 2005).

Other aspects of nondeclarative memory (e.g., procedural memory, probabilistic learning) follow the same pattern. Older adults show generally preserved benefits from experience, but age differences in behavioral and neural effects grow with demands on controlled processing or the possibility for competing alternatives, and similar behavioral patterns for young and old adults can mask substantial differences in neural activity and brain volume (Fera et al., 2005; Howard & Howard, 1992; Kennedy, Rodrigue, Head, Gunning-Dixon, & Raz, 2009). Put in more neural terms, the likelihood of age-related deficits increases the more that experience-related change *depends on* regions (e.g., prefrontal cortex, striatum, medial temporal lobe) associated with controlled processing and age-related decline rather than *reducing demand on* those regions (see Howard & Howard, 2013, for discussion relevant to procedural learning).

Controlled and automatic processing also show different patterns in episodic memory, where distinctions are made between *familiarity*—the subjective feeling that the item or event has been previously experienced, and *recollection*—the retrieval of details associated with that previous experience. Familiarity is usually considered to rely on automatic processes, whereas recollection is most often characterized by controlled, effortful retrieval (see reviews by Wixted, 2007; Yonelinas, 2002). One caveat to this distinction is that recollection also has a less-discussed automatic form ("noncriterial recollection," or details that come to mind spontaneously; Yonelinas & Jacoby, 1996). At the behavioral level, older adults show relatively intact familiarity and rely on it more than (effortful) recollection, which is also more likely to be impaired in older adults (Jennings & Jacoby, 1993). The neuroimaging findings are broadly consistent with this view, as older adults show increased activity in rhinal cortex regions associated with familiarity and reduced activity in hippocampal regions associated with recollection (Daselaar, Fleck, Dobbins, Madden, & Cabeza, 2006).

However, age differences in familiarity-related activity and functional connectivity of other brain regions, especially prefrontal and parietal regions associated with cognitive control suggest that for older adults the familiarity signal may be less specific, increasing vulnerability to false memories (Dennis, Bowman, & Peterson, 2014; Duarte, Graham, & Henson, 2010). Some ERP evidence also suggests that preserved behavioral familiarity in older adults relies on different neural signals than for young adults (Wang, de Chastelaine, Minton, & Rugg, 2012; see review by Friedman, 2013). Consistent with the idea that controlled processing may be more demanding for older adults, when young and old adults are matched for recollection performance, older adults show more extensive activation than do young adults, especially in prefrontal and parietal regions, perhaps in compensation for reduced modulation of other regions (Angel et al., 2013; Morcom, Li, & Rugg, 2007). Interpretation is further complicated by the different methods used to assess familiarity and recollection across studies (e.g., remember-know vs. requiring detail identification vs. the process dissociation procedure) that may rely on different brain networks and be differently affected by aging and cognitive status (Duarte, Henson, & Graham, 2008).

Before it can be retrieved, information must first be encoded and stored. Storage or consolidation processes are difficult to study directly. However, changes in several neurobiological systems, including changes in cholinergic systems linked to reduced sleep quality in older age, appear to reduce the efficiency and duration of consolidation (see Gold & Korol, 2014, for a recent review). More relevant to our discussion of controlled versus automatic processing, older adults' reduced engagement of controlled processing at encoding is central to several major theories of age-related reductions in episodic memory. This reduction in controlled processing at encoding can result in less distinct, elaborated representations of the to-be-remembered item (Craik & Byrd, 1982; Craik & Rose, 2012) and in the "accidental" encoding of putatively irrelevant items, which compete with the target and interfere with its retrieval (Hasher & Zacks, 1988; Lustig, Hasher, & Zacks, 2007).

The neuroimaging evidence also suggests that older adults are less likely to self-initiate the encoding processes that support later episodic memory, perhaps due to structural and functional declines, especially in prefrontal cortex, but can bring them into play with instruction or training. In one of the first neuroimaging studies of cognitive aging, Grady et al. (1995) found that under intentional learning instructions (i.e., participants are told to learn items in preparation for a later memory test), older adults did not show activation in a number of regions associated with successful encoding in young adults, especially left inferior prefrontal cortex. This pattern was replicated in a number of subsequent studies and fit well with a "frontal lesion" model of aging. However, later studies showed that when participants were given a task (e.g., non/living or abstract/concrete judgments) that required semantic processing at encoding, older adults engaged these regions to nearly the same degree as young adults—and also showed activation in additional regions, especially right prefrontal cortex (Logan, Sanders, Snyder, Morris, & Buckner, 2002; Morcom, Good, Frackowiak, & Rugg, 2003).

Although there are some exceptions, such additional activation is often associated with better performance in older adults (see review by Eyler et al., 2011), raising the question of what it is compensating for. There are a number of possibilities that are not mutually exclusive. The most obvious, especially when older adults show bilateral prefrontal recruitment where young adults are lateralized, is that age-related structural and functional declines have reduced the efficiency or power of the cognitive control regions recruited by young adults. In such cases, the homologous region of the other hemisphere may be recruited to "help out." In addition, cognitive control regions may be recruited to help compensate for declines in more memory-specialized networks; for example, Salami et al. (2012) found that increasing age was negatively associated with activation of a memory-specific network including hippocampus and positively associated with activation of a more general frontoparietal cognitive control network. A third related possibility is both control and memory-specific processes are operating on degraded representations—for example, reduced sensory function in aging may make the features of an item less distinctive—creating greater demands on cognitive control downstream. In addition to sensory declines, older adults also have less specialized neural representations in regions associated with higher-level visual (and likely other sensory) processing (Carp et al., 2011; Park et al., 2012). To summarize, additional recruitment in older brains may reflect compensation both for reduced function in the regions young adults engage for cognitive control and increased demands on such control due to dysfunction in other systems.

Associational Memory May Be Especially Impaired in Aging

The associative deficit hypothesis (Naveh-Benjamin, 2000) posits that demands for associative processing are another major factor in age differences in memory (see also earlier work by Chalfonte & Johnson, 1996). The strong version of this hypothesis predicts that older adults will have difficulty not only connecting items to either items (e.g., paired associate memory) or to the context (e.g., source memory) and but also with binding together the features of an item (e.g., font, color, modality, and size). However, a meta-analysis by Old and Naveh-Benjamin (2008) comparing the size of age differences for item versus associational memory found greater age deficits for associational memory only for item associations with other items or with context (Spencer & Raz, 1995) and not for intra-item features.

As Old and Naveh-Benjamin (2008) noted when discussing the results of their meta-analysis, from a neurobiological perspective there may be (at least) two major components to older adults' associative memory deficits (see Sander, Lindenberger, & Werkle-Bergner, 2012 for a more detailed discussion). One is the frontally mediated cognitive control component that also applies to item memory as described above. This component may explain why the size of the associative memory deficit is influenced by factors such as the number of items to be associated (i.e., interference or fan effects), encoding instructions, test format, and metamemory (see also Bender & Raz, 2012). It may also explain why Campbell, Trelle, and Hasher (2014) found evidence for what they termed "hyper-binding". After studying a series of paired associates, older adults were more likely than young adults to incorrect identify as "old" unstudied pairs that re-arranged items temporally close together on the study list. In this case, it may not have been the associative process itself that was dysfunctional in older adults, but instead the cognitive control processes influencing which items were still active in attention and working memory and thus candidates for binding. The binding/association process itself is likely more strongly influenced by a medial temporal lobe/hippocampal component that is relatively automatic. This component also likely undergoes some degradation with age, though not to the same degree as the frontal component (Raz et al., 2010). Age-related declines in medial temporal structures also seem to show larger individual differences (Raz et al., 2010), which may be related to pathological but preclinical conditions such as iron concentration (Rodrigue, Daugherty, Haacke, & Raz, 2013) or amyloid (Doré et al., 2013).

Default Network Dysregulation

In addition to the age differences in task-related activation described above, research over the past decade has established that older adults also have reduced deactivation of the "default network"—a relatively consistent set of regions thought to support processes preferentially involved in task-unrelated, unconstrained thought. In contrast to the varied findings of age-related reductions versus increases in activation found in task-positive regions, age differences in default network deactivation are almost always in the direction of reduced deactivation by older adults. This pattern was first described in the context of a semantic judgment task used to encourage deep incidental encoding (Lustig et al., 2003), and has since been demonstrated across a wide array of both memory and non-memory tasks (see reviews by Grady, 2012; Hafkemeijer, van der Grond, & Rombouts, 2012).

Although its activity is modulated when engaging in a wide variety of tasks (Shulman et al., 1997), the default network plays a special role in memory–cognitive control interactions. The posterior cingulate/retrosplenial cortex is a primary hub of the network, and is also heavily interconnected with medial temporal and frontal regions (see Buckner, Andrews-Hanna, & Schacter, 2008, for an extensive review of research on the default network). Studies in nonhuman primates (Pandya, Van Hoesen, & Mesulam, 1981) also indicate connections with lateral prefrontal cortex though this has not been as clearly established in humans. These connections put it in a privileged position with regards to memory and cognitive control, and are disrupted in older adults (Andrews-Hanna et al., 2007). Furthermore, posterior cingulate/retrosplenial cortex shows a unique activation pattern in memory processing known as the "encoding-retrieval flip": decreases in activity during successful encoding, increases in activity during episodic retrieval. Both sides of the flip are smaller in older adults, but age deficits in the encoding–deactivation component appear especially large (Vannini et al., 2013) and linked to reduced subsequent memory in older adults (de Chastelaine, Wang, & Rugg, in press; de Chastelaine & Rugg, 2014; Miller et al., 2008).

Serious investigation of the default network is a relatively recent phenomenon (sparked by Gusnard & Raichle, 2001), and there are still many questions about its function and alteration with age. However, it appears to make at least two major contributions to age differences in memory. First, failures to deactivate during encoding are linked to failures to encode regardless of age (Daselaar, Prince, & Cabeza, 2004); as mentioned earlier these failures are more common in older adults. These age differences increase with demands for control (Persson, Lustig, Nelson, & Reuter-Lorenz, 2007) and are often interpreted to reflect a failure to disengage from task-unrelated thought.

Thus, failures to deactivate the default network may be related to older adults' increased distractibility. In a particularly interesting study supporting this idea, Stevens et al. (2008) found that during unsuccessful encoding older adults showed increased connectivity between default network regions and auditory cortex, suggesting that they were distracted by irrelevant thoughts about the scanner noise. Second, the ongoing activity of the default network may serve an important role in consolidation and integrating new learning into existing knowledge structures (Albert, Robertson, & Miall, 2009; Lewis, Baldassarre, Committeri, Romani, & Corbetta, 2009). Disruptions of this network in older adults may therefore contribute to reductions in associational memory and delay-related memory impairments in older adults. Disruptions in default network activity are especially pronounced in older adults with amyloid deposition and/or genetic risk for Alzheimer's disease, another strong indicator of its role in age-related memory declines.

MODIFYING FACTORS: QUALITATIVE AND QUANTITATIVE EFFECTS

A number of variables can affect the size and direction of age differences in memory. As described above, these include task demands for controlled or associative processing, and individual differences influenced by lifestyle and genetics (see Raz & Lustig, 2014, for recent work on the latter front). More subjective factors including emotion and strategy use also have important effects. Findings that older adults' performance can be influenced by the degree to which task instructions invoke negative stereotypes about memory and aging (Hess, Auman, Colcombe, & Rahhal, 2003; Rahhal, Hasher, & Colcombe, 2001) initially led to the hypothesis that participants from Eastern (and American Deaf) cultures, thought to have more positive stereotypes about aging, might show fewer age-related declines in memory (Levy & Langer, 1994). However, later studies failed to find strong support for this idea. Instead, culture may have greater effects on qualitative aspects of memory. That is, rather than affecting how much people remember, cultural influences may be more evident in what they pay attention to (e.g., the aspects of an item that differentiate it from or associate it with other members of a category) and thus later remember. There is still some debate as to whether the size of these cultural differences is larger or smaller in older adults as compared to younger ones: on the one hand, older adults have spent longer internalizing their own culture and thus may be more strongly influenced by it; on the other hand, age-related declines in neuroplasticity and distinctiveness may become a more overwhelming contributor to individual differences in brain structure and function (see reviews by Gutchess & Huff, in press; Park, 2002; Park & Gutchess, 2006).

Age differences in emotion–memory interactions are robust and represent an interesting exception to age-related reductions in cognitive control (see Mather, 2012, for an extensive review). Compared to young adults, older adults show a bias towards remembering positive information. This appears to be a controlled, strategic process aimed at maintaining positive mood and emotional balance in the face of limited (life) time (Carstensen, 1993, 2006). For example, the effect is eliminated or even reversed under divided attention (Knight et al., 2007), and older adults show reduced subcortical but increased cortical responses to emotional stimuli, suggesting top-down regulation of the emotional response (see review by Samanez-Larkin & Carstensen, 2011). In addition, some of the prefrontal regions associated with emotional control show less structural decline in aging than do those associated with other forms of cognitive control (Fjell et al., 2009; Salat, Kaye, & Janowsky, 2001). Mather

(2012) suggests that older adults may engage emotional regulation more consistently than young adults in everyday life as well as in the lab, which could lead to a positive feedback loop of "use it and don't lose it" between structure and function and explain the generally lower rates of depression in older adults. However, if those structures are damaged, for example by cardiovascular disease, the resulting impairment may make depression particularly severe and resistant to treatment.

Emotion effects on memory represent a special case of older adults increasing their exercise of control and, like cultural effects, may have a greater impact on what is remembered rather than how much. In contrast, increasing environmental support affects the size of age differences in memory. As described previously in the section on controlled processing and encoding, changing the task or environment to reduce demands on self-initiated processing—for example, asking participants to engage in a semantic decision task that encourages deep processing rather than simply telling them to memorize items—often differentially improves the performance of older adults. However, care must be taken that the guided, supposedly supportive task does not itself place high demands on cognitive control, or the effects may be reversed and exacerbate age-related performance deficits (Luo et al., 2007). In some cases, environmental support at either encoding or retrieval can result in older adults' brain activity, as well as behavior, more closely resembling that of young adults (Angel et al., 2010; Logan et al., 2002).

Older adults' use of environmental support and other compensatory strategies in everyday life may help explain why, despite the apparently large age-related declines in memory and other cognitive functions on laboratory tasks, older adults often perform as well or even better than young adults in real-world situations (Ng & Feldman, 2008; Verhaeghen, Martin, & Sedek, 2012). This is demonstrated dramatically in the domain of prospective memory: In naturalistic settings, where older adults can make use of environmental supports such as notes and calendars, they reliably outperform young adults. In the lab, where subjects are typically denied such supports, young adults have the advantage (see meta-analysis by Henry et al., 2004). Likewise, when examining the everyday memory errors most commonly reported by older adults (Ossher, Flegal, & Lustig, 2012), the most frequent errors were those least amenable to environmental support, such as tip-of-the-tongue errors or forgetting the name of a new acquaintance. In contrast, errors were very rare in situations where routine, reminders, or maps could provide supportive guidance or cues.

Putting aside the task and the environment, one of the most important factors in determining memory performance is the individual. Nyberg, Lövdén, Riklund, Lindenberger, and Bäckman (2012) describe large longitudinal studies in which some older adults show little or no evidence of memory decline. They suggest a distinction between brain or cognitive *reserve*, which allows an individual to maintain good performance despite age-related pathology (Stern, 2002), and brain *maintenance* factors that protect from such pathology. Genetics and lifestyle impact both, but through different pathways. Reserve factors may provide a larger bank of neural or cognitive resources that can be drawn down by pathology before reaching clinical levels, or methods of compensation for pathological decline. Brain maintenance factors, in contrast, prevent that pathology from occurring in the first place.

INTERVENTIONS: HOPE FOR IMPROVEMENT?

In addition to reserve or maintenance, intervention programs often aim for a third possibility: brain and/or cognitive *enhancement*. Although there is an increasing interest in combined, multimodal interventions, most studies can be roughly divided into those that target brain function directly through exercise, nutrition, or pharmaceuticals, and those that use behaviorally based training, targeting one or more cognitive domains. Cardiovascular training has attracted the most attention, with modest but reliable effects on memory, perhaps in part through its larger effects on executive function and cognitive control (see Smith et al., 2010, for a recent meta-analysis); it also improves hippocampal size as well as frontal function (Erickson et al., 2011; Weinstein et al., 2012). The effectiveness of behaviorally based interventions has been questioned, but recent meta-analyses indicate small but significant effects on a number of cognitive functions including memory (Au et al., 2014; Gross et al., 2012; Kelly et al., 2014). On the other hand, most researchers still advise strong caution when considering the often-exaggerated claims of commercially based programs (e.g., Stanford Center on Longevity, 2014), especially when it comes to the transfer of training benefits to other tasks.

Two developments may help improve the reliability of training and transfer. One is a shift away from training specific strategies and towards training processes, with the idea that the likelihood of benefits transferring from the training task to other tasks increases with the overlap in processing demands. Many early studies of memory training started from the premise of older adults' failure to self-initiate the deep, elaborate encoding processes thought to support later memory, and were designed to teach these strategies. For example, as part of what is to date the largest clinical trial of different behavioral training methods, the ACTIVE study gave older adults instruction and practice on memory strategies including categorization, visualization, and mnemonics (e.g., method of loci). This resulted in moderate benefits to memory performance that lasted for 5 (though not 10) years (Rebok et al., 2013, 2014). These benefits were for the most part restricted to certain closely related laboratory memory assessments, and did not show significant effects on everyday function (Willis et al., 2006). Similar findings of improvements on the training task and closely related tasks but very limited transfer have been found in most studies of strategy-based training (see Lustig, Shah, Seidler, & Reuter-Lorenz, 2009, for review).

The desire for broader transfer has led to an increased emphasis on training processes or abilities (see reviews by Lustig et al., 2009; Klingberg, 2010). A number of investigators focus on the executive functions of working memory, as these are thought to underlie performance on a wide range of tasks both in and out of the laboratory (Dahlin, Neely, Larsson, Bäckman, & Nyberg, 2008; Stepankova et al., 2014; see Morrison & Chein, 2011, for review). Dahlin et al. leveraged neuroimaging data to provide strong evidence for the notion that transfer depends on processing overlap. For young adults training on a letter-updating task that activated striatum transferred to another working memory task (n-back) that also activated striatum, but not to another task (Stroop) that also had high executive demands but of a different sort (conflict processing/inhibition rather than updating) and did not activate striatum. Further, older adults did not activate striatum for the updating task prior to training and did not show transfer, suggesting that this overlap was a critical contributor to the transfer effects seen in young adults. This use of neuroimaging to identify shared neurocognitive processing components between training tasks and potential transfer tasks holds powerful promise for demonstrations of transfer within the lab, though it faces obvious practical difficulties for transfer to real-world memory situations that typically are not amenable to neuroimaging.

With regards to training episodic memory, Ranganath, Flegal, and Kelly (2011) noted that the memory processes mediated by the medial temporal lobe (e.g., association and binding) are thought to be largely nondeliberate and ongoing, and thus unlikely to be further improved by training. Instead, most episodic memory training programs focus on improving its inputs at encoding or the downstream processing of its outputs at retrieval. At encoding, these interventions may take either a bottom-up approach of trying to improve perceptual processing and thus the distinctiveness of to-be-encoded representations (Mahncke et al., 2006), or top-down approaches that try to train older adults to engage more attention and control (presumably supporting deeper, more elaborative processing) at encoding (Bissig & Lustig, 2007; Lustig & Flegal, 2008; see also Paxton, Barch, Storandt, & Braver, 2006, for a non-memory example). At retrieval, training may focus on recollection processes that help distinguish between cue-appropriate responses and other items that are familiar but incorrect (Jennings & Jacoby, 2003; Jennings, Webster, Kleykamp, & Dagenbach, 2005). Both of these methods have shown transfer to other laboratory episodic memory tasks, and encoding training has been linked to reductions in self-reported everyday memory (Lustig & Flegal, 2008), but further testing of real-world outcomes is needed to establish their value long term.

The other development that may improve training outcomes is increased attention to individual differences. In cardiovascular training, several studies now suggest that the benefits are especially large for those at genetic risk for dementia (Ferencz et al., 2014; Head, Bugg & Goate, 2012; see Raichlen & Alexander, 2014, for a review). In cognitive training studies, findings have been mixed as to whether greater benefits accrue to those who started with high or low baseline function. This variance is most likely caused by interactions between the individual's ability and the difficulty and range of both the training and outcome tasks. Greater benefits may accrue to high-ability participants if low-ability participants have difficulty with the training task itself. On the other hand, if they are able to master the training task, those with lower baseline ability have the most room for improvement. Adaptive programs that allow the participant to begin at a high level of performance and gradually increase demand on the to-be-trained processes as performance improves may help foster benefits in both groups.

One intriguing possibility is that increased attention to individual differences may be combined with initially structured adaptive training to help improve training and transfer. Kirchhoff, Anderson, Barch, and Jacoby (2011) and Kirchhoff, Anderson, Smith, Barch, and Jacoby (2012) found that at baseline, many older adults reported not using any strategy at all during an intentional encoding task. However, after a series of training sessions that exposed them to a number of encoding strategies (e.g., pleasantness ratings, self-relevance, sentence generation) they increased strategy use on an intentional encoding task administered approximately 2 weeks later, even without specific instructions to do so. They also increased prefrontal brain activity during the encoding task, recollection-related hippocampal activity during the retrieval task, and their recollection performance after intentional encoding improved to the level of young adults. Importantly, after initial exposure to the different encoding strategies, participants were allowed to choose which they chose to practice, which may have enhanced both their ability to master the strategy and the likelihood that they would use it in other circumstances. Consistent with this interpretation, performance and brain activity improvements were specific to the intentional encoding condition and did not generalize to an untrained semantic encoding task (abstract/concrete judgments). Thus, the improvements most likely stemmed from an increased self-initiation of preferred deep encoding processes after training. Likewise, Lustig and Flegal (2008) found that training task improvements were related to reductions in self-reported everyday memory errors when the training task enforced adequate encoding time but allowed participants to choose their own strategies, but not when a specific strategy was enforced.

Together, these findings suggest that providing constraints—which might alternatively be termed "environmental support"—that cue deep encoding but providing latitude in how that deep encoding is implemented may bridge the heretofore troublesome gap between improving older adults' memory abilities and getting them to self-initiate the transfer and use of those improvements. Bottiroli, Cavallini, Dunlosky, Vecchi, and Hertzog (2013) also found promising results using an even more proactive approach to the mastery and transfer of successful encoding: participants who received training in successful encoding strategies, including how to implement those strategies, and discussed with the trainer how they could be adapted to other tasks showed the greatest transfer, even to tasks that were not specifically discussed. Orthogonal to the question of training strategies or abilities, training older adults' metacognition and self-initiation may prove critical for promoting transfer.

SUMMARY AND CONCLUSIONS

Our bodies—including our brains—change with time, and so do the strengths and weaknesses of our memories. A neurocognitive approach to the study of memory and aging highlights the role of processing components that may be differently weighted in different individuals and situations to result in decline, preservation, or even improvement. Controlled and associative processes appear to be the most vulnerable, corresponding to age-related declines in the prefrontal and medial temporal lobe regions that subserve them. Memory tasks that rely heavily on controlled processes may take an especially large hit, as these processes are dependent on the brain regions that show some of the largest age-related declines and also under increasing pressure to compensate for age-related declines in sensory or bottom-up processing. On the other hand, time also grants a wealth of experience and semantic knowledge that is largely preserved, and that may contribute to a prioritization of controlled processing towards maintaining stable, positive emotion.

Thus, the picture that emerges from the study of memory and aging is not one of gloom and inevitable decline. Longitudinal studies indicate that some older adults maintain relatively high levels of performance even in advanced age, and even those that are not so privileged can often perform as well or even better than young adults by making use of environmental support. Furthermore, the knowledge gained from studies of memory and aging guides the design of interventions. Our understanding of how to preserve or improve the memories of older adults is still relatively rudimentary, but meta-analyses suggest positive effects overall and point to promising directions for future research. As controlled and associative processes play an important role in age-related memory declines, they are also important targets for intervention. Because medial temporal-lobe-mediated associative processes are relatively automatic, they do not provide easy footholds for behaviorally based training, but may be improved by cardiovascular training and other biologically based means. In contrast, age differences in controlled processing offer a number of targets for intervention: demands on them can be reduced by improving bottom-up processing, by increasing the efficiency of controlled memory processes such as elaborative encoding and recollection, and by increasing their use via improved metacognition. It has been said that happiness at all ages is "good health and a bad memory," but we would argue for good health and a memory that is well-controlled.

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CHAPTER

9

Audition and Language Comprehension in Adult Aging: Stability in the Face of Change

Arthur Wingfield and Amanda Lash

Department of Psychology and Volen National Center for Complex Systems, Brandeis University, Waltham, MA, USA

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INTRODUCTION

Tout d'abord poussé par ce qui se fait en aviation, j'ai appliqué aux insectes les lois de la résistance de l'air, et je suis arrive…à cette conclusion que leur vol est impossible (Magnan, 1934).

Older adults are the fastest-growing segment of the US population, with the number of adults age 65 or older expected to grow to 70.3 million in 2030 (Kempler, 2005). Among this group, hearing loss is the third most prevalent chronic medical condition, exceeded only by arthritis and hypertension (Lethbridge-Ceijku, Schiller, & Bernadel, 2004).

Although hearing loss is a common accompaniment of adult aging, it has historically been considered as an independent issue in aging research. We now know, however, that there are effects of hearing loss beyond simply missing or misidentifying individual words in a spoken message. That is, even with milder hearing losses the perceptual effort required for successful speech recognition may draw on cognitive resources that would otherwise be available for downstream comprehension operations (Wingfield, McCoy, Peelle, Tun, & Cox, 2006) or encoding what has been heard in memory (Pichora-Fuller, 2003; Rabbitt, 1991; Surprenant, 2007; Wingfield, Tun, & McCoy, 2005). When combined with age-related declines in working memory, processing speed, and executive function (Salthouse, Atkinson, & Berish, 2003), comprehension of everyday speech can represent a significant challenge at both the perceptual and cognitive levels.

Challenges for Speech Comprehension

The efficiency with which everyday spoken discourse is comprehended belies the number and complexity of the operations that must be performed for its success. As speech arrives at a rate that averages between 140 and 180 words per minute (wpm), the listener must: (i) extract the physical features of the acoustic signal and resolve the speech phonology; (ii) match this input phonology in a best-fit manner with phonological representations of potential word candidates in the listener's internal lexicon; (iii) determine the syntactic and semantic relations among the lexical elements in the utterance, and detect the underlying propositions or "idea" units represented; (iv) determine the relations among these propositions in order to construct overall coherence to the utterance, often with the need for extended inference. This is not merely a feed-forward system, however, but one in which operations overlap in time and involve continual feed-back from higher levels at each level of analysis.

Unlike reading, where the reader can use eye movements to control the rate of input, with speech, the rate of input is controlled by the speaker and not by the listener. Those operations that cannot be performed "on-line" as the speech is being heard, must be accomplished retrospectively on a brief, capacity-limited memory trace of the original input. As an added challenge, much of everyday speech is notably underarticulated, such that word recognition must rely heavily on acoustic and linguistic context (Lindblom, Brownlee, Davis, & Moon, 1992). That this lack of articulatory clarity goes unnoticed in everyday listening reflects the continual interaction between the *bottom-up information* supplied by the sensory input, supported by *top-down information* from linguistic and real-world knowledge.

Albeit more subtle in normal aging than in neuropathology such as Alzheimer's disease or other dementing illness, the biological changes that accompany adult aging have a measurable impact on structure and network dynamics that carry cognitive function (Burke & Barnes, 2006). The consequences of these changes are seen in declining effectiveness of episodic memory (Wingfield & Kahana, 2002), reduced processing speed and working memory capacity (Salthouse et al., 2003), and reduced efficiency in executive function and inhibition

(Hasher, Lustig, & Zacks, 2007; McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010).

In spite of these impediments, the comprehension of spoken language in healthy aging typically reflects relative stability, or at most a gradual decline, rather than an abrupt or catastrophic failure. The question is thus not only why performance in some aspects of language tasks declines in adult aging, but why in normal aging performance remains as stable as it does. In phrasing the question this way, we address one of the most fundamental questions in current neurobiology: how stable behavior can be produced in spite of changes in underlying neural structures and circuit parameters (Prinz, Bucher, & Marder, 2004).

Our goal in this chapter is to examine the effects of cognitive change and age-related hearing loss on speech comprehension, and on memory for what has been heard. As we do this we consider the two sides of the aging, hearing acuity, and speech comprehension coin. On the positive side we show how spared linguistic knowledge can overcome sensory and cognitive decline to maintain stable speech comprehension in adult aging. On the negative side we present the cognitive costs that come with age and the perceptual effort attendant to reduced hearing acuity. (A good discussion of age-related issues in language production can be found in Burke & Shafto (2004).)

AGE-RELATED HEARING LOSS

Although population studies show a general decline in hearing acuity in adult aging, there is wide variability from individual to individual. Estimates of the incidence of age-related hearing loss (*presbycusis*) vary, but a reasonable estimate is that some 40–45% of adults over the age of 65 show some degree of hearing loss, with this number increasing to 83% in the population over the age of 70 (Cruickshanks, Wiley et al., 1998).

In clinical audiology the degree of hearing loss is categorized based on hearing acuity in the major speech frequency range, and is referred to as *slight*, *mild*, *moderate*, *severe*, or *profound* (Katz, 2002), with the single largest group of older adults with impaired hearing falling in the mild-to-moderate range. It is a public health issue that the majority of individuals who would benefit from amplification do not regularly wear hearing aids, especially those in the moderate loss range (Chien & Lin, 2012; Fischer et al., 2011).

Audition: Some Preliminaries

The detection of speech, or any other auditory stimulus, begins with the mechanical transmission of vibrations of the eardrum (*tympanic membrane*) induced by the sound energy arriving at the ear. This vibration sets in motion three small articulated bones in the *middle ear*, collectively called the *ossicles*. The function of the ossicles is to transmit, and mechanically amplify, these vibrations to a second membrane (the *oval window*) that separates the middle ear from the *inner ear*. Vibration of this second membrane sets in motion a fluid located in the *cochlea*, a snail-shaped structure about the size of a pea or the nail on one's little finger. Located inside the cochlea is a thin membrane (the *basilar membrane*) that runs the length of the cochlea, along which lie some 12,000–15,000 *outer hair cells*. The motion of the *cochlear fluid* causes a wave-like movement of the basilar membrane that translates into differential movement of the hair cells along different regions of the membrane sensitive to particular sound frequencies. This movement of the outer hair cells stimulates approximately 3500 *inner hair cells* that transduce this stimulation into coded neural impulses that pass through the *cochlear nuclei* and *superior olivary complex* in the brainstem, the *medial geniculate nucleus* in the thalamus, and end in the primary auditory receiving area of the brain (*Heshl's gyrus*) located along the superior portion of the temporal lobe.

Types of Hearing Loss

The term, *peripheral hearing loss* includes either a conductive (middle ear) or sensorineural (inner ear) hearing loss. These are typically measured by determining the lowest intensity at which pure tones of various frequencies can first be detected (*pure-tone thresholds*). As we shall see, however, in the case of age-related hearing loss, such auditory thresholds tell only part of the story.

Conductive Hearing Loss

Any dysfunction in the outer or middle ear is termed a conductive hearing impairment. (The *outer ear* refers to the ear canal [*external auditory meatus*], the cartilaginous tube that runs from the ear itself [the *pinna*] to the tympanic membrane). The consequence of a conductive loss is a general attenuation of the loudness of the sounds one hears. The most common, and easily treatable, cause of a conductive impairment is a plugging of the ear canal by an excess accumulation of cerumen (ear wax). More serious is a conductive loss due to restricted movement of the ossicles themselves, whether due to inflammation or infection in the middle ear (*otitis media*), or an age-related stiffening of the ossicles. The integrity of ossicle movement in the middle ear can be measured using *tympanometry*, a relatively non-invasive procedure in which the eardrum, and hence the ossicles, are set in motion by a controlled burst of air pressure, with the measured strength of the pressure return serving as an index of the conductance properties of the ossicles (Fowler & Shanks, 2002). Available medical and surgical treatments can often ameliorate this type of loss.

Sensorineural Hearing Loss

The emblematic type of hearing loss in adult aging, however, is a sensorineural hearing loss that results from the loss of hair cells in the inner ear, especially from the high-frequency-sensitive region of the basilar membrane. This loss or attenuation of high-frequency sounds can have a debilitating effect on speech recognition especially for high-frequency speech sounds, such as the "s" as in "same," the "f," as in "fish," or the voiceless "th" as in "thing."

Hair cell loss in different frequency regions of the cochlea can be detected by measuring *distortion-product otoacoustic emissions* (DPOAEs). In this test pure tones of particular frequencies are delivered to the ear, with a small but sensitive microphone placed in the ear canal that can detect the sound of hair cell movements, if present, in the region of the basilar membrane most sensitive to these frequencies. Auditory evoked potentials (AEPs), including the auditory brainstem reflex (ABR), which measure neural responses to clicks or tones recorded from surface electrodes, can assess the integrity of the ascending auditory pathways.

Although hearing acuity is often represented as an average pure tone threshold (pure-tone average; *PTA*) for sounds in the major speech frequency range (e.g., a PTA across 500, 1000, 2000, and 4000 Hz), a more complete picture of an individual's acoustic sensitivity is depicted with an *audiogram*, which is a plot of the sound level, measured in decibels (dB), needed to detect sounds across a range of frequencies. A 0-dB line in the upper part of the audiogram represents a hearing level (HL) at each frequency normed for young adults with good hearing; hence the possibility of a hearing threshold of less than 0 dB.

Figure 9.1 shows the typical shape of an audiogram for an older adult with a sensorineural hearing loss plotted for the left and the right ears over the range of frequencies from 250 Hz to 8000 Hz. One can see a mild attenuation at the lower frequencies (e.g., 250–500 Hz) with a gently increasing degree of loss in the higher-frequency ranges. The shaded region in Figure 9.1 represents the primary frequency range of speech, with vowels represented at the lower part of this frequency range (e.g., 500 Hz) and

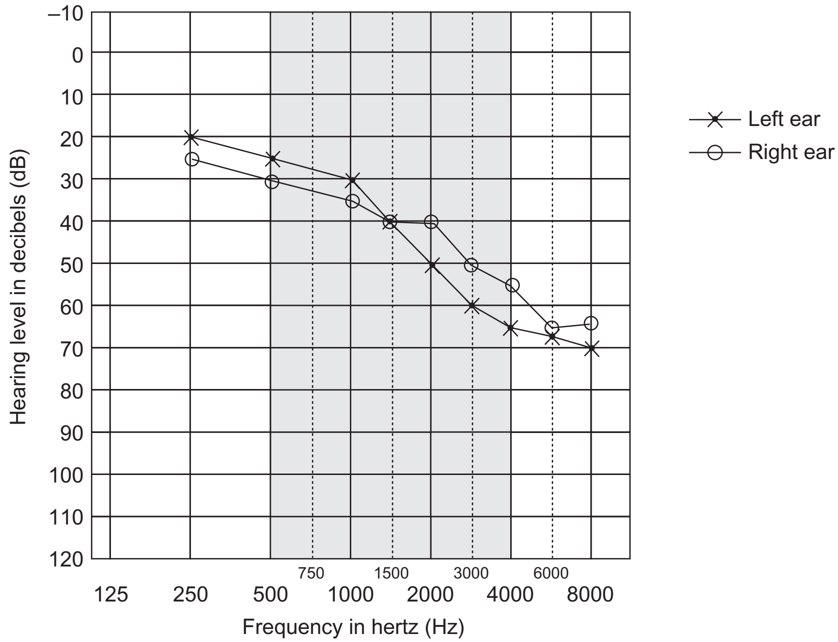

FIGURE 9.1 Typical shape of an audiogram representing age-related sensorineural hearing loss. The abscissa shows frequencies tested (in Hz); the ordinate shows sound level (in dB) necessary to hear pure tones at each of the tested frequencies. The shaded portion represents the major speech frequency range.

higher-frequency speech sounds, such as the voiceless consonants, at approximately 4000 Hz, although the full range of human speech can even be somewhat higher. (A conductive hearing loss will show a relatively flat profile across the frequency range, while a noise-induced hearing loss often shows a selective loss at about 4000 Hz within an overall steeply sloping loss across the high-frequency range.)

Central Processing Deficits

Although pure tone thresholds are the most commonly used index of hearing acuity, for many older adults sensitivity to pure tones is not a good predictor of their hearing for speech. In addition to reduced acuity, per se, the older auditory system often shows decreased efficacy in temporal and spectral resolution that can significantly degrade the clarity of the speech signal (Humes & Dubno, 2010). These so-called "central" deficits can contribute to the common complaint of many older adults of a special difficulty in understanding speech, even when amplified. The nature of these central processing disorders represents an area of active research in regard to testing (Cox, McCoy, Tun, & Wingfield, 2008), definition (Humes et al., 2012), and anatomy (Canlon, Illing, & Walton, 2010). An excellent review of major findings from animal and human research on the nature of age-related hearing loss, its epidemiology, and training possibilities to enhance everyday communication can be found in Gordon-Salant (2014).

Variability in Age-Related Hearing Loss

The previously noted variability in hearing acuity among older adults, like many changes in adult aging, can be accounted for by genetic as well as environmental influences. In the case of hearing acuity environmental factors include exposure to noise, medications with ototoxic properties, and risk factors such as cardiovascular disease (Gates, Cobb, D'Agostino, & Wolf, 1993), cigarette smoking (Cruickshanks, Klein et al., 1998), and diabetes (Bainbridge, Cheng, & Cowie, 2010).

In a study of genetic influence on hearing acuity we compared hearing acuity for 179 monozygotic (MZ) twin-pairs and 150 dizygotic (DZ) twin-pairs ranging in age from 52 to 60 years. Although there was a significant correlation between the hearing acuity of the DZ twin-pairs, the correlation was significantly higher for the MZ twin-pairs, with biometrical modeling indicating that between 65% and 70% of the variance in better-ear hearing acuity in the middle- and high-frequency ranges could be accounted for by genetic influences (Wingfield, Panizzon, Grant et al., 2007). The specific genes that appear as risk factors for age-related hearing loss remain an active area of research (Yamasoba et al., 2013).

Speech in Noise: A Hallmark of Aging Hearing

Listening to speech in a noisy environment is a part of one's listening life: whether one is attempting to listen to a companion over the sound of traffic, or the "babble" of many people speaking in a noisy restaurant. Although a challenge for all listeners, one of the hallmarks of aging hearing is a special difficulty for speech recognition in noise, even when speech recognition in quiet is relatively good (Gordon-Salant & Fitzgibbons, 1995; Humes, 1996).

Separating Speech from Noise

Energetic masking refers to the reduced audibility of a target speaker caused by the fusing of the acoustic energy from the target speaker and background noise. Among the features listeners use to perceptually separate a single speaker from the "noise" of other speakers are differences in spatial location made possible by such factors as intensity and phase differences at the two ears, and the use of voice quality, speech rate and the metrical patterns of the various speakers.

Older adults with reduced auditory sensitivity can be deprived of some or all of these cues, making separation of a complex auditory environment into separate acoustic "streams" especially difficult (Marrone, Mason, & Kidd, 2008; Singh, Pichora-Fuller, & Schneider, 2008). Although this early-stage perceptual separation is often considered to be an automatic, resource-free process, there is evidence that this early-stage separation may be resource-demanding (Heinrich, Schneider, & Craik, 2008). Good reviews of the processes involved in auditory stream segregation and "auditory scene analysis" can be found in Bregman (1993) and Shinn-Cunningham and Best (2008).

Informational Masking

Informational masking refers to interference from concurrent stimuli beyond energetic masking alone. A prime example is the finding that attempting to attend to a target speaker with one or two other talkers in the background, in which individual words can be identified, causes more interference than a background "babble" of many voices, in which no individual words can be distinguished (Tun & Wingfield, 1999).

The term, *cocktail party problem* was coined by Cherry (1953) to refer to one's ability to attend to a single speaker while apparently ignoring the content of other speakers' voices. In young adults this ability to filter or attenuate distraction from a second speaker is well developed. For example, in an experiment in which young adults were instructed to "shadow" (repeat while listening) the content of a target speaker heard in one ear over earphones, listeners were often unaware that the voice of a concurrent, to-be-ignored speaker delivered to the other ear, had changed from speaking English to speaking French (Treisman, 1964). Although attention may appear to be absolute, some monitoring of an apparently unattended speaker must be occurring, as one can, about a third of the time, hear one's name when it is spoken by an "unattended" speaker (Conway, Cowan, & Bunting, 2001; Moray, 1959).

Selective attention to a single speaker in a cocktail party situation is less effective in older adults (Tun, O'Kane, & Wingfield, 2002) and especially so for adults with hearing loss (Shinn-Cunningham & Best, 2008). This decrement in attending to a target speaker with another talker in the background is due in part to energetic masking, and in part to informational masking at the cognitive level. For example, consistent with Treisman's (1964) findings, an experiment conducted by Tun et al. (2002) found that young adults were no more distracted by a competing speaker speaking in English than they were by a competing speaker speaking in an unfamiliar language (Dutch). By contrast, older adults showed differentially greater interference when the competing speaker was speaking in meaningful English, suggesting that in the older adults the to-be-ignored speech was not only "leaking through" an inhibitory filter but that its content could not be fully ignored (Tun et al., 2002). This content-specific interference effect is consistent with arguments for an inhibition deficit in adult aging (Hasher et al., 2007).

COMPENSATION THROUGH LINGUISTIC KNOWLEDGE

We began this chapter with a quote from the French entomologist, Antoine Magnan, writing in 1934 that the wing-size to weight-ratio of many flying insects, such as the bumble bee, should make it impossible for them to fly. The answer, of course, is that these early calculations failed to take into account the full complexity of factors relating to the structure and movement of insects' wings that do in fact allow them to fly (Sane, 2011). In a similar way, when one contemplates the age-related limitations on processing speed, working memory, inhibitory processing, and reduced hearing acuity, one may ask why comprehension of connected speech by older adults is as good as it is. The answer in this case is older adults' ability to compensate for these processing deficits with linguistic knowledge, typically spared in healthy aging (Kempler & Zelinski, 1994). This compensation occurs at both the neural and behavioral levels. At the neural level, when challenged by syntactically complex sentences older adults engage a compensatory recruitment of regions in the frontal and temporoparietal cortices bilaterally in support of left hemisphere core sentence-processing regions to a degree not shown for young adults (Peelle, Troiani, Wingfield, & Grossman, 2010; Wingfield & Grossman, 2006). In the following sections we focus on compensation at the behavioral level; first for the perceptual identification of individual words, and then for comprehension and recall of spoken sentences.

Effects of Age and Hearing Acuity on Word Recognition

In the absence of a linguistic context there are a number of word-level factors that influence the ease with which a spoken word will be recognized. These include the relative frequency with which a word occurs in the language, with common words recognizable with less sensory information than rare words (Grosjean, 1996; Howes, 1957), and easier recognition of words with fewer words that share phonology with the target word (Luce & Pisoni, 1998). This latter point is embodied in the *neighborhood activation model* (NAM) of word recognition. This model posits that the more words that share phonology with a target word (its phonological density) the greater the difficulty of recognizing that word when, for example, it is degraded by background noise (Sommers, 1996). A complementary model, the *onset cohort* *model*, places an emphasis on the beginnings of words, with the suggestion that hearing the onset of a word will activate all words that share that beginning sound, with the size of the onset cohort trimmed as the word unfolds in time and more of the word onset is heard (Marslen-Wilson & Zwitserlood, 1989). In either case, the differences in articulatory clarity and variability in speakers' utterances demand that models of word recognition must be based on a best fit rather than an absolute fit between a sensory input and potential word candidates.

Although hearing acuity will affect the probability and/or speed with which a word will be correctly identified, Sommers and Danielson (1999) have shown that older adults, even when hearing acuity is taken into account, require differentially greater signal clarity than young adults to identify words that share phonology with a large number of words than for words with fewer phonological neighbors. The problem is not the loss of vocabulary knowledge. Indeed, while young adults may outperform older adults on tests of word retrieval, older adults often outperform young adults on tests of vocabulary knowledge (Kavé & Yafé, 2014). Rather, the Sommers and Danielson finding can be viewed as a second incidence of an age-related inhibition deficit affecting speech processing. In this case it is the suggestion that older adults' word recognition is negatively influenced by a reduced ability to inhibit phonologically similar but incorrect competitors that were initially activated along with the ultimately correct response (Sommers, 1996; Sommers & Danielson, 1999).

Effects of Contextual Facilitation

Over a century ago, James McKeen Cattell observed that a word presented in the context of a sentence, or a letter in the context of a word, could be recognized faster than when the same stimulus was presented without such contextual constraints (Cattell, 1886). This reflects a general principle of perception that the more probable a visual or auditory stimulus, the less sensory information will be needed for its correct recognition (Morton, 1969). This principle has long been instantiated for spoken words by showing facilitated word recognition whether the probability of a stimulus word is increased by giving a semantically associated word, by providing a category description of the target word or by presenting the word within a linguistic context (Black, 1952; Bruce, 1958). Analogous studies have shown that older adults' recognition of degraded words is facilitated to an equal, and often greater, degree than for young adults when a word is heard within a sentence context relative to a neutral context (Cohen & Faulkner, 1983; Pichora-Fuller, Schneider, & Daneman, 1995; Wingfield, Aberdeen, & Stine, 1991).

Although many studies have contrasted recognition for words in a neutral versus a constraining linguistic context, one can examine the degree to which systematically increasing the degree of contextual constraint affects the ease of word recognition. This can be done by using a so-called "cloze" procedure (Taylor, 1953), in which the transitional probability of a word in a sentence context is estimated by the percentage of individuals who give that word when asked to complete a sentence with what they believe would be the most likely final word. Using such materials it has been shown for written words (Morton, 1964) and spoken words (Wingfield et al., 1991) that the ease of word recognition is inversely proportional to the transitional probability of the word in a sentence context.

Benichov, Cox, Tun, and Wingfield (2012) conducted a study with participants aged 19–89 years, with levels of hearing acuity ranging from normal hearing to mild-to-moderate hearing loss. (As previously noted, this is the most common degree of loss among hearing-impaired older adults.) A regression analysis showed that hearing acuity, although a predictor of the signal-to-noise ratio necessary to correctly recognize a word in the absence of a constraining linguistic context, dropped away as a significant contributor to recognition of sentence final words by the time the linguistic context yielded an average cloze probability 0.53. By contrast, cognitive ability, represented as a *z-score* composite of the individuals' episodic memory, working memory, and processing speed accounted for a significant amount of the variance in word recognition for words heard in a neutral context and for all degrees of contextual constraint examined.

Expectation and Entropy in Word Recognition

An interesting finding in the Benichov et al. (2012) study was that age contributed significant variance to recognition scores even when word recognition was statistically controlled for hearing acuity and cognitive function. Although the cognitive battery sampled several components of cognitive function, inhibition was not specifically tested. This aspect was investigated by Lash, Rogers, Zoller, and Wingfield (2013), who examined effects on word recognition of age, hearing acuity, and expectations for a word based on a linguistic context, but also on effects of competition from other words that might also fit the semantic context. The technique used was *word onset gating*, in which a listener is presented with increasing amounts of a word's onset duration until the word can be correctly identified (Grosjean, 1996). Computer editing was used to present participants with just the first 50 ms of a target word, with instructions to say what they believed the word might be. If unable to do so they were presented with the first 100 ms of the word, then the first 150 ms of the word, and so forth, with the amount of word onset duration increased in 50 ms increments until the word could be correctly identified. (To put these figures into perspective, the average duration of a word-initial consonant-plus-vowel (CV) is just over 200 ms.)

Figure 9.2 shows the mean amount of word onset information (gate size in ms) needed for correct identification of a target word when heard in a neutral context ("The word is…") or when the word was preceded by a linguistic context with a measurable but low probability of suggesting the target word (e.g., "The cigar burned a hole in the FLOOR" [$P = 0.03$]), a medium probability level (e.g., "The boys helped Jane wax her FLOOR" [$P = 0.10$]) or a higher probability (e.g., "Some of the ashes dropped on the FLOOR" [$P = 0.43$]).

It can be seen on the left side of Figure 9.2 that when heard in a neutral context older adults with a mild-to-moderate hearing loss (poor hearing) required a significantly greater amount of a word onset to correctly identify a target word than a group of age-matched older adults with good hearing acuity for their ages, and with these participants in turn requiring a greater amount of word onset for recognition than a group of young adults with age-normal hearing acuity. As would be expected from our prior discussion, one also sees in Figure 9.2 that the difference between these three participant groups diminishes as the transition probability of the target word in a particular sentence context is progressively increased to the point where the differences between the older adults with poor and good hearing acuity is no longer significant.

An advantage of published cloze norms e.g., (Lahar, Tun, & Wingfield, 2004), is that when participants have been asked to complete sentence stems, also reported is the full range of responses given by each of the participants, and the number of participants giving these alternative responses. These data allow one to estimate not only the expectancy of a sentence final word based on the transitional probability of that word in the sentence context, but

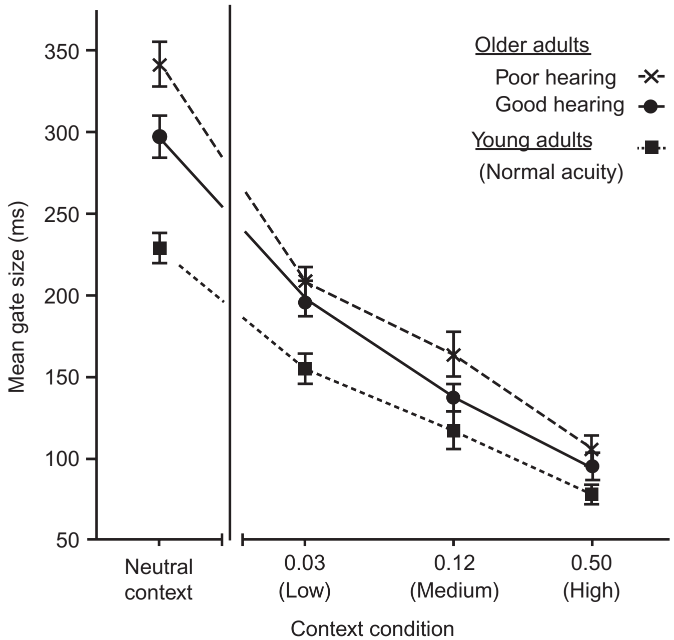

FIGURE 9.2 Mean amount of word onset information (onset gate size in ms) needed for correct identification of a sentence-final target word heard in a neutral context or when the word was preceded by a linguistic context with a low, medium or high probability of suggesting the target word. Probabilities are based on published norms representing the likelihood that individuals will complete a sentence with the target word. *From Lash et al. (2013, p. 243). Copyright 2013 by Taylor & Francis. Reprinted with permission.*

also the uncertainty (*entropy*) implied by the number, and probability distribution, of alternative responses also potentially implied by the context. When this was done, it was shown that more of a word onset was needed for recognition when the sentence context activated a large number of highly competitive word possibilities, with this effect of competition more detrimental to the older adults. That is, while context-based expectancy facilitated word recognition for all three participant groups, a negative effect of a distribution of strong competitor responses was a factor related to age, independent of the older adults' level of hearing acuity (Lash et al., 2013). These results are consistent with Sommers and Danielson's (1999) proposition that older adults have greater difficulty than their young adult counterparts in inhibiting non-target responses. In Sommers and Danielson's case the competition came from the presence of a larger number of phonological "neighbors" of target words. The present case differed only in that response competition came from the distribution of words that also shared a contextual fit with the semantic context.

The study by Lash and colleagues, like most studies of contextual facilitation on word recognition, examined effects of a preceding linguistic context. It often happens, however, that one realizes the identity of an indistinctly heard word only retrospectively, as one hears the context that follows the acoustically ambiguous word. It is here that older adults with reduced working memory capacity are at a disadvantage. Although older adults can make good use of a preceding context to aid word recognition, they are less effective relative to young adults in retrospective word recognition based on a following context that implies a need for an effective memory trace of the acoustically ambiguous region (Wingfield, Alexander, & Cavigelli, 1994).

Comprehension and Recall at the Sentence Level

Among the best-studied linguistic challenges are those related to complex syntax. Consider the following sentence that expresses its meaning using a subject-relative embedded clause structure: "*The author who insulted the critic hired a lawyer.*" There are two major thematic roles represented in this sentence: the author, who is the agent who performs both actions (insulting and hiring), and the lawyer, who was hired. Comprehension requires the listener to understand that *The author hired a lawyer* is the main clause of the sentence, interrupted by the relative clause, *who insulted the critic*.

Now consider a second sentence with the same nine words but with the meaning expressed using an object-relative embedded clause structure: "*The author who the critic insulted hired a lawyer.*" In this type of structure, not only does the embedded clause interrupt the main clause, but the head noun phrase (the author) functions as both the subject of the main clause (hiring the lawyer) and the object of the relative clause (being insulted). Because the thematic roles in object-relative sentences require extensive integration, they are more difficult to process, and hence give the listener a greater cognitive burden, than subject-relative sentences (Carpenter, Miyaki, & Just, 1994). Another impediment is that the non-canonical word order of object-relative sentences violates the expected frequency-based subject–verb–object word order in English. This word order expectancy would ordinarily work in most cases of everyday speech, but in this case the expectancy must be inhibited for a correct interpretation. (See Novick, Trueswell, & Thompson-Schill, 2005, for arguments relating to frontal lobe function for effective inhibition of syntactic expectations when sentences with non-canonical word orders are encountered.)

Whether on-line syntactic parsing draws on attentional resources or whether these resource limitations operate at the level of post-interpretive processes remains an issue for debate (Caplan & Waters, 1999). It is well established, however, that age-related resource limitations constrain successful comprehension of sentences, most notably when complex syntax places a heavy demand on working memory (Carpenter et al., 1994).

Figure 9.3 shows data from Stewart and Wingfield (2009) for participants who heard isolated monosyllabic words versus subject-relative and object-relative sentences of the sort described above. The stimuli were presented to older adults, either with a mild-to-moderate hearing loss or with good hearing for their ages. A group of young adults with age-normal hearing acuity was included to illustrate a maximal performance level for the task. The stimuli were initially presented below the level of audibility and then increased in loudness in 2-dB increments until the single-word stimuli and all nine words of the sentence stimuli could be correctly reported.

The three panels in Figure 9.3 show the cumulative percentage of stimuli correctly reported as a function of increasing amplitude in 2-dB increments for the three groups of participants. Although all show similar S-shaped psychophysical functions, each group reaches the 50% correct threshold (indicated by the horizontal dotted lines) with different sound levels. The finding that accurate recall appears with at a lower sound intensity for the two types of sentences relative to correct recall of the isolated words illustrates the effectiveness of linguistic support for recognition and recall. A comparison of the top, middle, and

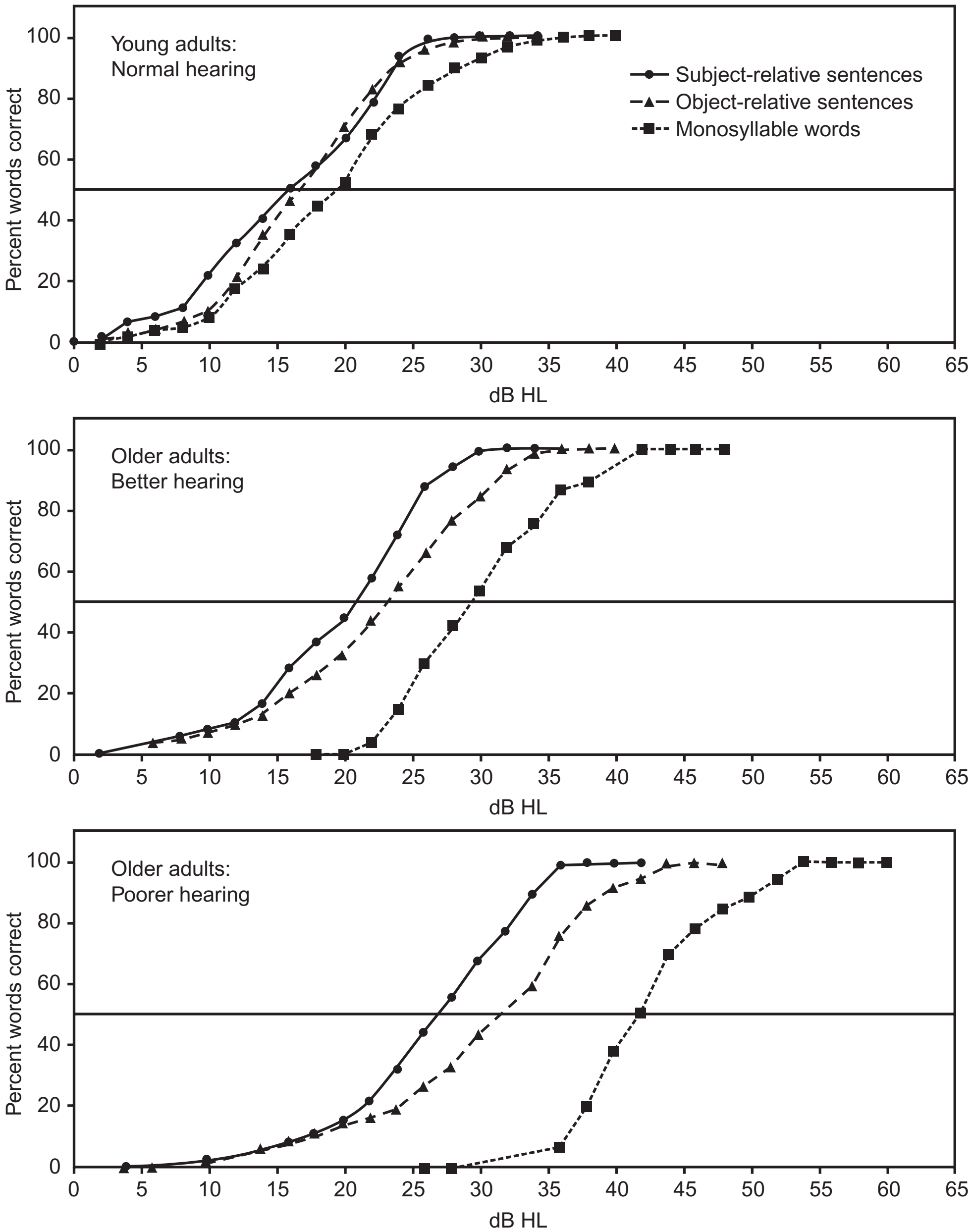

FIGURE 9.3 Cumulative percentage of words correctly reported for single-word stimuli and for sentences with subject-relative and object-relative clause syntactic structures as a function of sound level increased in 2-dB increments. Data are shown for young adults with normal hearing (top panel), older adults with good hearing acuity (better hearing; middle panel), and older adults with mild-to-moderate hearing loss (poorer hearing; bottom panel). The horizontal lines in each panel show the points at which 50% of the words in each of the three conditions were reported correctly. *From Stewart and Wingfield (2009, p. 151). Copyright 2009 by the American Academy of Audiology. Reprinted with permission.*

lower panels of Figure 9.3 shows there to be a greater degree of facilitation for sentences versus words that is larger for the older adults with good hearing acuity relative to the young adults, and larger still for the older adults with hearing impairment.

Figure 9.3, however, also illustrates a limiting factor in older adults' sentence recall. This is the observation that accurate sentence recall appears with a lower sound level for the simpler subject-relative sentences than the more complex object-relative sentences, with the magnitude of this difference reflected in the greater displacement of the curves for the older adults with hearing impairment. To put this in practical terms, for the better-hearing older adults, increasing the syntactic complexity from a subject-relative to an object-relative structure was equivalent to decreasing the sound level by an average of 4.8 dB. For the older adults with mild-to-moderate hearing loss it was equivalent to a 7.8-dB decrease in sound level. Importantly, this is so even though the two sentence types were both meaningful English, spoken by the same speaker, and contained the same words, differing only in the syntactic structure used to express the meaning.

These findings fit well with the assumptions of age-related resource limitations and our understanding of sentence processing (Carpenter et al., 1994). To the extent that resolving the meaning of object-relative and subject-relative sentences serves as a precursor to their effective recall, the greater demands on working memory resources of comprehending object-relative sentences would have a differentially greater impact on older relative to young adults due to older adults' more limited initial working memory resources. To this one may add older adults' reduced efficiency in inhibition that would, as indicated earlier, put them at a disadvantage in dealing with the non-canonical (unexpected) word order of object-relative sentences. The exaggeration of the syntactic effects by hearing loss suggests a further drain on resources needed for perceptual operations; a perception-based reduction in resources that might otherwise be available for syntactic resolution and encoding what has been heard in memory.

The most direct way to separate the effects of aging and hearing acuity is to use a four-group design consisting of good-hearing and impaired-hearing young adults and good-hearing and impaired-hearing older adults. This can be illustrated in a study that combined two perturbations that differentially challenge older adults: complex syntax and rapid speech rates. The stimuli in this study were short, six-word sentences, in which either a male character (e.g., boy, uncle, king, nephew) or a female character (e.g., girl, aunt, queen, niece) was the agent of an action. Critically, the sentences were heard either with a subject-relative structure (e.g., "Men that assist women are helpful") or an object-relative structure ("Women that men assist are helpful"). The listener's task was simply to press a key to indicate whether it was a male or a female who was performing the action, with the sentences presented at a fast-normal rate of 205 wpm or computer time-compressed to be heard in 80%, 65%, or 50% of their original playing time (corresponding to speech rates of 258, 321, and 410 wpm).

The data from this experiment are shown in Figure 9.4 for a group of young and older adults with good hearing acuity for their ages, and young and older adults who had a mild-to-moderate hearing loss. Inspection of the left panel of Figure 9.4 shows that comprehension accuracy for the simpler subject-relative sentences, as measured by correct selection of the gender of the agent of the action, was unaffected by either hearing acuity or speech rate within the limits tested. For the older adults hearing acuity only begins to appear as a comprehension challenge at the two highest compression ratios tested. A very different picture emerges for the counterpart sentences with an object-relative structure heard by the same

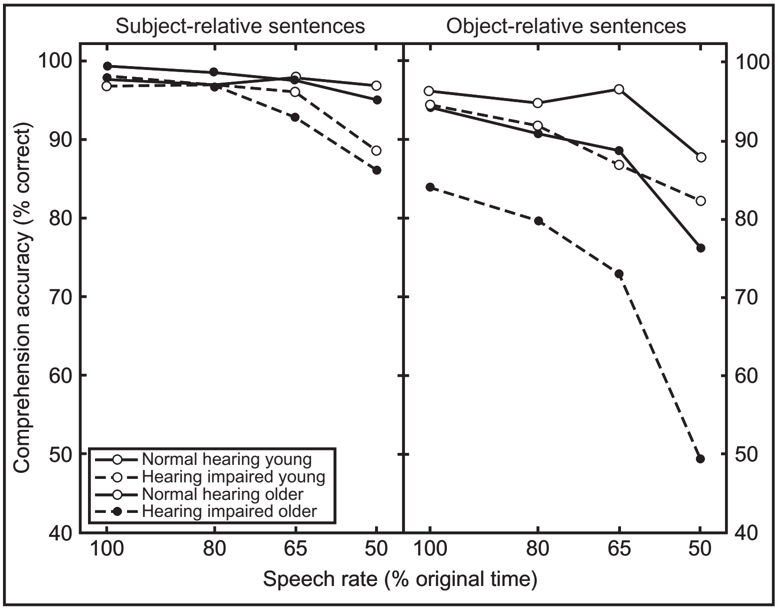

FIGURE 9.4 Comprehension accuracy for sentences with a subject-relative clause structure (left panel) and with an object-relative clause structure (right panel) as a function of speech rate expressed as a percentage of original speaking time. Data are shown for young and older adults with good hearing for their ages and young and older adults with a mild-to-moderate hearing loss. *From Wingfield et al. (2006, p. 493). Copyright 2006 by the American Academy of Audiology. Reprinted with permission.*

participants. In this case one sees an effect of hearing acuity for the young adults at all but the original fast-normal speech rate, and an even greater effect of speech rate, amplified by hearing loss, for the older participants.

This experiment illustrates two important points. The first is that older adults, to include those with a mild-to-moderate hearing loss, can be expected to show excellent speech comprehension with the linguistic support inherent in meaningful sentences, even with relatively rapid speech rates, so long as sentence length and syntactic structure do not put special demands on working memory resources. The second point is that age differences in comprehension accuracy for speech will appear when the processing load is increased either by syntactic complexity of the speech materials, reduced hearing acuity, or both. These results also serve to emphasize that neither age-related cognitive constraints, nor hearing acuity alone, will give the full picture for individuals' effectiveness in sentence comprehension.

There are two detrimental effects of time compression, both of which put the older adult at a special disadvantage. One is the removal of ordinarily available processing time at the level of linguistic processing that would especially challenge a slower processing system. This factor can be revealed by the insertion of pauses at linguistic boundaries that allow older adults' processing to "catch up." When this is done one can raise both younger and older adults' performance to a level close to their comprehension performance for non-compressed speech (Wingfield, Tun, Koh, & Rosen, 1999). The second factor is at the perceptual level where, with a very high compression ratio (in this study equivalent to an unnaturally rapid rate of 300 wpm), there is a loss of richness of the speech signal that, for older adults, cannot be rescued even with the insertion of periodic silent periods (Wingfield et al., 1999).

Compensatory Support from Speech Prosody

Prosody is a generic term for the full array of acoustic features that accompany natural speech. These include the intonation pattern (pitch contour) of a sentence that is carried by the fundamental frequency (*Fo*) of the voice, and word stress (a complex subjective variable based on loudness (amplitude), pitch and syllabic duration). An especially important feature of speech prosody that specifically aids syntactic parsing is syntax-tied timing patterns, such as the pauses that sometimes occur between major syntactic elements of a sentence and the lengthening of clause-final words that signal that a major clause boundary has been reached. Like the use of linguistic context to aid word recognition, older adults can be shown to make good use of prosody to guide syntactic parsing, and often to a differentially greater degree than their young adult counterparts (Kjelgaard, Titone, & Wingfield, 1999). They also give the same relative weighting to each of the major prosodic features (timing, stress, pitch contour) to aid syntactic parsing as young adults (Hoyte, Brownell, & Wingfield, 2009).

Support from Other Sensory Cues

Being able to see a speaker's face when he or she is speaking can sometimes produce better speech recognition than simply hearing the person in the absence of visual cues, especially when there is background noise. That is, there may be supplemental information available to a listener if the listener can see the speaker's articulatory movements as they are talking. Gaining such an advantage requires both effective extraction of the visual cues, and then the ability to integrate the auditory and visual information into a single percept. It may be that older adults are less effective than young adults in initial detection or encoding of the visual cues but perhaps not in combining the information from the two modalities (Sommers, Tye-Murray, & Spehar, 2005). In considering these issues it is also important to recognize that being able to see a speaker while he or she is talking can help focus one's attention to the speaker, with attendant benefits to selective listening in the presence of noise. A good review of the literature and discussion of these issues can be found in Mishra (2014, pp. 13–15).

DOWNSTREAM EFFECTS OF PERCEPTUAL EFFORT

We have several model assumptions that guide our approach to understanding the mechanisms by which a constrained cognitive system accompanied by reduced hearing acuity affects older adults' speech comprehension at the word, sentence, and discourse levels: (i) at the level of word identification we assume a reciprocal balance between bottom-up information determined by the clarity of the speech signal and top-down information supplied by linguistic knowledge (Morton, 1969), with the latter largely preserved in healthy aging; (ii) the application of this knowledge is supported by temporally overlapping memory systems varying in duration and content characteristics (Mattys, 1997) that include a very brief *echoic* trace in the order of several seconds (Darwin, Turvey, & Crowder, 1972) that allows for maintaining the coherence of speech streams and for local misrecognition repair; (iii) comprehension of sentences with complex syntax, and full narrative comprehension at the discourse level are assumed to be carried by an age-limited working memory system guided by executive control processes that includes elements of inhibition (Cowan, 1999; Engle, 2002; McCabe et al., 2010); (iv) in the case of degraded input, perceptual operations will be slowed by a shift from automatic to controlled processing, with the latter increasing the drain on working memory resources (Rönnberg et al., 2013), with such a shift seen in graded rather than dichotomous terms (Chun, Golomb, & Turk-Brown, 2011). To the extent that controlled processing engages working memory resources, both age-related limitations in cognitive control and perceptual effort associated with hearing loss would have a negative effect on speech comprehension, especially under conditions representing heavy processing demands. Such high-demand conditions would include on-line analysis of speech with complex syntactic or propositional structures, often when the processing load is further compounded by rapid or degraded speech input.

An independent measure of the resource drain associated with perceptual effort can be revealed by a decline in secondary-task performance (Fraser, Gagne, Alepins, & Dubois, 2010; Larsby, Hallgren, Lyxell, & Arlinger, 2005; Sarampalis, Kalluri, Edwards, & Hafter, 2009). For example, Tun, McCoy, and Wingfield (2009) using a four-group design (young and older adults with good hearing acuity and young and older adults with a mild-to-moderate hearing loss) measured the moment-to-moment accuracy in using a computer mouse to track a randomly moving visual target on a computer screen while listening to and recalling a spoken word list. Relative to the single-task tracking performance of each group, older adults showed a greater cost of dividing attention than young adults as measured by a decline in tracking accuracy during recall. Within each age group, however, those with hearing impairment showed reduced accuracy in concurrent visual tracking, and especially so for the hearing-impaired older group. Such results are consistent with a shared-resource argument in which hearing-related listening effort drew resources needed to support accuracy in the visual-motor tracking task. Additional evidence for effects of listening effort appears in the measurement of pupil dilation based on the finding that greater cognitive load causes an increase in pupil size (Piquado, Isaacowitz, & Wingfield, 2010). Reliable data are beginning to appear in the literature that show an increase in adjusted pupil size while listening to speech for older adults, and older adults with hearing impairment (Kuchinsky, et al., 2012; Zekveld, Kramer, & Festen, 2011).

These findings are compatible with a so-called "effortfulness hypothesis" (Rabbitt, 1968, 1991); the general notion that successful perception in the face of a degraded input may draw resources that would ordinarily be available for downstream operations, in this case, such as comprehension of sentences with complex syntax and for encoding what has been heard in memory. As such, many failures in comprehension and/or recall of spoken language may have a sensory source, even when it can be shown that the speech itself had been successfully, albeit effortfully, processed. This view has been reinforced by experiments with normal-hearing participants in which speech passages, word-lists and verbal paired-associates have been acoustically masked. These studies have reliably shown a recall decrement for the materials, even when the level of masking has been adjusted to add perceptual difficulty while not preventing successful word identification (Amichetti, Stanley, White, & Wingfield, 2013; Murphy, Craik, Li, & Schneider, 2000; Surprenant, 2007). Indeed, even masking a single word in a word-list can have a negative effect on recall, not merely for that word, but for the one or two words prior to it (Cousins, Dar, Wingfield, & Miller, 2014).

BROADER ISSUES OF AGE-RELATED HEARING LOSS

Many older adults with hearing loss express the mental, and sometimes even a physical, toll taken by the continual daily effort expended on simple audition and the need to understand often complex speech from a less than clear input. In addition, and perhaps as a consequence of this effort, hearing loss can lead to reduced social interaction, isolation and loss of self-efficacy (Kramer, Kapteyn, Kuik, & Deeg, 2002).

It is the case that, as the nervous system ages, one may expect changes in sensory and cognitive systems along with other biological change (Li & Lindenberger, 2002). Recent large-scale studies have affirmed a small but statistically significant correlation between the presence and degree of peripheral hearing loss among older adults as measured by pure-tone sensitivity, and the appearance of all-cause dementia, as well as performance on cognitive tests in non-demented individuals. Strikingly, this relationship appears even when the data are statistically controlled for age, gender, education, presence of diabetes, smoking history, and hypertension (Lin, 2011; Lin et al., 2011).

As Lin (2011) has pointed out, a relationship between hearing loss and cognitive decline does not tell us whether the continuous cognitive effort hearing loss imposes on a daily basis takes a cumulative toll on cognitive reserves, whether the cognitive decline is caused or exacerbated by depression and social isolation that often accompanies hearing loss, or whether the concurrent decline in hearing acuity and cognitive function are both a reflection of an aging nervous system. Undoubtedly, all of these factors may be contributing in varying degrees to this relationship (cf., Gates, Anderson, McCurry, Feeney, & Larson, 2011; Humes, Busey, Craig, & Kewley-Port, 2013; Peelle, Troiani, Grossman, & Wingfield, 2011).

CONCLUSIONS

Traditionally, theorists have focused on just one direction of effects of limited resources, whether the focus is on a concurrently performed cognitive task constraining perceptual effectiveness (Kahneman, 1973) or perceptual effort reducing effectiveness of concurrently or sequentially performed cognitive tasks (Rabbitt, 1968, 1991; Murphy et al., 2000). However, one can postulate a single interactive dynamic in which limited resources may impede successful perception when the quality of the sensory information requires perceptual effort for success, while successful perception in the face of a degraded input may draw on resources that might otherwise be available for concurrent or downstream cognitive operations.

The related notions of cognitive effort and resource allocation have had descriptive utility in the literature for over a century (Titchener, 1908, and later Kahneman, 1973), yet the mechanisms that may underlie the negative effects of effortful listening on comprehension and recall remain to be determined. At issue is why the processing of a degraded input impairs the ability to recall identifiable words relative to clearly articulated, non-acoustically degraded words (Cousins et al., 2014; Piquado, Cousins, Wingfield, & Miller, 2010).

For older adults with a hearing impairment perceptual effort is a constant in their lives, and, as we have noted, it can be a source of stress and mental fatigue (Fellinger, Holzinger, Gerich, & Goldberg, 2007). Indeed, although our focus in this chapter has been on the effects of age-related hearing loss on spoken language comprehension, analogous concerns arise for written materials in the presence of degraded vision (Dickinson & Rabbitt, 1991; Gao, Levinthal, & Stine-Morrow, 2012). At a public health level, studies such as those cited above raise the question of whether the availability of well-fitting hearing aids may have ameliorating effects on potential age-related cognitive decline. To date this remains an interesting but still open question. A part of this question will not merely be the use of hearing amplification, per se, but also possible differential effects of different signal processing algorithms becoming available in modern hearing aids. This question of cognitive amelioration may also be extended to the increased employment of cochlear implants for older adults with more severe hearing loss (Lin et al., 2012).

Listening to and comprehending spoken language is an important human capability regardless of age. This comprehension places demands on the effectiveness of both cognitive and sensory processes. A major theme of this chapter has been the relative stability of speech comprehension in spite of the sensory and cognitive changes known to accompany adult aging. As we have seen, this stability is maintained by the compensatory utilization of age-spared linguistic knowledge, to include such features as vocabulary, syntactic knowledge, and the ability to effectively use speech prosody to aid in syntactic operations. On the negative side, we have seen that perceptual effort attendant to reduced hearing acuity can take a toll on downstream cognitive operations, such as effective encoding of what has been heard in memory.

Since the pioneering work of Welford (1958), the cognitive aging literature has been consistent in representing mental performance in adult aging as a balance between declines in basic processes such as memory, attention, and processing speed, versus the maintenance of skills and knowledge acquired through a lifetime of experience. As we have attempted to show in this chapter, comprehension and memory for spoken language stand as a model of this delicate balance.

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CHAPTER

10

Exercise, Cognition, and Health

Kirk I. Erickson[1] and Teresa Liu-Ambrose[2]

[1]Department of Psychology, University of Pittsburgh, Pittsburgh, PA, USA [2]Department of Physical Therapy, University of British Columbia, Vancouver, BC, Canada

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INTRODUCTION

The expected increase over the next several decades in the proportion of adults over the age of 65 may lead to a concomitant increase in the proportion of age-related diseases and disorders, including age-related cognitive decline, Alzheimer's disease (AD), and other types of dementia (Association, 2010). Age-related cognitive decline is relatively ubiquitous and may precede frank cognitive impairment and dementia later in life. In fact, brain pathology and brain atrophy are thought to precede the onset of age-related cognitive decline by several decades,

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indicating a growing need to identify factors earlier in life that either precipitate the onset of cognitive decline or protect against decline (Jack & Holtzman, 2013). Lending support to this idea, individual variability in both the extent and rate of decline in episodic memory, processing speed, and executive function suggests the presence of factors that influence the trajectory of cognitive losses (Salthouse, 2010). These results suggest some promising hypotheses that age-related cognitive decline may not be inevitable and that if the factors contributing to individual variation in cognitive decline could be identified we may be able to more effectively test interventions to prevent, delay, or even reverse accumulated losses (Erickson, Gildengers, & Butters, 2013).

Over the past several decades there has been an increase in the number of non-pharmaceutical products marketed as tools to potentially mitigate cognitive losses and dementia in late life. Some of these products, such as nutraceuticals and cognitive training video games, have become a major source of revenue for some organizations but are currently based on rather equivocal empirical support. Health behaviors, such as regular participation in physical activity, have also garnered attention as promising methods of reducing the risk for cognitive impairment and will be discussed in depth in this chapter.

One basic premise of this literature is that the brain, including its molecular, cellular, and structural architecture, retains the capacity to change in a favorable way in late adulthood. This premise is not as self-evident as is sometimes assumed. For example, an argument has long been made, with plentiful support from animal research, that the brain loses some of its capacity for plasticity with increasing age (Kolb & Teskey, 2012). Although animal research has not argued for a complete absence of brain plasticity in late life, a diminished capacity for plasticity may suggest that physical activity or cognitive training interventions could have limited effects in altering cognitive and brain outcomes in late adulthood. As will be seen in this chapter, it appears that the brain retains a natural capacity for plasticity in late adulthood and that physical activity has the capacity to take advantage of this natural characteristic of the brain.

Despite the many unanswered questions in this field, and the need for much more research to be conducted, we will conclude that there is considerable promise for non-pharmaceutical approaches that focus on health behaviors, and in particular physical activity, to positively influence neurocognitive function in late adulthood. We have organized this chapter by first defining important terminology and then describing epidemiological and observational results. We then discuss recent interventions and brain imaging studies that attempt to determine the neural correlates of cognitive improvements resulting from physical activity and finish by discussing the potential molecular mechanisms, other health behaviors, and take-home messages of this line of research.

DEFINITIONS

Before proceeding to a discussion of research findings it is important to first define the terminology that will be used throughout this chapter. First, the term "physical activity" is a general term often referring to any activity that may be aerobic or non-aerobic in nature and independent of the type, dose, or frequency of the activity. This may include moderate-to-vigorous forms of structured aerobic activities such as brisk walking, tennis, or swimming and hobbies such as gardening, carpentry, or dancing (Caspersen, Powell, & Christenson, 1985). Physical activity has historically been measured in cross-sectional and observational studies of cognitive aging by self-report questionnaires that ask participants to report their levels of physical activity by questions such as "On average, how many city blocks do you walk per day" (Erickson et al., 2010). The strength of these approaches is that self-report questionnaires can be easily administered in studies with large sample sizes and do not take much time to score, but their weaknesses are that they may be prone to both social desirability biases and may not reliably capture non-structured activity throughout the day (Erickson, Weinstein, & Lopez, 2012). More recent studies have begun to successfully employ objective measures of physical activity using monitoring devices, such as accelerometers and pedometers (Gow et al., 2012). These studies tend to demonstrate a greater magnitude of benefit of physical activity on cognitive and brain outcomes than studies using self-report questionnaires (Middleton et al., 2011).

Participation in physical activity influences physical fitness, such as cardiovascular endurance, muscle strength, muscle endurance, flexibility, and body composition. One measure of cardiovascular endurance is maximal oxygen capacity (VO_{2max}) and it is often used to assess the efficacy of interventions to improve cardiovascular fitness. That is, aerobic exercise interventions in which participants are randomized to a condition that receives a structured form of aerobic exercise (i.e., brisk walking) or to a more non-aerobic control condition (i.e., stretching), often use VO_{2max} to test whether the intervention effectively improved cardiovascular endurance. Most randomized exercise interventions examining neurocognitive outcomes have used aerobic forms of activity such as brisk walking with older adults, but more non-aerobic forms of activity such as resistance training have also been conducted and will be described in this chapter. Resistance training studies often incorporate measures of muscular strength (e.g., 1-repetition maximum), power, or endurance. In sum, the term "physical activity" is general and includes many forms of exercise such as strength training or aerobic exercise while VO_{2max} is a measure of aerobic capacity that is modifiable by participation in aerobic activities.

EPIDEMIOLOGICAL STUDIES

Epidemiological studies are observational in nature and examine whether engagement in physical activity is associated with longitudinal changes in cognitive function or risk for dementia. With few exceptions, these studies have found that physical activity is associated with reduced cognitive decline and a lower incidence of dementia. For example, in a study by Larson et al. (2006) 1740 men and women over the age of 65 without cognitive impairment reported the number of times per week that they performed different physical activities for at least 15 min over the past year. After a follow-up period of 6.2 years, the incidence rate of AD was significantly higher for individuals that engaged in physical activity fewer than three times per week (19.7 per 1000 person years) as compared to those who engaged in physical activity more than three times per week (13.0 per 1000 person years). In another study, Podewils et al. (2005) reported that over a course of 5.4 years in 3375 men and women over 65 years of age, greater engagement in self-reported physical activity was associated with a reduced risk of AD. Retrospective studies have also found that self-reported physical activity during early to midlife is associated with a reduced risk of dementia (Dik, Deeg, Visser, & Jonker, 2003; Middleton, Barnes, Lui, & Yaffe, 2010; Rovio et al., 2005) and mild cognitive impairment (MCI) (Grande et al., 2014). Meta-analyses of prospective studies have confirmed these associations. For example, in a meta-analysis of 15 prospective longitudinal studies including more than 33,000 participants that were followed for 1–12 years, greater engagement in physical activity was associated with nearly a 40% reduced risk for cognitive decline (Sofi et al., 2011). In sum, these studies and many others (Yaffe, Barnes, Nevitt, Lui, & Covinsky, 2001) make a convincing case that greater engagement in physical activity is associated with a reduced risk of cognitive decline and AD. In fact, Barnes and Yaffe (2011) suggest that physical activity may be the single most important modifiable risk factor for dementia in the United States.

Several recent studies have begun to use objective measures of physical activity and fitness in relation to risk for AD, and suggest that these instruments may be more sensitive to physical activity patterns throughout the day and less susceptible to biases associated with self-reports. For example, Barnes, Yaffe, Satariano, and Tager (2003) examined self-report measures of physical activity in addition to objective measures of cardiorespiratory fitness (VO_{2max}) in a 6-year study of 349 individuals over the age of 55. They found that only objective fitness measures were significantly associated with reduced cognitive decline. In another study, Buchman et al. (2012) reported that greater total daily physical activity as assessed by 10 days of continuously monitored actigraphy was associated with a twofold reduced risk of AD over a 4-year period in 716 older adults, even after controlling for self-reported physical activity. Indeed, correlations between self-reported physical activity and objective physical activity levels are often relatively low (Westerterp, 2009), which might explain why larger samples are often necessary to detect associations using self-report measures of activity while smaller samples are sufficient for detecting associations with objective measures.

Overall, the epidemiological literature has provided convincing evidence that engaging in physical activity is involved in the risk for AD, however these studies have many limitations including the use of a wide range of physical activity measures, inconsistent use of more comprehensive cognitive batteries, and the key challenge of interpreting the causal directions between physical activity and risk for AD. For example, it is possible that those individuals experiencing subtle losses in cognitive function may choose to avoid engagement in physical activity or that loss in physical functions is a prodromal marker for cognitive decline and dementia-related pathology. Randomized interventions in which physical activity is systematically increased for a period of several months is more capable of addressing this issue.

Physical Activity and Fitness Associations with Cognition

The examination of fitness, physical activity, and cognition dates back to the 1970s when Spirduso and Clifford (1978) found that older adult athletes performed significantly better on a series of simple reaction time and choice reaction time tasks compared to their sedentary counterparts and performed similarly to that of younger (18–25-year-old) adults. The association between higher fitness levels, greater amounts of physical activity, and superior cognitive performance has now been replicated in dozens of studies (Bunce, Barrowclough, & Morris, 1996) and meta-analyses of cross-sectional studies have demonstrated that engaging in physical activity or having higher fitness levels is associated with significantly better cognitive performance (Etnier, Nowell, Landers, & Sibley, 2006).

Randomized Trials of Aerobic Exercise on Cognition

Although cross-sectional studies have conclusively shown associations between physical activity, fitness, and cognitive function, these studies are naturally limited in their ability to make causal inferences about participation in physical activity and cognitive outcomes. Thus, the positive associations described in the cross-sectional literature could reflect an inherent difference between higher fit and lower fit adults in response styles, personality, genetic, or other biological or psychosocial factors. In other words, cross-sectional studies are potentially confounded by unmeasured third variables that covary with a propensity to engage in physical activity or to have higher fitness levels. To partially circumvent this issue, randomized controlled trials have been conducted that assign individuals to one of two conditions: (i) a treatment condition that receives moderate-intensity physical activity such as brisk walking or resistance training, or (ii) a control condition that receives light stretching or educational course materials. For example, in one intervention, Dustman et al. (1984) randomized 43 sedentary, but cognitively healthy, older adults to one of three groups for a 4-month period: an aerobic training group that received three 1-h walking and slow jogging sessions per week, a control group that received light strength and flexibility exercises, and a non-exercise control group. They found that the aerobic exercise condition showed improvements on measures of memory, processing speed, and inhibitory control while each of the control groups did not improve on any of these measures. Similar effects were found in a sample of 124 cognitively healthy, but low-fit older adults that were randomized to 6 months of either a brisk walking condition or to a stretching-and-toning control condition (Kramer et al., 1999). They found that the exercise group, compared with the control group, demonstrated improvements on measures that were more executive in nature including task-switching, response compatibility, and stopping tasks, while tasks and conditions less executive in nature did not show the same benefits from the exercise treatment.

The results from Kramer et al. (1999) suggested a degree of domain specificity with exercise such that executive functions may be affected more than other cognitive domains. This hypothesis was tested in a meta-analysis of 18 randomized exercise interventions that included both treatment and control groups (Colcombe & Kramer, 2003). The results suggested that the effects of exercise on cognitive function were both general and specific; general in the sense that nearly all cognitive domains improved after exercise, but specific in the sense that executive functions were affected more than other cognitive domains. Results from other meta-analyses of exercise interventions have shown relatively consistent patterns (Angevaren, Aufdemkampe, Verhaar, Aleman, & Vanhees, 2008; Hindin & Zelinski, 2012; Smith et al., 2010), but also suggest that the positive effects of exercise might be moderated by age such that older adults benefit more than younger participants (Etnier et al., 2006; Smith et al., 2010).

Resistance Training on Cognition

Although resistance, or strength, training has a broad range of systemic benefits (Borst, 2004; Layne & Nelson, 1999), very few studies to date have focused on the role of resistance training in promoting cognitive health. However, it is noteworthy that a meta-analysis (Colcombe & Kramer, 2003) of randomized controlled trials found that aerobic exercise programs that were combined with resistance training had a greater positive effect on cognitive function than aerobic exercise alone (effect size = 0.59 vs. 0.41, SE = 0.043, $P<0.05$). A key randomized controlled trial supporting the hypothesis that resistance training is beneficial for cognitive function was conducted by Cassilhas et al. (2007). They demonstrated that resistance training three times per week for 24 weeks significantly improved several measures of cognitive function among 62 community-dwelling senior men aged 65–75 years. Extending the work of Cassilhas and colleagues, Liu-Ambrose et al. (2010) found that resistance training improved selective attention and response inhibition in senior women. Specifically, 155 community-dwelling women participated in a 12-month trial that required them to engage in progressive resistance training either once or twice per week. Compared with a balance and tone control group, those in the resistance training groups performed significantly better on the Stroop Colour-Word Test at trial completion.

Effects of Exercise on Impaired Populations

These promising results from cognitively healthy older adults have prompted researchers to examine whether participation in exercise could enhance cognitive function in adults with MCI or dementia. For example, one study randomized 33 older adults with MCI to either an aerobic exercise group or to a stretching control group for 4 days per week for 6 months (Baker et al., 2010a). They found sex-specific effects such that the women in the study showed improvements in cognitive function after the intervention while the men showed only marginal improvements. In another study, 86 women with MCI were randomized to receive 2 days per week of aerobic exercise, resistance training, or a balance and toning control condition (Nagamatsu, Handy, Hsu, Voss, & Liu-Ambrose, 2012). They reported that both aerobic exercise and resistance training improved memory performance compared to the control condition. More specifically, aerobic exercise improved verbal learning memory while resistance training improved associative memory. However, only resistance training improved executive functions. These, and other studies (Lautenschlager et al., 2008), suggest that modest amounts of exercise may be an effective and low-cost method of improving cognitive function in individuals with MCI or the early stages of dementia.

Cross-Sectional Associations Between Physical Activity and Gray Matter Volume

Since 2003 there has been a dramatic rise in the number of studies using neuroimaging methods to examine whether engaging in physical activity influences the integrity of the human brain—either in terms of volume, morphology, white matter tracts, or functional outcomes. As will be described below, these studies using magnetic resonance imaging (MRI) or positron emission tomography (PET), have provided persuasive evidence that the brain retains some degree of plasticity in late adulthood and that only modest amounts of physical activity are necessary to promote a healthy brain.

One way to examine brain integrity is through assessments of gray matter volume. Unfortunately, the brain atrophies in late adulthood, and does so non-uniformly, with the prefrontal cortex, caudate nucleus, and medial temporal lobes showing the most precipitous losses. In a study to test whether higher cardiorespiratory fitness levels would be associated with greater gray matter volume, Colcombe et al. (2003) recruited 55 cognitively healthy older adults between 55 and 79 years of age and used a semi-automated method of calculating regional gray matter volume throughout the brain. As predicted, older age was associated with reduced gray matter volume in the prefrontal cortex and medial temporal lobes, but higher cardiorespiratory fitness levels attenuated the age-related decline in gray matter volume in these same regions. Thus, these results suggested some regional specificity to the effects of fitness on the brain: those regions largely supporting higher-level cognitive functions and executive functions were more strongly associated with fitness than other regions.

In another cross-sectional study, Weinstein et al. (2012) examined gray matter volume as a function of cardiorespiratory fitness levels in 139 cognitively healthy older adults and found that higher fitness levels were associated with greater gray matter volume in the prefrontal and anterior cingulate cortex and that greater gray matter volume was associated with better performance on several different cognitive outcomes including attentional control and memory processes. In fact, this finding has now been replicated in studies across the lifespan (Chaddock, Erickson, Prakash, Kim et al., 2010; Chaddock, Erickson, Prakash VanPatter, et al., 2010; Chaddock, Pontifex, Hillman, & Kramer, 2011; Chaddock et al., 2012).

Consistent with cardiorespiratory fitness results, Floel et al. (2010) used self-reported measures of physical activity in 75 cognitively healthy older adults and found that greater engagement in physical activity was associated with greater volume of the prefrontal cortex even in those with low amounts of physical activity (also see Gow et al., 2012) indicating that only modest amounts of physical activity may be sufficient for altering gray matter volume. The links with cognitive performance suggest that greater volume is not simply a meaningless by-product of higher fitness and physical activity levels but contributes to elevated cognitive function in late adulthood.

In addition to the prefrontal cortex, several studies have examined associations with the volume of the hippocampus, a region that plays a critical role in memory formation and predicts conversion to AD. For example, Erickson et al. (2009) examined cardiorespiratory fitness levels in 165 cognitively healthy adults and found that higher fitness levels were associated with greater hippocampal volumes and that larger hippocampi were associated with better spatial memory performance. In addition, Bugg, Shah, Villareal, and Head (2012) and Szabo et al. (2011) have reported that higher fitness levels are associated with larger hippocampal volumes and better executive function and reduced rates of forgetting in cognitively healthy older adults. Overall, these results provide provocative evidence that there are positive associations between hippocampal volume and physical activity habits or fitness levels.

Randomized Trials of Exercise on Gray Matter Volume

The results from the cross-sectional neuroimaging studies described above are compelling, but are limited in their capability to make causal inferences about physical activity and brain volume. To circumvent these challenges in interpretation, Colcombe et al. (2006) conducted a randomized clinical trial in 59 cognitively healthy older adults and found that 6 months of participation in moderate-intensity exercise 3 days per week resulted in an increase in gray matter volume in the prefrontal and anterior cingulate cortex compared to a stretching-toning control group. There is also evidence for plasticity of the hippocampus with exercise. For example, Erickson et al. (2011) randomized 120 cognitively healthy older adults to either a brisk walking exercise group or to a stretching-toning control group for 12 months. They found that the brisk walking condition increased the size of the hippocampus while the stretching control group showed a decline over the same period.

Associations Between Physical Activity, Fitness, and White Matter Integrity

White matter integrity also declines in late adulthood and has been linked to slower processing speed and poorer executive function. Fortunately, several studies have examined if physical activity is associated with elevated white matter integrity in late life. In one study, Tseng et al. (2013) using diffusion tensor imaging (DTI) examined white matter integrity in ten older adult athletes compared to ten sedentary controls. They found that the older adult athletes had greater white matter integrity and fewer white matter lesions compared to their sedentary peers. Similar effects were found when examining cardiorespiratory fitness levels in a sample of 26 cognitively healthy older adults (Johnson, Kim, Clasey, Bailey, & Gold, 2012) (also see Marks et al., 2007) and when using self-reported levels of physical activity. For example, in 276 older adults, Tian et al. (2014) found that greater self-reported physical activity levels were associated with greater white matter integrity in the medial temporal lobes and cingulate cortex. Although few randomized trials have as of yet examined effects of increasing physical activity on white matter integrity, one randomized intervention of 70 cognitively healthy older adults found negligible group-wise effects of the intervention on white matter integrity, but found that those individuals showing a greater change in aerobic fitness levels from the aerobic exercise intervention showed an increase in white matter integrity after the completion of the intervention (Voss, Heo et al., 2013). These results are consistent with those reported for gray matter volume, but since there has only been one randomized intervention examining white matter integrity, it remains difficult to draw causal conclusions about whether an exercise intervention influences this tissue property.

Aerobic Exercise Effects on Functional MRI Patterns

In addition to volumetric studies, several functional MRI studies have examined whether exercise changes the dynamics of brain function. For example, Colcombe et al. (2004) found in cognitively healthy older adults that higher cardiorespiratory fitness levels were associated with greater brain activation during an attentionally demanding task in the prefrontal and parietal cortices and reduced activation in the anterior cingulate cortex. Similar effects were found in older adults randomized to receive either an exercise brisk walking condition compared to those randomized to a stretching-toning condition (Colcombe et al., 2004). Other functional MRI studies have found similar associations such that greater prefrontal cortex activation is associated with higher fitness levels (Prakash et al., 2011; Vidoni et al., 2013) or that maintenance of physical activity after the completion of an intervention resulted in greater prefrontal cortex activation (Rosano et al., 2010). Greater amounts of self-reported physical activity have also been associated with increased activity in the prefrontal cortex compared to sedentary peers (Smith, Nielson, Woodard, Seidenberg, Verber et al., 2011) and a 12-week randomized exercise intervention in individuals with MCI increased activation in the prefrontal cortex during a semantic memory task (Smith et al., 2013). In addition to task-evoked activation patterns, Voss et al. (2010) found that higher cardiorespiratory fitness levels were associated with greater functional connectivity in regions of the so-called default mode network, and these associations explained some of the link between cardiovascular fitness and cognitive function (also see Burdette et al., 2010).

Effects of Resistance Training on Cerebral Blood Flow and fMRI Patterns

In a cross-sectional study of 59 older adults, Xu et al. (2014) acquired MRI resting state cerebrovascular perfusion data. It is hypothesized that one mechanism by which physical activity maintains cognitive function in older adults is by augmenting cerebral perfusion. Xu et al. demonstrated that women who engaged in resistance training at least once per week exhibited greater cerebrovascular perfusion than women who did not. This interaction remained significant after controlling for other physical activity, demographics, and health variables.

In a 12-month randomized controlled trial of resistance training with 155 older women aged 65–75 years old, Liu-Ambrose, Nagamatsu, Voss, Khan, and Handy (2012) showed that twice-weekly resistance training increased neural activation in the anterior portion of the left middle temporal gyrus and the left anterior insula extending into lateral occipital frontal cortex. Among older women with MCI, Nagamatsu et al. (2012) demonstrated that twice-weekly resistance training improved associative memory performance (i.e., the ability to remember items that were previously presented simultaneously). In conjunction, regional patterns of functional plasticity were found in the resistance training group. Specifically, three key regions in cortex showed greater functional activation during the associative memory task after 6 months of training—the right lingual gyrus, the right occipital-fusiform gyrus, and the right frontal pole.

Mediators and Moderators

Animal studies have been influential in our understanding of the molecular pathways that explain how exercise affects the brain. These studies have shown that exercise is capable of increasing the rate of angiogenesis, or the production of new capillary beds, in several brain areas including the cerebellum, striatum, and cortex (Voss, Vivar, Kramer, & van Praag, 2013). A greater number of capillary beds in the brain allows more nutrients and oxygen to enrich the tissue, thereby providing a healthier environment for existing cells. Exercise also increases the proliferation and survival of new neurons in the dentate gyrus of the hippocampus, which are involved in enhanced learning and memory associated with exercise (Erickson, Miller, & Roecklein, 2012). These cellular changes are likely occurring through a cascade of several different molecules including increased BDNF and IGF-1 expression, decreases in pro-inflammatory cytokines, and changes in several different neurotransmitter systems including dopamine and serotonin (Hillman, Erickson, & Kramer, 2008). Because of the limitations in studying these molecular pathways in human brain tissue, research has examined the extent to which blood-based changes in these molecules may be linked to improvements in either cognitive or brain function. For example, Erickson et al. (2011) found that increases in hippocampal volume after a 12-month aerobic exercise intervention were positively correlated with increased serum BDNF levels. Voss, Erickson et al. (2013) also reported that aerobic exercise-related changes in functional connectivity were correlated with increases in serum BDNF and IGF-1 levels while IGF-1 was associated with cognitive improvements after resistance training (Cassilhas et al., 2012). Exercise-induced changes in insulin sensitivity and pharmacokinetics may also play a role in mediating the improvements in cognitive performance (Baker et al., 2010b; Tarumi et al., 2013). Nonetheless, despite this promising research we still have a poor understanding in humans of how the different molecular pathways are related to brain and memory functions that improve with exercise and how the different molecular systems may differ between resistance and aerobic exercise (Cassilhas et al., 2012).

Exercise does not influence neurocognitive function equally for all people. That is, some individuals benefit more than others and understanding the factors that may be attenuating or magnifying the effects may encourage the development of tailored interventions. There is some evidence that exercise may be able to attenuate the genetic susceptibility associated with risk for dementia. For example, Smith, Nielson, Woodard, Seidenberg, Durgerian, et al. (2011) has shown that the positive effect of physical activity on functional MRI activation is moderated by the APOE genotype such that APOE ε4 carriers benefited more than non-carriers from physical activity. In support of this result, Head et al. (2012) using PET reported that APOE ε4 carriers showed reduced amyloid levels when they engaged in greater amounts of physical activity relative to APOE ε4 carriers that did not engage in physical activity. Although not all studies have shown the same effects (Podewils et al., 2005), there is growing evidence that genetic susceptibility for cognitive or brain decay may be an important moderator of physical activity with those carrying the risk allele demonstrating the greatest benefits of physical activity (Erickson, Banducci et al., 2013).

Other Health Factors Related to Cognition

In this chapter we have focused on the effects of physical activity and exercise as an important health behavior that influences cognitive and brain function in late adulthood. This emphasis on physical activity, however, does not mean that other health behaviors and health factors are not important in influencing cognitive and brain function in late adulthood. In fact, there is considerable evidence that high blood pressure is associated with both impaired cognitive function, an increase in white matter lesions, increased risk for dementia, and reduced gray matter volume (Bender & Raz, 2012; Goldstein, Bartzokis, Guthrie, & Shapiro, 2002; Kivipelto et al., 2001; Leritz et al., 2010; Tzourio, Dufouil, Ducimetiere, & Alperovitch, 1999; Whitmer, Sidney, Selby, Johnston, & Yaffe, 2005). In fact, the association between high blood pressure and poorer cognitive function may be exacerbated by genetic susceptibility for dementia (de Leeuw et al., 2004; Peila et al., 2001; Zade et al., 2010), indicating moderating effects between genetic and health-related variables. Obesity is also an important health factor that has been found to increase the risk for dementia (Raji et al., 2010) and is related to impaired white matter integrity (Verstynen et al., 2013) throughout the brain and reduced activation in prefrontal brain circuits (McFadden, Cornier, Melanson, Bechtell, & Tregellas, 2013). Unfortunately there is limited evidence for weight loss interventions to have any lasting impact on cognitive performance in late life (Siervo et al., 2011).

Insulin resistance and leptin resistance are often both correlated with obesity and high blood pressure and both play an important role in cognitive function and brain health. Along these lines, more studies have been examining the impact of the metabolic syndrome (MetS) on cognitive function throughout the lifespan. MetS is a cluster of metabolic factors that increase risk for cardiovascular diseases and often includes the presence of Type II diabetes or insulin resistance. Using the MetS criteria, several studies have reported associations with both brain volume (Onyewuenyi, Muldoon, Christie, Erickson, & Gianaros, 2014) and impaired cognitive function (Yates, Sweat, Yau, Turchiano, & Convit, 2012) in mid to late life. These studies, and many others, have suggested an important role of cardiovascular and metabolic risk factors in cognitive and brain health and risk for dementia in late life. In fact, improvements in cardiovascular health may be an important pathway by which increased physical activity has long-term positive effects on the brain.

CONCLUSION

It is clear that cross-sectional research has shown that higher fitness levels and greater engagement in physical activity are almost uniformly associated with elevated cognitive function, greater prefrontal cortex and hippocampal volume, greater white matter integrity, increased prefrontal activation during challenging cognitive tasks, and increased resting state connectivity between the hippocampus and prefrontal cortex. Although there have been fewer randomized trials of exercise, those that have been conducted have supported the cross-sectional research and demonstrate that interventions are capable of improving cognitive function—especially executive and memory function, increasing gray matter volume, improving resting state connectivity, and increasing the efficiency of task-evoked activation. Finally, the cognitive and neuroimaging studies are supported by a large body of epidemiological studies that have clearly demonstrated that engaging in greater amounts of physical activity is associated with a reduced risk of experiencing cognitive decline or dementia. In short, epidemiological, cognitive, and neuroimaging studies have provided a body of convincing research on the positive effects of exercise on brain health and function.

Despite these promising results there are several outstanding issues that have yet to be resolved. First, although there is growing evidence from cross-sectional and intervention research that both aerobic and resistance exercise influence brain and cognitive outcomes in MCI and dementia, more studies are needed to characterize and understand these effects. For example, we have a poor understanding of the potential for physical activity to act as a primary or secondary prevention of dementia or as a treatment for existing impairments. Along these lines, there is currently no evidence that an exercise intervention will have long-term consequences on slowing the incidence rates of dementia. Answers to these issues could have far-reaching public health implications for both dementia and other neurologic and psychiatric conditions.

There is also a paucity of research on the most appropriate dose of exercise, the frequency or duration, or the type of exercise most effective for enhancing memory and cognitive function. In addition, we still know very little about whether the exercise prescription would differ depending on the baseline cognitive status of the individual. Although most intervention studies have reported that 3 days per week is sufficient for detecting significant improvements in brain and cognitive outcomes, we have little evidence for whether greater frequencies or intensities of activity would be more beneficial or whether lower frequencies would show equivalent effects (Nagamatsu et al., 2012). Before physical activity can be widely prescribed as a method of improving cognitive function there is a need to identify the doses in which activity would prove to be most beneficial for the widest range of adults.

Finally, although we have a growing understanding of the possible mechanisms for how exercise influences the brain along with clear associations between other cardiovascular and cardiometabolic health factors and brain function, we have a poor understanding of the primary pathways involved and the ways in which cardiovascular, metabolic, and physical activity behaviors and predictors influence brain health and function together. Since these factors are correlated with one another, it will be important to determine the extent to which associations between obesity and brain health can be independently explained by physical inactivity, hypertension, or other cardiovascular risk variables.

In sum, we have highlighted some of the most recent and compelling research on physical activity and cognitive function and argue that this research demonstrates not only a hope that physical activity could be a promising method for improving brain function but that it also demonstrates a clear capacity for brain plasticity in late adulthood.

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CHAPTER

11

Personality and Health: Reviewing Recent Research and Setting a Directive for the Future

Patrick L. Hill[1] *and Brent W. Roberts*[2]

[1]Department of Psychology, Carleton University, Ottawa, ON, Canada [2]Department of Psychology, University of Illinois at Urbana-Champaign, Champaign, IL, USA

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For decades, researchers have noted the importance of understanding how individual differences influence health and well-being (Adler & Matthews, 1994; Eysenck, 1985; Ferguson, 2013; Smith, 2006). Toward this end, studies have consistently supported the role of personality variables, such as traits, motives, and goals, as informative for predicting current and future health outcomes. While initial work along this front focused solely on the "direct effects" of personality dispositions on health, more recent work has focused on understanding the pathways by which this influence occurs, as well as the extent to which personality effects get "under the skin" and predict physiological markers (Hampson, 2012). Given the changing contexts and behaviors that influence health, as well as the developmental specificity of certain disorders and illnesses, research on personality and health cannot operate without acknowledgment of the aging process. In other words, researchers must actively consider the effects of personality on health through the lens of lifespan developmental theories.

To support and encourage research along this front, this chapter strives toward tackling some less typical topics related to personality and health. This shift in focus corresponds to the need to start taking some things "for granted," if research is to continue to advance. For instance, gone are the days when one needs to justify claims like "personality predicts health" (see Ferguson, 2013; Hampson, 2012; Smith, 2006, for reviews), or that "personality can change across the lifespan" (see Caspi & Roberts, 2001; Roberts, Walton, & Viechtbauer, 2006; Roberts, Wood, & Caspi, 2008, for reviews). Instead, we focus our review on three questions that have shaped the zeitgeist of personality and health research. First, does personality predict physiological markers of health? Second, does the role of personality on health operate through different pathways across the life course? And similarly, could personality impact health by promoting success and achievement of developmentally specific benchmarks? Third, how might changes in health and well-being shape one's personality development? While relatively less research has addressed this final question, it should prove a particularly important topic of inquiry for aging researchers in the years ahead, given the naturally deteriorative progression of health throughout the lifespan.

PERSONALITY TRAITS: DEFINITIONS AND CLASSIFICATIONS

Like the field itself, our chapter will focus on the role of traits in explaining how personality can predict health outcomes. Over recent decades, research has accrued to describe the role of other person-based variables, such as goals (Elliot & Sheldon, 1998; Emmons, 1992; King, 2001), life narratives (Pals, 2006; Pennebaker & Seagal, 1999), and emotions (Pressman & Cohen, 2005; Salovey, Rothman, Detweiler, & Steward, 2000) on physical health and well-being. However, much less work has focused on these non-trait components with respect to the three objectives for the current chapter, a point we touch upon in the discussion section.

Prior to beginning our review, some definitional issues merit discussion. To start, we define personality traits as "relatively enduring, automatic patterns of thoughts, feelings, and behaviors that reflect the tendency to respond in certain ways under certain circumstances" (Roberts, 2009, p. 140). With respect to health psychology, two aspects of this definition are particularly valuable to consider. First, by noting the role of cognitions in traits, it provides a valuable linkage to the social-cognitive work on health intervention programs. Indeed, variables like self-efficacy and perceived control can and should be viewed as aspects of or at least concomitants of dispositional traits (see Roberts et al., 2014, for more detail).

Second, this definition of traits provides insight into the strength of the relationships one should expect when it comes to health outcomes. Traits are not to be viewed as perfect predictors of how one will act in any given situation. Even highly conscientious individuals occasionally partake in too much frivolity and drink or eat to excess. Indeed, if one merely looks at the correlations for performing the same behavior across two instances, studies often report magnitudes similar to what Cohen (1988) would deem only a medium effect size (Borkenau, Mauer, Riemann, Spinath, & Angleitner, 2004; Funder & Colvin, 1991). As such, it is highly unlikely that traits will ever prove "strong" predictors of health outcomes, particularly when paired with the knowledge that a wealth of other variables also influence physical health (e.g., socioeconomic status, intelligence, bad luck).

Accordingly, while most of the effects reviewed here are small to medium in magnitude, it is perhaps more impressive that they are consistently demonstrated at all. Moreover, meta-analytic work suggests that personality traits often provide as strong of effects on outcomes like mortality as do "traditional" predictors like socioeconomic status and IQ (Roberts, Kuncel, Shiner, Caspi, & Goldberg, 2007). The impressive power of personality may be no clearer though than when predicting physiological markers of health, including outcomes determined by multiple factors, such as cardiovascular disease, obesity, and physical fitness known to be highly influenced by genetics and early environment.

DISPOSITIONS AND HEALTH: A BRIEF HISTORY OF MODELS IN THE FIELD

One of the most well-referenced models connecting personality and health comes from a review by Adler and Matthews (1994) that was updated recently in Bogg and Roberts (2013). This work presents three general pathways by which personality traits predict who gets ill. First, dispositions predict who participates in health behaviors (Bogg & Roberts, 2004; Smith, 2006), which in turn influence physiological mechanisms and ultimately health. Second, personality traits can predict these mechanisms directly. Third, personality traits may correspond with or influence social environmental characteristics, which then influence both of the constructs above. Evidence for the first claim is now well-known (see Bogg & Roberts, 2004; Hampson, 2012), and some work has long linked personality traits to social environmental factors, such as occupational success (Roberts, Caspi, & Moffitt, 2003), marital stability (Roberts et al., 2007), relationship quality (Hill, Nickel, & Roberts, 2014), and broader institutions such as community and religious affiliations (Lodi-Smith & Roberts, 2007). As the second pathway (through physiology) has become of increasing interest in the past decade, we review this literature in greater detail as our first focus below.

While relatively simple in its presentation, this framework has proven a valuable foundation for more contemporary models in the field given the broad empirical support described above (Bogg & Roberts, 2013; Ferguson, 2013; Friedman, Kern, Hampson, & Duckworth, 2014). Comparing these models to the original Adler and Matthews (1994) work demonstrates just how far the field progressed within that two-decade span. Now there is a greater recognition that personality traits can influence the ways by which individuals seek assistance for their health, think about and cope with potential issues, and even become aware of these concerns. However, relatively few models have considered whether and how these different links might change over the life course. In addition, only recently have papers acknowledged the potential for health itself to influence whether adults can change their dispositional tendencies (Kern & Friedman, 2011; Sutin, Zonderman, Ferrucci, & Terracciano, 2013).

Accordingly, our review advances the claim that even the most multidimensional models of personality and health today often fail to capture just how impressively complex the relationship between these two variables may in fact be. Therefore, we present the evidence for these additional links, as well as the recent work connecting personality and physiological mechanisms, and then conclude by noting how best to account for this work in the extant models.

PERSONALITY TRAITS AND PHYSIOLOGICAL MARKERS OF AGING

When considering the role of personality on physiology, we focus below on markers of clear interest to the process of healthy aging. Specifically, we organize our review into effects on inflammatory markers and cardiovascular variables. Most of the research along these fronts has focused on the role of the higher-order Big Five personality traits (Digman, 1990; John, Naumann, & Soto, 2008): extraversion, agreeableness, conscientiousness, neuroticism (or conversely, emotional stability), and openness to experience. As noted elsewhere, conscientiousness and neuroticism tend to be the strongest predictors of health behaviors (Hampson, 2012), results that appear to carry over to the physiological domain.

Inflammatory Markers and Personality Traits

Quite recently, a number of studies have pointed to the potential for the Big Five traits to predict markers of inflammation. For instance, multiple studies now point to consistent relationships between traits and interleukin-6 (IL-6) levels (Sutin, Terracciano, et al., 2010; Turiano, Mroczek, Moynihan, & Chapman, 2013). Increased levels of IL-6 lead to greater inflammation in reaction to an injury, which while beneficial in acute cases, becomes problematic when its production is more chronic in nature. This marker is of particular interest for aging researchers, given its propensity to increase with age (Maggio, Guralnik, Longo, & Ferrucci, 2006).

Across multiple samples, research suggests that conscientious and emotionally stable (less neurotic) individuals tend to exhibit lower levels of IL-6, even when controlling for an array of health behaviors and other control variables (Chapman et al., 2011; Sutin, Terracciano, et al., 2010; Turiano et al., 2013). These significant relations have been exhibited across multiple facets, or lower-order traits, for each broader domain trait (Sutin, Terracciano, et al., 2010). Moreover, research suggests that it may be valuable to examine the interaction between these two traits (Turiano et al., 2013). Interestingly, while neuroticism in general positively predicts IL-6 levels, those findings suggest that being moderately neurotic may be adaptive in the context of high conscientiousness. These findings point to the potential for a "healthy neurotic" (Friedman, 2000), or the possibility that having some anxiety may be a good thing when it comes to health, otherwise one might miss health concerns or symptoms when they become present.

Another outcome that has been targeted in personality research is C-reactive protein (CRP), another variable for which elevations can be valuable in cases of acute injuries, though chronically elevated levels have been associated with a greater risk of cardiovascular disease (Lagrand et al., 1999). Although fewer studies have examined CRP, the results again often suggest a beneficial role for conscientiousness (Mõttus, Luciano, Starr, Pollard, & Deary, 2013; Sutin, Terracciano, et al., 2010), although this is not always the case (Armon, Melamed, Shirom, Berliner, & Shapira, 2013). Additionally, studies have suggested a positive role for openness to experience (Armon et al., 2013; Mõttus et al., 2013), but maladaptive effects for neuroticism (Armon et al., 2013; Sutin, Terracciano, et al., 2010).

Cardiovascular Indicators and Personality Traits

Another important domain of interest is how personality traits predict cardiovascular markers. Such research builds from some of the "classic" work on personality and health, wherein hostility and aggression were linked to greater risk of cardiovascular disease (see Booth-Kewley & Friedman, 1987, for a review). More recent efforts also have shown that conscientiousness and neuroticism predict a wide variety of cardiovascular health outcomes, positively and negatively, respectively (Hagger-Johnson et al., 2012; Schwebel & Suls, 1999; Shipley, Weiss, Der, Taylor, & Deary, 2007). For instance, neuroticism predicts mortality risk from cardiovascular disease (Terracciano, Löckenhoff, Zonderman, Ferrucci, & Costa, 2008). However, efforts to find consistent linkages at the physiological level have proven difficult, perhaps in part due to the inherent variability with cardiovascular markers. For example, one study demonstrated relationships between personality traits with blood pressure readings for both extraversion and agreeableness, but underscored the modest nature of these effects (Miller, Cohen, Rabin, Skoner, & Doyle, 1999).

That said, it is interesting to note that relationships between cardiovascular health and personality traits appear to hold even when considering potential counter-explanations. For instance, at least one study has found little evidence that common genes may underlie both personality traits and cardiovascular risks (Pilia et al., 2006). Furthermore, the study above on blood pressure found that even those modest associations with personality traits held when controlling for various health practices (Miller et al., 1999). In other words, personality traits appear associated with cardiovascular health, even when accounting for how both are influenced by our genes and experiences.

Instead of focusing on one cardiovascular outcome or another, a more promising approach may be to consider constellations of biomarkers and health indicators. One recent direction has been to focus on how personality might predict diagnoses of "metabolic syndrome," which reflects whether one presents with multiple risk factors, including poor blood pressure, cholesterol issues, and higher waist circumference. Diagnoses along this front are in turn predictive of major health issues such as obesity, diabetes, and even death by cardiovascular causes (Grundy, 2008; Grundy et al., 2005). Therefore, it is of interest to note that research is beginning to suggest that conscientious, agreeable, and emotionally stable individuals might experience a reduced risk for metabolic syndrome (Sutin, Costa, et al., 2010). Similarly, aspects of neuroticism like depression and distress appear predictive of greater risk (Heiskanen et al., 2006; Mommersteeg, Kupper, & Denollet, 2010).

Two recent studies from the Dunedin Multidisciplinary Health and Development Study examined more comprehensive sets of physiological health markers that used inflammatory, cardiovascular, and metabolic indices (Israel et al., 2014; Moffitt et al., 2011). In the first study, composite measures of childhood low self-control were used to predict health-related physiological markers at age 32 both in composite and individually (Moffitt et al., 2011). Children who were lower in self-control at age 10 showed early signs of poor health at age 32 even when controlling for cognitive ability and socioeconomic background. In particular, low self-control predicted elevated levels of CRP, higher incidence of metabolic abnormalities, and even elevated levels of periodontal disease. In the second study, observer ratings of personality traits at age 26 were used to predict physiological markers of poor health at age 38 (Israel et al., 2014). Once again, conscientiousness was related to fewer health-related problems as indexed with a composite of physiological abnormalities such as high blood pressure, inflammatory markers, low HDL cholesterol, elevated CRP, and poor pulmonary functioning.

Although past research has linked higher levels of conscientiousness to lower levels of self-reported diseases (Goodwin & Friedman, 2006), links to objectively defined diseases or disease markers are less common. Some research has tied low conscientiousness to poor glycemic control in type I diabetes patients (Lane et al., 2000). While other research has shown that high conscientiousness is a protective factor for renal failure in dialysis patients (Brickman, Yount, Blaney, Rothberg, & De-Nour, 1996). Yet strong links to well-known diseases such as diagnosed cardiovascular disease or certain forms of cancer are rare.

In contrast, one disease of aging, Alzheimer's disease, has been consistently linked to conscientiousness (Terracciano et al., 2014). From simple cross-sectional studies differentiating people with Alzheimer's versus those without (Duchek, Balota, Storandt, & Larsen, 2007), to longitudinal prospective studies (Wilson, Schneider, Arnold, Bienias, & Bennett, 2007), conscientiousness has been shown to be a protective factor for Alzheimer's disease. Moreover, a recent meta-analysis of the longitudinal prospective studies showed that conscientiousness was not only protective at the aggregate level, but also in each and every one of the studies that were analyzed (Terraccianno et al., 2014). Quite possibly the most interesting aspect of this line of research is the finding in post-mortem studies that the level of neuropathology does not mediate the relation between conscientiousness and Alzheimer's disease (Terracianno et al., 2013; Wilson et al., 2007). In other words, conscientiousness appears to have an influence on Alzheimer's development that is unaccounted for at the level of known pathology. Moreover, many of the factors that one would presume to account for the role of conscientiousness in Alzheimer's such as cardiovascular disease, smoking, and poor health failed to account for the effect of conscientiousness (Wilson et al., 2007). Thus, conscientiousness appears to protect against the onset of Alzheimer's disease but the reasons why remain elusive.

In sum, research has begun consistently demonstrating linkages between conscientiousness and biomarkers of aging and health. Nonetheless, much work remains to be done. Future research must continue to reconsider what these relations mean, why they occur, and what are the best methods for combining biomarkers into meaningful constellations, which may prove most useful for health care application.

PERSONALITY AND HEALTH ACROSS ADULTHOOD: MODERATORS, MODERATED MEDIATORS, AND MORE

The literature above presents the case for why personality traits are related to biomarkers of the aging process. However, another important question is whether personality predicts health differently across the adult years, as well as if these relationships are explained by the same mechanisms. In other words, are the links between traits and health *moderated* by age, and is there any evidence for *moderated mediation*, or that the variables linking personality to health may do so to a stronger or weaker extent throughout adulthood?

Age as a Moderator of Personality Traits and Health

The impressive strength of personality as a predictor of health comes in part from the fact that these relationships often are quite stable throughout the life course. For instance, research suggests that conscientiousness positively predicts self-rated health across adulthood (Hill & Roberts, 2011). Similarly, moral personality traits, like dispositional forgiveness and gratitude, appear to predict emotional and subjective health relatively equally throughout adulthood (Hill & Allemand, 2011; Hill, Allemand, & Roberts, 2013). However, this research has been relatively limited, even when discussing more subjective health outcomes like happiness and affect (see Hill, Mroczek, & Young, 2014, for a review). As such, more research is needed to examine the potential moderating role of age.

Age as a Moderator of the Linkages Between Personality Traits and Health

One potential reason for this paucity of work might be that it often proves difficult to make clear theory-driven predictions for why such linkages might occur. Presumably simpler is the possibility of describing why personality traits would differentially predict health behaviors across the lifespan, or that certain behaviors may be more important for health at different periods of adulthood, either of which would lead to these indirect effects being conditional by age. The intuitiveness of these predictions results from the well-known fact that individuals face greatly different risks for illness and mortality across adulthood. As such, one would anticipate that specific behaviors would prove more or less beneficial in the face of the changing needs for health. As such, the indirect pathways between personality traits and health should differ across adulthood, mostly as a result of the links between specific health behaviors and health changing in magnitude (the "second" half of the pathway).

With respect to the "first" half, research has shown that age moderation effects differ depending on the specific behavior evaluated. For instance, a meta-analysis of conscientiousness and health behavior (Bogg & Roberts, 2004) found that the trait was a stronger predictor of activity level, alcohol use, drug use, unhealthy eating, risky driving, and tobacco use for younger than older adults. One rationale for these findings is that these behaviors might be of greater relevance for younger adults, or at least have greater variability during this period, in turn allowing a greater opportunity for moderation effects. However, similar arguments could be made for risky sexual activity, suicidal behavior, and violence, outcomes that failed to show any age moderation in that sample. In addition, research also has demonstrated little evidence for age as a moderator of the links between conscientiousness and medical adherence (Hill & Roberts, 2011). Similarly, work on gratitude shows little age moderation when predicting medical care behaviors (Hill et al., 2013). It may be that the effect is especially small and only detectable with the sample sizes that are afforded in meta-analytic work.

In other words, age may prove to be a more specific rather than universal moderator of the links between personality and either health or health behavior. Accordingly, it is worth noting a few other potential moderators. For instance, research has suggested that socioeconomic status might play a role, insofar that traits may prove differentially protective or deleterious based on economic strata (Chapman, Fiscella, Kawachi, & Duberstein, 2010). In addition, one of the more promising avenues in recent health psychology research considers the potential for traits to serve as the moderators. Along this front, one of the more consistently published effects is that conscientiousness may prove to moderate the known negative relationship between neuroticism and health, a dynamic that leads to the "healthy neurotic" phenomenon (Friedman, 2000; Turiano et al., 2013). Specifically, the detriments associated with neuroticism might be buffered by being relatively conscientiousness at the same time. Interestingly, some evidence even suggests that it may be better to be both conscientious and (somewhat) neurotic than to be conscientious and emotionally stable (Turiano et al., 2013). In this respect, one can see the healthy neurotic concept at play; some anxiety might prove adaptive in order to encourage one to maintain vigilance with respect to health promotion, a process that comes more easily for conscientious individuals. These trait-by-trait interactions will prove an exciting avenue for future personality and aging research, particularly given the known associations between adult role engagements and development on conscientiousness and neuroticism (Bleidorn et al., 2013; Lodi-Smith & Roberts, 2007).

The Full Role of Age on the Linkages Between Personality and Health

Based on the evidence above, one might conclude that age plays only a limited role in describing the pathways between personality traits and health, although this evidence is notably limited in some key places. However, this work should not be taken as evidence that these pathways are wholly consistent across the adult years. Indeed, multiple studies have pointed to the fact that these indirect effects are conditional on age, primarily due to the differing relationships between health behaviors and health (Hill & Roberts, 2011; Hill et al., 2013). For instance, conscientious individuals adhere better to their medication regimens, a mediator that appears more relevant for understanding the health benefits of the trait later in the lifespan (Hill & Roberts, 2011). Certainly it proves rather intuitive that following your medications is more important as you get older. While these explanations for moderated mediation might be less exciting or novel compared to the potential roles for age discussed above, they can provide valuable insights into holes in the literature and directions for future research. For instance, if conscientiousness appears similarly predictive of health across adulthood, but certain mediators (e.g., medication adherence) are stronger predictors for older adults, what are the variables that better explain the health benefits of conscientiousness for younger adults? Questions like these will help build upon current models of personality and health to examine the roles of different potential mediators not only relative to each other, but also relative to the developmental period of interest.

HEALTHY LIVING AS A CATALYST FOR PERSONALITY DEVELOPMENT

To this point, our discussion and more broadly the field has focused on how personality traits lead to health outcomes. This directionality is expected for two primary reasons. First, personality traits were classically assumed to exhibit little to no change during the adult years (Costa & McCrae, 1992), and in fact, research does point to the fact that personality stability tends to increase with age (Roberts & DelVecchio, 2000). Second, to justify the merit of studying personality traits, early research often focused on showing their value for predicting "hard" medical outcomes, like mortality. As such, it is unsurprising that relatively little research has examined the potential for health (or changes in health) to have lasting effects on personality development in adulthood.

We present the case here for additional research on this front based on three relatively recent findings. First, markers of subjective wellbeing appear to predict changes in adult personality traits (Hill, Turiano, Mroczek, & Roberts, 2012; Specht, Egloff, & Schmulke, 2013). Second, living a healthy lifestyle might engender a more adaptive personality profile (Stephan, Sutin, & Terracciano, 2014; Takahashi, Edmonds, Jackson, & Roberts, 2013). Third, experiencing a major illness might enact lasting personality change. Each of these points is taken up below, as support of calls for increasing work on the "other side" of the personality and health relationships (Kern & Friedman, 2011). When possible, across each section we will discuss two potential findings of relevance: (i) evidence that initial status in health or health behavior predicts personality trait change, or "predictive effects," (ii) results that suggest changes in these health variables coincide with those on personality traits, or "correlated change effects."

Subjective Wellbeing and Adult Personality Change

Health clearly reflects a number of dimensions outside of simply risk for physical ailments, including one's social and psychological wellbeing (World Health Organization, 1948). As such, it is worth noting that individuals higher on these other dimensions of health appear to experience more "adaptive" changes on personality profiles. For instance, one study examined how life satisfaction predicted changes in personality maturation among German adults (Specht et al., 2013). This work demonstrated that individuals initially more satisfied with their lives were prone to become more emotionally stable, agreeable, and conscientious over the span of the next 4 years. Similarly, research has demonstrated correlated changes between personality traits and social wellbeing, insofar that increases in social wellbeing tend to coincide with adaptive trait changes (Hill et al., 2012).

A few interpretations of these findings are possible, which lead to directions for future research on positive aging and personality development. First, if life satisfaction and social wellbeing serve as proxies for health and adaptive aging, these findings present evidence that healthier individuals experience more positive personality change. Second, if these indicators of subjective wellbeing serve as proxies for adaptive role attainment (e.g., marriage, community engagement, employment, etc.), then the findings discussed above provide support for the claim that success in adulthood might promote positive personality change, as has been suggested before (Roberts et al., 2008). Third, the studies above may present evidence when people act in ways that promote health and wellbeing, they reap the rewards thereof, which serves as a form of feedback for which personal dispositions and characteristics upon which they should focus. Disentangling these three closely linked hypotheses should serve as a catalyst for future research, and relatively recent work has begun to test this third possibility.

Healthy Behaviors as Predictors of Personality Change

While this work is in its infancy, research has begun to test whether enacting a healthier lifestyle could promote positive personality change, and the findings are modestly positive thus far. For instance, one study found that individuals who reported an increased tendency to engage in preventative health behaviors (wellness maintenance, accident control, physical activity, etc.) over a 3-year span also tended to increase on conscientiousness during that period (Takahashi et al., 2013). In addition, research with middle-aged and older adults has demonstrated that more physically active individuals were less likely to experience maladaptive changes in personality over time (Stephan et al., 2014), although the effects were fairly modest in magnitude. Taken together, these correlated change and longitudinal findings point to the potential for healthy engagement to beget positive (or less negative) personality changes among adults. Moreover, it is important to note that both studies found effects for conscientiousness, and the second also demonstrated some findings with respect to agreeableness, suggesting that the effects are not specific to those traits for which assessments often explicitly ask about activity, agency, and engagement (e.g., extraversion and openness).

Major Illness as a Predictor of Personality Change

To this point, we have focused on the role of positive health outcomes and behaviors on personality change and development. However, equally, if not more, intriguing is the potential for negative health outcomes and major health-related struggles to influence personality change. This intrigue comes from the fact that one could easily expect significant findings to occur in either direction. Individuals who experience a life-changing medical event (e.g., stroke, heart attack, etc.) may fall into a depressogenic mindset and be more likely to perceive that their health outcomes are beyond their control; in turn, these individuals could focus less on living a self-controlled, emotionally stable lifestyle and thus experience personality corruption as a result. Alternatively, experiencing such an event might shake individuals from their initially negative lifestyles, and redirect them toward a more conscientious and less neurotic path. The second possibility may prove particularly likely given that individuals who experience negative health events are likely to be lower on adaptive personality traits in the first place (Goodwin & Friedman, 2006; Hampson, 2012).

Though limited, research has demonstrated a complex set of results that support both possibilities. For instance, one study of Finns found that emerging adults diagnosed with a chronic disease were more likely to remain introverted and neurotic than their peers (Leikas & Salmela-Aro, 2015). However, this life event also was associated with the potential for becoming more conscientious with time. Among older adults, work suggests that reporting a greater disease burden predicts becoming more conservative and less open to new experiences (Sutin et al., 2013), a change that could help individuals avoid future disease exposure, but also potentially increase mortality risk (Turiano, Spiro, & Mroczek, 2012). In addition to these longitudinal findings, more retrospective work has suggested that observers (e.g., caregivers, family, friends) often report changes in personality among patients experiencing Alzheimer's disease or stroke (Stone et al., 2004), typically in the negative direction. In sum, research points to the potential for individuals to change their personalities following a major health concern in both adaptive and maladaptive ways, often depending on the illness in question. Research thus should potentially compare self-reports and observer-reports for the traits in question, as observers could pick up on changes less discernible to the patient, which serves as one direction for future work.

CURRENT AND FUTURE DIRECTIONS

No longer is it the case that aging or health researchers need to be convinced of the value inherent in studying personality traits. Research consistently demonstrates that certain dispositions and personal characteristics lead individuals to live healthy or less healthy lives (Hampson, 2012; Smith, 2006), and in turn age more adaptively throughout the lifespan. Given this background, we focused on three central directions for ongoing research in the field. First, we discussed the potential for personality to predict physiological markers of aging and physical health. Second, we elaborated on the potential for personality traits to influence health through different mechanisms and pathways across the lifespan. Third, recent research suggests the potential for a bidirectional relation between health and personality, underscoring the role that our wellbeing can play in shaping our personality development.

In considering these points, and how they should direct future work, it appears valuable to return to and amend the prototypical models explaining the links between personality traits and health (Adler & Matthews, 1994; Bogg & Roberts, 2013). Certainly research has supported all of their initial predictions, insofar that personality traits can predict changes in the social environment (Asendorpf & Wilpers, 1998; Donnellan, Larsen-Rife, & Conger, 2005), health behaviors (Bogg & Roberts, 2004; Takahashi et al., 2013), and biophysiological mechanisms (Sutin, Costa, et al., 2010; Turiano et al., 2013), which all in turn influence physical health and wellbeing. Given the work described above, we note three additional considerations when applying this model to understanding personality and aging. First, researchers must consider the potential for age to moderate all links in the framework. For instance, during different points in adulthood, the causal direction between personality and the social environment may change (Hill, Payne, Jackson, Stine-Morrow, & Roberts, 2014). Moreover, certain biomarkers of health play a stronger role on health and physical limitations later in the life course than earlier. As such, researchers are encouraged to always consider the theoretical framework within the context of a lifespan developmental perspective, insofar that certain variables will provide a differential explanation for the role of personality on health across the lifespan.

Second, while necessarily complicating the model and its predictions, further work is needed on potential bidirectional relationships. Research must strive toward understanding health as a potential feedback loop throughout the model. Experiencing greater wellbeing, or more positive aging compared to peers should alert individuals to the potential value both of continuing with a more adaptive behavioral regimen, but also ultimately of the underlying dispositional characteristics involved. As such, one can consider the possibility for healthy individuals to develop more positive personality profiles, in part as a result of enacting more behaviors associated with those adaptive traits. For instance, wellness or illness could lead one to restructure daily activities and reorganize goals, which in turn leads them to increasing on conscientiousness.

Third, both of these additions, as well as the literature described above, underscore the value of studying the linkages between personality and healthy aging by employing not only longitudinal predictive models, but also models that consider the role of correlated changes. Initially, the field focused for obvious reasons on the potential for personality or health behaviors to precede long-term changes in health and wellbeing. As such, we were left with models that only moved from left to right. Instead, it has become evident that researchers must strive toward understanding that these relationships are inherently dynamic in nature, and thus capitalize upon the methodological and analytic techniques that account for this fluidity. For instance, it no longer proves valuable simply to measure personality at a single time point, if under the assumption that assessment will serve as a proxy for personality across the span of the study. While there is clear evidence in support of the general stability of personality traits during adulthood (Roberts & DelVecchio, 2000), aging research would inherently benefit from avoiding the assumption that one measurement fits all.

While these alternations would be valuable, it also will prove important to consider Adler and Matthews' (1994) definition of "individual dispositions" more thoroughly. Note that even their initial article avoided reducing this term down to simply personality traits, and instead considered other characteristics such as moods and explanatory styles. Similarly, researchers must continue to move beyond traits, and into studying the person more inclusively, looking at all potential aspects of identity and self (Roberts & Wood, 2006). Moreover, there is clearly a large literature on how our attitudes and beliefs shape our health decisions (Lawton, Connor, & Parker, 2007), work that often goes without connection to the personality literature described herein. We thus would encourage researchers not only to assess constructs outside of the domain of traits, but also to more readily incorporate multiple aspects of the person (traits, motives, attitudes) when building models of healthy aging, which could look to recent work (Bogg & Roberts, 2013; Ferguson, 2013;

Friedman et al., 2014) for some guidance. By following the suggestions and guidelines set forth by this review, we believe the field of personality and health can continue to age positively.

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CHAPTER

12

Cognitive Training in Later Adulthood

Sherry L. Willis[1] *and Sylvie Belleville*[2]

[1]**Department of Psychiatry and Behavioral Sciences, University of Washington, Seattle, WA, USA**

[2]**Department of Psychology, University of Montreal, Montréal, Canada**

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INTRODUCTION

This chapter is a selective review of the literature on behavioral-based cognitive training with a focus on midlife and later adulthood. Neural outcomes and correlates associated with behavioral-based interventions are reviewed. We first discuss differing perspectives on interventions with older adults, and the key questions addressed by those with a magnification versus compensatory orientation. We begin the review with more traditional approaches that involve single cognitive domains and focus on strategy or component training. We then discuss practice-based approaches including variable priority, whole-task (full emphasis) training, and multi-domain studies involving a combination of these approaches. Multi-domain studies focusing on activity engagement are also considered. We then review the burgeoning literature on computer- or mobile-based interventions, including both computerized training and casual gaming approaches. In a final section we discuss the emerging study of neural correlates and outcomes of behavioral interventions and consider the important contributions made by neuroimaging. We consider issues and debates on transfer with regard to each of these approaches, as well as factors, such as maintenance or durability of training effects, use of adaptive training techniques, and the role of control groups.

Theoretical Perspectives and Assumptions on Training

Intervention studies differ not only in the training protocol but also in theoretical perspective and key questions addressed regarding cognitive aging (Lövden, Bodammer, & Kuhn, 2010; Reuter-Lorenz & Park, 2014). A major question underlying most cognitive intervention studies has focused on the range of plasticity or modifiability of cognitive functioning and interindividual differences in training effectiveness (Lövden, Brehmer, Li, & Lindenberger, 2012).

Magnification Perspective

Age, given the predominance of cross-sectional studies in cognitive aging, has been the most common individual difference variable examined, with early training studies involving primarily extreme age group (young–old) comparisons of training effects (Jaeggi, Buschkuehl, Jonides, & Perrig, 2008; Li et al., 2008). Age groups were said to differ in baseline level of cognitive resources or reserve and the initially more able were hypothesized to show greater training gain. The assumption is that there would be a positive association between baseline performance and magnitude of training gain.

Thus, interindividual differences (e.g., age) in training gains were expected to be magnified and to increase with training (Lövden et al., 2012). This approach to intervention has recently been described as *magnification* (Lövden et al., 2012), or as *testing the limits* in earlier formulations (Baltes, 1987). Plasticity in this view represented the capacity for change not only in the target cognitive domain, but particularly in transfer to other domains. The intervention focuses primarily on *practice* on one or multiple tasks, with no strategy or instructional training; the initially more able, having greater cognitive resources, should need only practice to reach the highest levels of performance. More recently, intervention studies with this orientation have also been concerned with neural plasticity and assumed that cerebral change or plasticity precedes or accompanies behavioral plasticity (Lustig, Shah, Seidler, & Reuter-Lorenz, 2009). Neural plasticity is often referenced as an alteration in processing efficiency, often associated with broader frontal brain activation.

Compensatory Perspective

A second major perspective toward intervention developed early in cognitive training research with older adults and has been described as *compensatory* or *remedial* in nature (Brom & Kliegl, 2014; Craik et al., 2007). This approach acknowledges the increasing likelihood of cognitive deficits associated with normal aging and focuses on compensating for less efficient functioning, particularly in less able older adults, via strategy or component training approaches (Belleville et al., 2006; Belleville, Clement, & Mellah, 2011; Schaie & Willis, 1986). Interindividual differences are also of concern within a compensatory perspective, but focus often on differences *among* older individuals within the same age range, rather than groups differing widely in age/cohort. In contrast to findings based on a magnification approach, individual differences are *reduced* as a function of training; and the less able elderly often demonstrate the largest training gains; baseline performance is negatively related to training gain (Schaie & Willis, 1986).

Some researchers have adopted the term *flexibility*, rather than plasticity, to describe the compensatory mechanism—flexibility indicates the capacity to optimize performance within the constraints of the aging process, with some researchers assuming that these constraints lie primarily in neural structural constraints. Malleability of cognitive performance in training results from the support provided by strategy use and instruction to restore or compensate for effects of cognitive aging. Neural functioning is also of concern within a compensatory approach, but often addresses interindividual differences in neural function among individuals varying in baseline cognitive performance and differential neural outcomes. For example, low functioning elderly, as a result of training, may show an increase in activation, rather than decreased activation (increased efficiency) shown by more able elderly and younger adults in the magnification approach.

COGNITIVE TRAINING: BEHAVIORAL INTERVENTIONS AND BEHAVIORAL OUTCOMES

Strategy Training

Strategy-based studies involve the *compensatory* perspective described above, focus on strategies aimed at compensating for aging-related cognitive deficits (Brom & Kliegl, 2014; Verhaeghen, Marcoen, & Goossens, 1992). They typically focus on a single complex mental ability, such as episodic memory or reasoning (also mental rotation), and involve training on strategies that are specific to the target ability. Thus, strategies differ markedly by the ability trained. Memory strategies are quite different, for example, to reasoning strategies (Jobe et al., 2001). Usually multiple strategies, specific to the ability, are trained. Strategies often reduce the complexity and attentional/memory demands for a given ability. Training items have traditionally closely resembled the format of measures and items employed in assessing the ability, although a variety of stimuli (numbers, letters, shapes) are employed and are not identical to test items. Recent strategy training protocols have increasingly emphasized subjects using the strategies in everyday activities and naturalistic settings (e.g., remembering a grocery list, remembering names at a party, etc.).

Episodic Memory

Memory programs typically rely on the teaching of mnemonics or strategies that provide rich and distinctive encoding (Craik et al., 2007). These include strategies that promote semantic elaboration, organization of material or strategies based on visual and interactive imagery (Rebok et al., 2013). For instance, in the method of loci participants learn to associate items to be remembered to a sequence of loci in a familiar environment (Gross et al., 2014). The technique is useful in learning sequences of items (e.g., word list) or temporally organized items. Interactive imagery is used to remember pairs or groups of items that are not easy to associate otherwise. Participants learn to pair the items in a vivid and interactive image. This technique has been used to learn the names of people. In this case, participants are taught to identify a salient feature in the person's face and to make an interactive image with a meaning given to the name of the person. Verbal strategies have also been frequently used. Categorical grouping, semantic elaboration, and organization of material have been proposed as ways to memorize lists of words or complex material such as texts or conversations.

There is an extensive literature that has examined the efficacy of those types of mnemonic strategies using experimental designs (Craik et al., 2007; Kueider, Parisi, Gross, & Rebok, 2012; Rebok et al., 2013). These studies examined whether various strategies showed differential levels of efficacy and whether their effect was durable and transferred to non-practiced tasks. Verhaeghen et al. (1992) performed a meta-analysis of 33 studies on memory training that comprised a total sample of 1539 healthy older adults. They reported that memory training that promoted encoding enhanced memory performance by approximately 0.7 standard deviations (SD) in healthy older adults. They also examined whether the characteristics of the training program determined efficacy. This provided critical information on the active ingredients that should be included in memory interventions designed for older adults. The findings that there were no differences in training efficacy as a function of the different types of mnemonics trained suggested that perhaps older adults with different learning styles and preferences are likely to benefit from different strategies and that efficacy is not restricted to a single type of strategy or mnemonic. However, efficacy of mnemonics may vary by type of material to be learned and recalled (Belleville et al., 2006). Method of loci may be particularly useful when words in a list belong to no common categories; whereas, strategies involving associations or organization (chunking) may be more useful when words in a list can be organized into superordinate categories, thus reducing the number of items to be remembered.

Moreover, reviews of memory training suggest that differences in efficacy occurred as a function of whether memory was trained in isolation (uni-factorial) or whether it was embedded in a multifactorial program (Belleville et al., 2006; Bier et al., 2015). For instance, programs that included attentional training, relaxation training or training meant to increase the ability to create interactive images have sometimes been found to improve memory more than programs focusing solely on memory strategies (e.g., method of loci). It was also found that shorter training sessions were more efficient than longer ones, perhaps because they reduced the negative effect of fatigue and attentional load on older adults' capacity to benefit from learning. Finally, there were clear indications that social interactions and mutual support are often important components of effective memory training as some authors reported better efficacy for group than individual training and for training involving a trainer, rather than self-directed training provided through instructional materials, such as a print manual.

Note that the meta-analysis published by Verhaeghen et al. (1992) was mostly based on small-scale non-randomized experimental studies, which limits conclusions regarding the specificity of the type of memory training program most effective and durable for promoting cognition and quality of life in healthy older adults. The Advanced Cognitive Training in Vital Elderly (ACTIVE) study was a large-scale randomized single-blind trial involving 2832 community-dwelling healthy older adults, which compared three different training programs. one of which targeted memory (Ball et al., 2002; Jobe et al., 2001). The 10-session memory program included training on a variety of mnemonics (e.g., categorization, semantic elaboration, visualization) and was unifactorial in that it did not include specifically training on non-memory dimensions, such as relaxation or imagery per se. Booster sessions were provided in a subset of participants 11 months following the end of the primary training and at 3 years follow-up; and efficacy was measured on a number of proximal and distal composite measures. Persons randomized to memory training were compared to those randomized to training on processing speed, reasoning or to a no-training condition. Memory training was found to selectively improve the memory composite measure (Ball et al., 2002; Jones et al., 2012; Rebok et al., 2013). The effect was still significant 5 years after the end of the training (Willis et al., 2006) but maintenance of training effects was not found at the 10-year follow-up (Rebok et al., 2014). Far transfer was examined to both self-reported and performance-based tasks of complex activities of daily living. At 10-year follow-up, memory-trained subjects reported less difficulty performing daily activities compared to controls.

There has been the suggestion that broader training transfer might occur when memory training is embedded in a multifactorial or multidomain program, involving such components as relaxation, imagery training, and socialization (see discussion of multidomain interventions below). Another possibility is that the activity outcome measures were not sensitive or specific enough to capture the type of daily activities that rely on episodic memory capacities or fail to reflect situations when mnemonics were used by trained participants. Use of journals or logs to record use of memory strategies may provide more sensitive and direct assessments of memory use in daily life, or new technologies (e.g., mobile devices) to test memory in real-life environments (Greenaway, Duncan & Smith, 2012).

Inductive Reasoning

Reasoning training has focused on improving the ability to solve problems that require linear thinking, involve rule-based problem-solving, and that follow a series pattern or sequence (Blieszner, Willis, & Baltes, 1981; Schaie & Willis, 1986; Willis & Nesselroade, 1990). Such problems, for example, involve identifying the pattern in a series of letters or numbers, or understanding the pattern in an everyday activity such as the dosing for a prescription drug or travel schedule. Participants were taught strategies to identify the pattern or sequence required to solve the problem and how to apply these strategies to determine the next item in the pattern. Participants were given an opportunity to practice the strategies in both individual and group exercises. The exercises involved abstract reasoning tasks as well as reasoning problems that related to activities of daily living (e.g., identifying medication dosing pattern and filling a pill reminder case).

The reasoning training program has been implemented with a trainer in small group settings in the ADEPT (Blieszner et al., 1981) and ACTIVE (Jobe et al., 2001; Willis & Caskie, 2013; Willis et al., 2006) studies and in one-on-one training sessions within the Seattle Longitudinal Study (SLS) training study (Schaie & Willis, 1986). Self-directed, at-home training has also been conducted with couples, compared to a single-subject condition (Margrett & Willis, 2006). Inductive training was employed as a comparison treatment at-home condition within the Senior Odyssey trial (Stine-Morrow, Pairsi, Morrow, Green, & Park, 2007; Stine-Morrow, Parisi, Morrow, & Park, 2008). Within the ADEPT and ACTIVE trials (Jones et al., 2013), significant training effects were found at immediate posttest and up to 10-year follow-up. For the ACTIVE trial, 68% of reason trainees experience reliable training improvement; effect size for reasoning training was 0.48 SD improvement at immediate posttest. In ACTIVE, booster training at 3-year follow-up demonstrated significantly enhanced effects beyond initial training. Significant near transfer effects to multiple measures of reasoning ability, measured as a latent construct, were reported in ADEPT and ACTIVE studies.

Within the SLS training study (Schaie & Willis, 1986), subjects' longitudinal cognitive trajectories prior to training were classified as exhibiting stability or decline on reasoning ability; training effects were compared for subjects showing prior decline or stability on the reasoning ability. Significant training effects occurred for both SLS subjects demonstrating prior stability or decline, with decline subjects showing somewhat greater effects. Training effects were maintained; baseline level and longitudinal training trajectories were found to be predictive of future cognitive impairment (Boron, Turiano, Willis, & Schaie, 2007; Boron, Willis, & Schaie, 2007).

Moderators of training improvement and transfer of training to non-cognitive factors were examined within the ACTIVE trial (Willis & Caskie, 2013). Different factors were related to the reason score at baseline compared with the magnitude of training gain (Willis & Caskie, 2013). Higher education, MMSE, better health, and younger age were related to higher baseline score. In contrast, larger training gain was related to training adherence and MMSE. Subjects who at baseline were retrospectively classified as at risk for memory impairment and did not show improvement in memory training nevertheless showed improvement in both reasoning and speed of processing training, suggesting that normal elderly with memory deficits may still profit from training on alternative abilities, such as speed or reasoning. There was no transfer from reasoning training to other abilities (memory, speed) trained in ACTIVE. At 5-year and 10-year follow-up, reason-trained subjects reported less difficulty carrying out daily activities compared to the control group.

While no cross-ability for transfer was found, transfer to other domains was found in ACTIVE. Significant improvement in internal locus of control beliefs was found between baseline and 5-year follow-up for the reasoning group, compared to a no-contact control (Wolinsky et al., 2010). Also, at 5- and 10-year follow-up, the reasoning and speed of processing training groups had lower rates of at-fault collision involvement than controls based on motor vehicle records; training participants had an approximately 50% lower rate (per person-mile) of at-fault motor vehicle crashes.

The reasoning training condition within the Senior Odyssey program exhibited significant training effects on reasoning measures, compared to a gain in divergent thinking for the Odyssey condition (Stine-Morrow et al., 2014). In addition, reasoning participants exhibited a significant increase on the personality trait of openness to experience, compared to a waitlist control group (Jackson, Hill, Payne, Roberts, & Stine-Morrow, 2012). Memory self-efficacy beliefs at baseline were found to predict reasoning training gain within the Senior Odyssey program; self-efficacy had effects on how trainees allocated time to training materials over the course of the intervention (Payne et al., 2012).

Component-Specific and Variable Priority Training

Training studies involving a component (part-task) and/or a variable priority approach may more closely resemble a compensatory perspective to training than the magnification approach (Boot et al., 2010; Kramer, Larish, & Strayer, 1995). While these studies do not specifically involve use of strategies, they do reduce the complexity of the task by focusing successively on different components of a task and increasing the task demands across training sessions. In variable priority training skills are practiced alternately or successively in an integrated context. Adaptive training, often employed in these approaches, involves individualized training, calibrating and changing item difficulty, speed of responding, and/or sequencing of task components to the performance level of the subject.

Variable Priority Training: Attention

Numerous studies have reported that variable priority training reduces dual-task cost in healthy older adults (Bherer et al., 2005, 2008; Bier, de Boysson, & Belleville, 2014; Boot, Blakely, & Simons, 2011; Kramer et al., 1995). Variable priority was also found to increase attentional dual-tasking capacities in persons with mild cognitive impairment who experience executive control deficits (Gagnon & Belleville, 2012). In variable priority training, individuals are asked to complete a divided attention task but are instructed to emphasize one task over the other across different blocks of dual tasking. It has been argued that variable priority training may be more effective to improve dual-task coordination than fixed priority training, where participants perform the two tasks simultaneously by allocating the same amount of attention to each task (Bier et al., 2014; Gagnon & Belleville, 2011; Lee et al., 2012; Voss et al., 2012). Studies that have compared the two training types reported larger dual-task coordination gain following variable priority than fixed priority training.

There are many reasons why the variable priority approach might be more favorable than fixed priority training. One possibility comes from the fact that divided attention costs depend on both the ability to carry out each individual task and the ability to coordinate or divide attention. Because variable priority contains trials where each task is practiced with full attention, it would involve both training of the individual component tasks and training of the coordination component (Kramer et al., 1995). One other possibility is that variable priority training is more powerful because it increases the participant's ability to exercise self-control over the locus of attention. In support of this later hypothesis, Bier et al. (2014) have found that participants who practice each task individually in full attention did not improve their ability to divide attention among tasks, in contrast to those who were provided with variable priority and fixed priority training. This suggests that it is not the greater practice on the individual tasks afforded by variable priority training which is responsible for its larger efficacy but the fact that it promotes an active control of attentional resources. This could also explain the results obtained by Bherer et al. (2005, 2008) who failed to find larger gain following variable than fixed priority training. One possible explanation is that in this study, the divided attention task involved discretely presented trials and response timing was fixed and pre-determined by the investigator, in contrast to the previous studies where the two tasks had to be monitored simultaneously. This suggests that variable training increases self-regulation and top-down regulatory control capacities and has its strongest effect when the conditions require that participants control and monitor their response strategies.

Speed of Processing

The protocol utilized in speed of processing training suggests similarities to the variable priority approach. Speed of processing training has focused on improving speed of visual search and ability to perform an increasing number of attentional tasks quickly, as assessed on the useful field of view (UFOV) task (Edwards, Wadley, Vance, Roenker, & Ball, 2005; Roenker et al., 2003). Speed of processing is trained by systematically reducing the stimulus duration in a series of progressively more difficult information-processing tasks presented via computer. In the simplest UFOV task (Task 1) participants were asked to identify objects at increasingly brief exposures. Once this ability was mastered at the shortest possible stimulus duration, participants were asked to divide their attention between two tasks: stimulus identification in the center of a computer monitor and localization of another target presented somewhere in the peripheral vision (Task 2). Again task difficulty was increased by either decreasing stimulus duration, expanding the area within which targets can be localized or increasing the difficulty of the central identification task. Once this task was mastered for the most difficult condition and minimum stimulus exposure, Task 3 added visual distractors to the stimulus display. Stimulus duration was then reduced systematically once again in response to improving performance, alternating with increasing task difficulty as in Task 2. Finally in the most difficult training conditions (Task 4) task demand was increased even further by superimposing an auditory identification component over the visual tasks.

This training has been presented in a variety of formats, including a one-on-one condition with a trainer, in small groups, and currently in a gaming format for at-home self-directed administration (Edwards, Valdes et al., 2013; Roenker et al., 2003). For the ACTIVE trial, 87% of speed trainees experience reliable training improvement; effect size for speed of process training was 1.46 SD improvement at immediate posttest (Ball et al., 2002). Factors associated with baseline speed performance included older age, poorer health. and MMSE. Booster training at both 1-year and 3-year follow-up enhanced performance. Subjects, who at baseline were retrospectively classified as at risk for memory impairment and did not show improvement in memory training, nevertheless showed improvement in both reasoning and speed of processing training. Significant improvement in internal locus of control beliefs was found between baseline and 5-year follow-up for the speed group, compared to a no-contact control (Wolinsky et al., 2010).

Several studies in the Ball laboratory have demonstrated the effects of speed of processing on various driving behaviors, particularly for older adults with significantly slower speed of processing (Ball et al., 2002). Prior studies indicated that lower-functioning older adults not only profited from speed training but also demonstrated better on-road driving safety (Roenker et al., 2003). Specifically, older adults demonstrated significantly fewer dangerous on-road maneuvers after training—an improvement that endured 18 months later, as compared to a control group of older drivers who received traditional driver education and simulator training. In addition, low-functioning adults receiving speed training reported no more difficulty in driving situations (high traffic, driving in rain, merging traffic) than did normal-functioning adults receiving training (Edwards, Myers, Ross, Roenker, Cissell, Mclaughlin, et al., 2009). In the ACTIVE trial, it was first demonstrated that speed of processing training was associated with reduced motor vehicle crashes at 5 and 10 years following training (Ball, Edwards, & McGwin, 2010). ACTIVE trainees on speed also showed immediate improvements in performance of the Timed IADL Test, a performance-based assessment measuring speed and accuracy across four IADL domains (Edwards et al., 2005; Edwards, Ruva, O'Brien, Haley & Lister, 2013).

Effects of speed of processing training have also been examined in studies by Wolinsky, Vander Weg, Howren, Jones, and Dotson (2013) and others. Wolinsky compared 10 and 14 h of laboratory-based training and 10-h at-home training with an attention control group in midlife and older adults.. All speed training groups showed moderate training effects on the UFOV test with no age differences (midlife, older adult) in effect size. Also, small significant effects on Trials A & B, and Symbol Digit test were found; improvement on Stroop color test was not significant.

Whole Task Practice Training

Studies from a magnification perspective have often focused on the whole task (in contrast to a component or variable priority approach) and involved practice (in contrast to an instructional approach). The studies often involve age group comparisons assuming that older versus younger age groups differ in baseline resources and thus those with greater resources should exhibit the greatest training improvement—magnifying interindividual differences. Adaptive training techniques are often employed to maximize individual differences in training outcomes.

N-Back (Working Memory) Training

Perhaps the most frequently employed training task in magnification studies has been the n-back task, assumed to be a strong marker of working memory (WM) (Au et al., 2015). WM, considered to be a key determinant of many higher-order cognitive functions, is thus of much interest in studies from a magnification perspective. Training seeks to develop process-specific WM outcomes which some expect to lead to general, broader training transfer. Jaeggi et al. (2008) carried out one of the early n-back training studies reporting what was described as far transfer to one measure (Raven matrices) of fluid intelligence (Gf). Given that these findings on Gf transfer were not replicated in other labs (Chooi & Thompson, 2012; Shipstead, Redick, & Engle, 2012; Redick et al., 2013), much debate has ensued on both the construct represented by the n-back task and the potential of magnification (whole task practice) studies to demonstrate broad transfer.

Jaeggi and colleagues (Au et al., 2015) recently reported on a meta-analysis of n-back training research, but unfortunately limited studies reviewed young and midlife samples (18–50 years). They concluded that studies support the finding that various components of WM are modifiable, but that findings regarding broader transfer are equivocable. Thus, broad transfer effects (to Gf) were found to show modest or small effects, equivalent to a few test points. Generally transfer effects were assessed with only one Gf measure, often matrix reasoning. Similar limited transfer effects were reported in a meta-analysis by Melby-Lervag and Hulme (2013).

WM as a Multidimensional Construct: Implications for Training

There has been growing recognition of the limitations of using a single measure as either the training task or as a transfer measure (Au et al., 2015; Banqued et al., 2013; Schaie, Willis, Hertzog, & Schulenberg, 1987). Discussion of the limitations of a single measure outcome has focused on WM; however, the limitation holds for all cognitive training studies, including both compensation and magnification approaches. WM has been shown to involve multiple sub-processes including, updating, inhibition, and maintenance. These sub-processes may all influence or be differentially represented in various WM measures. For example, capacity may vary for span measures involving only maintenance versus also including sub-processes related to updating and inhibition. Since WM represents a construct of multiple sub-processes, assessment of training effects and transfer effects need to assess multiple sub-processes. Similarly, fluid intelligence is conceived as a second-order factor involving multiple abilities (e.g., inductive reasoning, configural relations). A single measure (Raven matrices) of a single ability (reason) is an inadequate marker of transfer to fluid intelligence.

Jaeggi and colleagues (Jaeggi, Buschkuehl, Perrig, & Meier, 2010) have also reported other issues with use of the n-back test as a training measure and as a marker of WM. Less difficult versions of the n-back task have been found to have poor reliability and thus inadequate measures of individual differences, due to low test reliability. Assessing the relationship of the n-back test to other cognitive domains is, thus, problematic. Of major concern are findings regarding the construct validity of the n-back test with other more complex WM measures.

The n-back task appears to be more related to simple span measures than more complex WM measures. Moreover, in relation to training transfer, the n-back measure appears related to Gf only at higher levels of load and to represent primarily attentional control within the Gf construct, thus not representing the multiple abilities included in the second-order factor of Gf (Baniqued et al., 2013).

Training Involving Multiple WM Subprocesses or Tasks

Other WM training studies have focused on a variety of WM tasks, rather than solely on the n-back task (Brehmer, Westerberg, & Bäckman, 2012; Li et al., 2008). Training involving multiple WM tasks increases the likelihood of involving multiple components of WM. Some training and transfer effects have been observed in studies using multiple tasks/processes. Zinke, Zeintl, Rose, Putzmann, and Pydde (2014) trained on multiple aspects of WM, involving verbal, visuospatial WM and executive control, using an adaptive training technique; transfer to one measure of matrix reason was reported, but not maintained at follow-up. In an elderly sample, Brehmer et al. (2012) compared young and older adults in practice on spatial and verbal WM tasks with one condition receiving adaptive training and another condition receiving the same tasks under a non-adaptive, low-difficulty protocol. Greater gains occurred for adaptive training. Older and younger subjects did not differ in training and transfer effects on verbal WM, but older adults did less well than young adults on spatial WM tasks.

Multi-Domain Training

Multi-Domain: Combined Strategy and Component Training

Historically, a large number of training studies have focused on a single cognitive ability or process. However, given that many factors are contributing to cognitive decline and functional loss in aging, this might not be the most sensible approach if the goal is greater transfer or generalization/application of training to everyday activities, leading to independence and quality of life (Park et al., 2014).

MEMO

Belleville and collaborators have developed a multifactorial approach for use with healthy older adults and persons with mild cognitive impairment (Méthode d'entraînement pour une mémoire optimale, MEMO; Belleville et al., 2006; Bier et al., 2015). The program involves small groups (4–8 individuals) and teaches a variety of mnemonics (method of loci, face-name association, interactive imagery, text hierarchization, semantic elaboration). It is multifactorial as it includes pre-training on attention and visual imagery abilities as well as general psychoeducational information on cognitive aging and lifestyle factors. In addition to training different cognitive components, the program includes a number of features to promote self-efficacy and generalization, for instance, homework exercises, instructions on how to implement the strategies in real-life situations, discussion about the difficulties encountered while using strategies at home, class demonstrations by the instructor, gradual decrease in support and cues while participants learn to apply the strategy; peer support facilitated by numerous occasions for participants to share strategies and discuss their challenges. These elements were meant to increase engagement and motivation and provide psychosocial stimulation in addition to cognitive training.

In a preliminary pilot study (Bier et al., 2015), positive training effects were found on word-list and face-name association tasks with a comparable magnitude of effects found in groups of healthy older adults and persons with mild cognitive impairment. The authors measured generalization using the self-evaluation complaint questionnaire (van der Linden et al., 1989). In this questionnaire, participants rate the frequency with which they encounter memory difficulties in different areas of their daily life, for instance difficulties in remembering political events or not being sure of whether one had already bought an item or not. Following training, participants reported fewer complaints regarding their memory. They also improved on a measure of general well-being. These two results suggest that the effect of the training might have generalized to concrete dimensions of their life. However, this study needs replication as it included only a small number of participants and did not involve a randomized design.

ACTIVITY ENGAGEMENT INTERVENTIONS

Computer- and Mobile-Based Training and Gaming

Computerized Training

One of the fast-growing and most controversial approaches to cognitive intervention involves the use of computers as the delivery mechanism for the intervention (Boot, 2015; Boot et al., 2011). It is important to distinguish two domains of computer-based interventions, although there is some overlap between the two.

One approach was developed largely by researchers in cognition, including cognitive aging, many of whom had conducted trainer-based intervention studies and sought to enhance training by utilizing technological resources, such as adaptive training, graphics, and use of latencies as either individualizing training or as a primary outcome (Kueider et al., 2012; Lampit, Hallock, & Valenzuela, 2014). In addition, computer-based training expanded the training context and scheduling beyond the laboratory and facilitated an individualized, more self-directed approach to intervention. These computer-based training studies focused on similar cognitive abilities and process to those discussed in earlier sections.

The second approach has involved cognitive researchers exploring the efficacy of commercial products, often described as casual video games, for enhancing cognitive functioning (Boot et al., 2011). Casual video games are highly popular, involve simple rules, can be completed in a short time period, requiring less rigor and skill than those played by serious gamers. It is estimated that 200 million people worldwide play casual video games.

COMPUTERIZED-COGNITIVE TRAINING

The effort to develop computer-based training, especially for older adults, evolved both from recognition of the potential for technology to enhance the training process, and the need for a more cost-efficient alternative to the trainer-based approach (Kueider et al., 2012). In addition, in the past decade the computer literacy of older adult cohorts has significantly increased; older adults are now the fastest-growing segment of internet uses with 42% of 65+ and 78% of 50–64-year-old adults using the internet (Pew Internet & American Life Project, 2010). Kueider et al. (2012) recently reviewed the cognitive focus and efficacy of computerized training studies with cognitively normal older adults over the period 1984 to 2011. The 21 classical cognitive training studies reviewed trained on seven aspects of cognition and used guided practice on standardized tasks, with half of the studies focused on processing speed with generally positive effects (five) or memory (five; including episodic, WM and spatial memory) with studies varying in efficacy. The studies met rigorous standards of randomized designs and pre-posttest assessment. They found effect sizes, in general, to be comparable to those reported in non-computerized training studies. Of the seven types of cognitive process included in studies, the effect sizes for studies varied from 1.3 for processing speed to 0.39 for visuospatial abilities, with the highest effect sizes for processing speed, reaction time, and WM. Reports from older adults who completed the computerized training were positive with high satisfaction ratings. Kueider et al. (2012) urge some caution in interpreting findings due to the wide variety of training approaches and cognitive processes involved in studies. Lampit et al. (2014) also reviewed 52 studies of computerized training with healthy older adults (60–82 years) with 32 group versus 19 home training contexts, from 1992 to 2014. Studies reviewed were limited to randomized controlled trials with training duration of at least 4 h, with focus on an active control. Training domains included speed of processing, WM attention, with approximately half of studies multidomain. Their conclusion was somewhat less positive, describing effects as small and significant, with generally less effect for WM and executive domains.

Casual Gaming Interventions

A more controversial domain in computerized training for older adults has focused on casual video games as the training approach (Boot et al., 2011). There have been two recent consensus statements from cognitive researchers on commercial gaming approaches for enhancing cognitive functioning in older adults (Max Planck Institute for Human Development and Stanford Center on Longevity, 2014). Both statements express concern regarding the limited reliable scientific research reported in high-impact, peer-reviewed scientific journals for claims made by some commercial promoters on the efficacy of “brain games” particularly for the elderly. The brain-training industry is unregulated and quasi-scientific claims are not vetted by any regulatory group, leaving prospective consumers to face the challenge of separating wild claims from serious science. Both consensus statements agree on optimism for the plasticity of cognitive and brain functioning into old age, acknowledging that training can improve performance on trained tasks, but few training programs have shown evidence for transfer to improved performance on everyday tasks and importantly no interventions have been shown to prevent or cure dementias such as AD. It is important to note that the concern for promoting video games as brain games is not inherent to the use of computers or mobile devices to deliver the tasks; it is that most commercial companies making unsubstantiated claims are providing their programs via computers and mobile devices.

ASSOCIATION OF COGNITIVE ABILITIES AND CASUAL VIDEO GAMES

One of the most basic and largely unexamined hypotheses underlying casual gaming is that these games do involve exercise of the basic cognitive abilities and processes shown to decline with age and thus have potential as a training tool (Boot, 2015; Boot et al., 2011). Recent research findings (Baniqued et al., 2013) question the strength and specificity of the association between key cognitive constructs (fluid intelligence, perceptual speed, episodic memory, WM, and attention) and 20 web-based games.

CHALLENGE OF CLASSIFYING GAMES BY COGNITIVE DOMAIN An a priori task analysis by game developers (Militello & Hutton, 1998; and subsequently by the study co-authors Baniqued et al., 2013) for grouping the 20 games by cognitive construct presumably tapped by each game was not substantiated. CPA analyses suggested that many games could be grouped into multiple categories; reasoning games often also loaded highly on WM and spatial reasoning game categories. Perceptual speed games also were heterogeneous and did not form a single group. These results indicate that intuitive task-based analyses of games may be insufficient when selecting games for interventions and required empirical validation. A series of factor analytic procedures resulted in five broad and over-lapping game groups: Reasoning-WM; spatial reasoning; attention tracking; and perceptual-visual-motor-speed games.

ASSOCIATION BETWEEN COGNITIVE ABILITIES AND GAME GROUPS A series of factor analyses resulted in identifying seven cognitive ability/process domains: fluid reasoning, speed, episodic memory, WM, general attention, shifting, inhibition. Correlations between game groups and cognitive constructs were examined. Most game scores, regardless of game group, were highly related to WM, fluid intelligence, and perceptual speed. The authors conclude that demonstrating the relationship between games and cognitive abilities is a critical first step if games are to be useful for training—a step often neglected in gaming research.

In a second study, Baniqued et al. (2014) conducted a training study with young adults to examine the ability–game associations found in Baniqued et al. (2013). Subjects were randomized to 15-h of practice on four memory-reasoning games with and without an adaptive training approach or to an active control. Although there was improvement on the games, transfer to the target abilities or untrained tasks was minimal.

One of the most successful studies of casual gaming with older adults focused on executive functions required in the Rise of Nations game (Basak, Boot, Voss, & Kramer, 2008). Training for 23.5 h involved multiple strategies including a variable priority approach. There was improvement both on game performance and on task switching, WM, and visual short-term memory. Individual differences in game performance were correlated with an improvement in task switching.

Research by Boot and colleagues (Boot, 2015; Boot et al., 2013) compared efficacy of an action game versus "brain fitness" game to improve abilities in older adults. Neither group showed significant improvement in cognitive abilities. However, there were important group differences in training adherence and enjoyment of training. The action game has lower adherence and was reported by older adults to be less enjoyable. Trainees perceived fewer benefits from playing the action game and more difficulties in game-playing associated with eyesight and arthritis, supporting prior research that older adults preferred games involving an intellectual challenge over fast-paced action games (McKay & Maki, 2010).

MCI Training

In recent years, there has been tremendous interest in the development of intervention programs focusing on age-related neurodegenerative diseases. The term mild cognitive impairment (MCI) has been proposed to identify the prodromal phase of Alzheimer's disease (AD). Persons with amnestic MCI have memory complaints and impaired performance on memory tasks, but they do not meet the criteria for dementia (Gauthier et al., 2006). Many of these individuals are in a transitional phase between normal aging and dementia and they have a ten-fold larger risk than non-MCI to progress to dementia. This phase has been identified as a strategic target for the provision of non-pharmacological preventive and/or clinical interventions, as during this phase, compensatory processes including neuroplasticity are still active and could be enhanced to delay expression of dementia symptoms (Clement & Belleville, 2010, 2012). In addition, cognition interventions are particularly appealing as a way to address cognitive problems in MCI because these persons still have the capabilities to learn compensatory strategies and these can have a tremendous impact on their quality of life (Clare, van Paasschen & Evans, 2009).

A large number of studies have examined whether cognitive training can improve performance in persons with MCI. Some of them relied on computerized training of multiple cognitive components (Cipriani, Bianchetti, & Trabucchi, 2006; Gunther, Schafer, Holzner,

& Kemmler, 2003; Rozzini, et al., 2007; Talassi, et al., 2007). Other interventions focused on structured group training in which participants were taught different memory strategies (Belleville et al., 2006; Kinsella et al., 2009; Kurz, Pohl, Ramsenthaler, & Sorg, 2009; Olazaran et al., 2004; Rapp, Brenes, & Marsh, 2002; Troyer, Murphy, Anderson, Moscovitch, & Craik, 2008; Wenisch et al., 2007; Olchik et al., 2013). Group interventions most often included education on memory, ways of coping with stress, and the teaching and practice of the learned strategies.

Overall, the results of these techniques have been mixed. Some studies reported improvement in participants' perception of their memory capacities (Rapp et al., 2002) or in strategic knowledge and self-reported used strategies (Troyer et al., 2008), but no difference in objective memory tasks. By contrast, a number of more recent studies have reported positive results on objective cognitive measures (Belleville et al., 2006; Kinsella et al., 2009; Kurz et al., 2009; Olazaran et al., 2004; Wenisch et al., 2007). For example, Belleville et al. (2006) found training-related improvement in objective memory outcomes, well-being, and subjective appraisal of memory in daily life situations. The program employed was a multifactorial intervention that included the explicit learning of memory strategies as well as training in non-memory capacities (attention, visual imagery) and non-cognitive (stress, self-efficacy, empowerment) strategies that were considered important factors in promoting the learning and proper use of the memory strategies. Multifactorial interventions that implicate extended practice and explicit generalization strategies may be the most effective way of improving memory performance in MCI, as they are likely best suited to the range of problems encountered in MCI. Similar results were reported by Kinsella et al. (2009), who found a significant effect of a multifactorial intervention involving family members that focused on prospective memory tasks, knowledge, and the use of memory strategies. Colleagues at the Mayo Clinic (Greenaway, Duncan, & Smith, 2012) have examined training with a memory support system (MSS) involving training in use of notebooks and calendars and including family members. Functional ability and memory self-efficacy improved with MSS training and functional ability improvement was maintained at 8-week follow-up. Care partners demonstrated improved mood at 8-week and 6-month follow-up. Wenisch et al. (2007) also found significant results on memory measures.

Note, however, that these studies have relied on small sample sizes and many of them did not compare their intervention to an active control group condition or randomized participants. Two studies that have involved well-controlled designs have reported fairly disappointing findings. The PACE study is a randomized control trial of cognitive activity in persons with MCI. One hundred and sixty participants enrolled in 90-min sessions twice per week for 5 weeks. A short booster session was provided by phone after 6 months and in a longer face-to-face booster after a year. The cognitive training program provided participants with a range of techniques to help manage their difficulties and participants were compared to a psychoeducational program that provided healthy lifestyle guidelines (Vidovich et al., 2009). Results (Vidovich et al., 2015) indicated no effect of the cognitive intervention relative to the control intervention on the primary outcomes, though some effects were found on secondary cognitive measures and on measures of quality of life.

Similar results were reported by Unverzagt et al. (2007) based on the results from the ACTIVE study. Though the study did not have access to clinically identified MCI, the authors examined whether performing below average on memory tasks at baseline predicted efficacy of the memory training program. They found that persons with a reduced memory score did not benefit as much as those with normal or above-average memory performance from memory training but benefit was equivalent for the processing speed and reasoning training.

These two studies suggest that persons with amnestic MCI might require intervention strategies that differ from the ones typically designed for healthy older adults. It is possible that this population requires interventions that are more intensive and multifactorial in nature, similar to the one that was proposed in the MEMO program (Bier et al., 2015). Another important issue is the identification of the most sensitive and valid outcome measures, given that this is a population likely to experience cognitive decline over the course of the study. Interindividual variability is also a challenge in this quite variable population. Interindividual differences can, of course, interfere with the ability to identify training effect because they have an impact on the effect size. It can also have tremendous consequences on the training approach to be selected. Within an individualized perspective, interindividual differences in disease etiology and brain characteristics as well as in psychological, motivational and lifestyle characteristics should be used to shape an appropriate intervention strategy. While this comes with methodological challenges, individualized approaches are likely to be the most beneficial in persons with prodromal AD because interdifferences are likely to have their largest effect in populations with mild clinical symptoms.

COGNITIVE TRAINING: NEURAL MECHANISMS AND OUTCOMES

Brain imaging techniques are powerful tools to better understand the impact and mechanisms by which cognitive training exerts its effect. Brain imaging can reflect the impact of training on the structure of the brain or on its function. Structural brain imaging provides information on the brain anatomy, including whole-brain volume, regional gray matter volumes, cortical thickness, and white matter integrity. In turn, functional brain imaging provides information on the regions or networks that are active when at rest or when performing a task, and can be used to identify the neurocognitive effects of the intervention. Functional brain imaging can provide critical information on the mechanisms through which an intervention enhances cognition. For instance, the patterns of change in brain activation can reveal whether the cognitive improvement has occurred through compensatory use of alternative regions/processes or whether it results from increased efficiency of specialized regions. Structural and functional brain changes can precede behavioral changes, and functional brain imaging can reveal changes that are not detectable at the structural level due to technical constraints. For this reason, these various neuroimaging domains or markers are likely to provide complimentary information.

Brain Imaging as a Surrogate Biomarker

These techniques can be used as “surrogate biomarkers” of training efficacy or to reveal the neurobiological mechanisms supporting the effect of cognitive training. The training-induced brain changes revealed by those techniques can also inform lifespan models of brain reorganization and compensation because they provide direct information regarding the impact that environmental stimulation exerts on brain structure and function.

In therapeutic trials, surrogate markers are used as clinically meaningful measures of the effect of a therapy (Fleming & DeMets, 1996; Katz, 2004), when assessment of the primary outcome is methodologically unfeasible. For instance, dementia, such as AD, is a clinically valid outcome when designing a study to measure whether cognitive training can prevent the progression of AD in pre-symptomatic individuals. However, detecting the progression of dementia may require too long a follow-up, or necessitate too large a sample to be used as a critical outcome in dementia prevention-delay studies. In turn, a biomarker which reflects the underlying neuropathology, for instance measures of hippocampal volume, neuronal injury, or amyloid deposition, can be used to assess the effect of training on the neuropathology of the disease (dementia) or on its progression (Rosen, Sugiura & Kramer, 2011; Valenzuela, Jones & Wen, 2003). For instance, reduced PET uptake at rest of [^{18}F]fluorodeoxyglucose (FDG) was suggested as a valid biomarker of neuronal injury in early AD and MCI (Albert, DeKosky, & Dickson, 2011; McKhann, Knopman, & Chertkow, 2011). A 6-month multicomponent cognitive training program was found to reduce decline in brain glucose metabolism in MCI and early AD participants (Forster, Buschert, & Teipel, 2011) suggesting that the program had an impact on some of the neuronal injuries that underlie AD. Some of the work by Hampstead and colleagues also exemplifies this approach. The authors found that training memory strategies in persons with MCI increased activation in the right hippocampus, hence partially restorating hippocampal function (Hampstead, Stringer, & Stilla, 2012). In both cases, neuroimaging was used as a surrogate marker to indicate that cognitive training could have an impact on the early biological expression of AD.

Brain Imaging to Identify Structural Plasticity

There is evidence that cognitive training has direct effects on brain structure. Boyke, Driemeyer, and Gaser (2008) examined the effect of a 3-month three-ball juggling learning program on gray-matter volume measured with voxel-based morphometry in younger and older adults. Following the learning phase, older adults showed increased volume in the visual cortex, in the left hippocampus and in the nucleus accumbens bilaterally. Overall, younger adults showed slightly larger volume increases than older adults, but it was only older adults who showed training-related changes in the hippocampus and nucleus accumbens.

Engvig, Fjell, and Westlye (2010, 2012a) examined the effects of an 8-week method of loci memory training on cortical thickness in middle-aged and older adults and on the white matter microstructure, using diffusion tensor imaging (DTI). Training was found to increase cortical thickness in the lateral orbitofrontal cortex bilaterally and right fusiform cortex; and these changes correlated positively with memory improvement. The authors also reported a non-significant increase in fractional anisotropy (FA) in the frontal areas of trained older adults and a significant decrease in those who received no training. These findings suggested that training might reduce white-matter degradation associated with aging. There were similar findings by Lovden et al., who reported increased FA (and decreased mean diffusivity) in older adults, following a multidimensional program in which participants practiced WM, episodic memory, and perceptual speed tasks. Overall the studies investigating the effect of training on the structure of the brain indicate that behavioral training can induce considerable structural plasticity in older adults.

Effects on Training for Brain Activation

Nyberg, Sandblom, and Jones (2003) were among the first to assess the effect of training with a task-related activation paradigm. They reported increased occipitoparietal PET-related activity in older adults trained successfully with the method of loci. Younger adults showed a similar pattern of brain changes following training with an additional increase in the prefrontal cortex. Belleville et al. (2011) used fMRI to assess memory-related activation following a 6-week multifactorial memory-strategy training program. In their program, participants were trained on a range of memory strategies including semantic elaboration, face-name association, and the method of loci. They assessed whether training would be found in specialized brain regions that are typically involved in verbal memory, or in alternative areas, that is, regions not typically involved in word memory. They found increased post-training activation in specialized brain regions as well as new areas of activation. These additional activations, they argue, would reflect the implication of alternative compensatory strategies. For instance, activation of the right inferior parietal lobe found following training might reflect the fact that participants applied the visual imagery techniques as a strategy to encode words. Interestingly, activation of the right inferior parietal lobe was found to correlate with the efficacy of memory training in persons with MCI, hence suggesting that this brain region might support successful compensation. Note that training in this study did not modify activation of the hippocampus, which is surprising given that the goal was to improve episodic memory and hippocampal function is thought to be impaired in MCI. This lack of hippocampal activation might be explained by the fact that the program used in this study relies heavily on the teaching of visual-based mnemonics and hence might promote recruitment of prefrontal and posterior brain regions rather than the hippocampus.

In a set of more recent studies, Hampstead et al. (2012) used a memory training method that relied on associative memory (relying on mental imagery to learn object–location associations). They found that hippocampal activation increased significantly in MCI following training compared to an exposure-control condition. Hence, enhanced hippocampal activation might be favored by the use of a more focused approach that targets associative memory. Overall, studies of memory training that have induced brain changes have mostly reported increased activation either in specialized regions or in alternative regions that are required by the mnemonics taught.

A few studies have assessed the neurofunctional basis of attention-executive training in older adults and while some have reported increased post-training activation, others indicated a mix of increased and decreased activation. Rosen and colleagues reported increased left hippocampal activation in MCI persons who were assigned to a computerized program designed to improve speed and temporal auditory processing (Rosen et al., 2011). Disadvantaged older adults participating in Experience Corps, a program promoting social engagement, also showed increased post-training activation in the left dorsolateral prefrontal cortex and anterior cingulate gyrus when performing the flanker-task (Carlson, Erickson, & Kramer 2009). Erickson, Colcombe, and Wadhwa (2007) and Erickson, Boot, and Basak (2010) measured changes in the pattern of fMRI activation during dual-task performance following attentional training in healthy older adults. They reported increased activity in the left VLPFC region (near Broca's area), which could reflect an increased reliance on verbal or inner speech strategies. They also observed decreased activity in the right VLPFC, suggesting a reduced dependence on response selection strategies or a more efficient stimulus–response–stimulus association. Brehmer et al. (2012) reported decreased post-training brain activity following a 5-week WM adaptive (individualized) training, a result which they interpret as reflecting improved neural efficiency. Braver and colleagues reported a combination of increased activation in response to the cue and reduced activation in response to the probe, following strategy training on task maintenance and updating.

Models of Training-Induced Brain Changes

A few models have been proposed to interpret the effects of cognitive training on the brains of older adults. Some of these models focus on naturally occurring compensation in older adults, in contrast to formal cognitive training approaches. One set of models (Clement & Belleville, 2012) has proposed that compensation in the early AD phase occurs by increasing activation within the specialized structurally impaired network. Other models propose that brain lesions can reveal latent regions that would have otherwise remained silent when performing the task. For instance, the HAROLD model (Cabeza, 2002) proposes that compensation occurs in aging through the recruitment of latent regions located contralaterally to those that are typically recruited by the task. According to the CRUNCH model (Reuter-Lorenz & Cappell, 2008), compensation is supported by both increased activation of specialized brain regions and by strategic recruitment of alternative regions. These two models align well with the findings that memory training in older adults often results in new activation of alternative (latent) brain regions, but they fail to account for the fact that attention training often reduces activation and that alternative types of training result in different types of brain changes.

In their theoretical framework for the study of adult cognitive plasticity, Lovden, Backman, Lindenberger, Schaefer, and Schmiedek (2010) argue that changes in plasticity occur when there is a mismatch between the environmental demand and the capacity of the system; their view of plasticity is more in line with a magnification perspective of training. Furthermore, they propose that processes representing plasticity result in *structural* brain changes that have functional consequences. They distinguish plasticity from the transient changes in pre-existing processes which would reflect the flexibility of the system in the face of changing demands; transient changes reflecting flexibility are more in line with a compensatory training approach. Finally, they argue that neuroplasticity can occur both following alteration of processing efficiency or modification in the knowledge base or strategy. Thus, reactive or plasticity processes might occur following a range of training modalities, but adaptive methods that adjust the task or training demands to the individual's capacity are those that would optimize plasticity. Notably, because this model distinguishes between flexibility and plasticity, one implication is that training studies involving examination of brain changes should report structural changes in addition to changes in functional activation.

The Scaffolding Theory of Cognitive Aging (STAC) proposes that cognitive compensatory scaffolding processes act to reduce the adverse effects of neuronal and functional changes and promote functional independence. Initially proposed in 2009 (Goh & Park, 2009), the model proposed that the aging brain retained the potential for positive neuroplasticity in response to stimulation and new learning and that engagement resulted in increased compensatory frontal and/or bilateral activation. In a revised version, the STAC-r model integrated individual differences in life course events as factors that had the potential to enrich or to deplete neural resources and compensatory capacities (Reuter-Lorenz & Park, 2014). Both the initial and the revised models propose that formal interventions and training can enhance cognitive resources and compensatory scaffolding and can have an effect on neuroplasticity.

The INTERACTIVE model proposed by Belleville et al. (2014), suggests that training-induced changes in activation depend on a complex interaction between the training modalities (i.e., format, target, training sequence) and the subject's individual factors (i.e., the presence, severity and location of a lesion, subject's cognitive reserve, level of expertise). Individual factors such as a genetic potential for brain plasticity, higher premorbid IQ or educational background might favor the use of an alternative network or structural remodeling. Pre-training proficiency might also be a relevant factor. Brain-based models of procedural learning have proposed that there is a shift in the regions of activation as a function of the level of automaticity in learning a task (Doyon & Benali, 2005). A similar phenomenon might occur when learning to apply complex new strategies. In addition, different populations may be differentially sensitive to restoration versus compensation effects. For instance, the efficacy of a restorative approach is probably dependent on the amount of structural damage in the impaired region with an optimal effect in the middle range of damage.

The model also proposes that the pattern of change in activation should align with the cognitive processes that are mobilized by the training. For instance, repeated or incremental practice on a task should result in decreased activation within the brain regions involved in a task, due to more efficient processing in specialized regions. In contrast, interventions involving metacognition or the teaching of new strategies would result in increased activation of the brain networks involved in those particular strategies. Thus, a finding that training results in activation of a network that was not active prior to training, should reflect the fact that there is a change in the process by which the task is completed. Hence, predicting the effect that a training format will have on the brain requires a precise understanding of the cognitive mechanisms that the intervention engages or modifies.

In a recent study that was published in support of their model, Belleville et al. (2014) report that the type and loci of the brain's response to training are largely dependent on the type of training provided. Attention training can also result in increased activation when compensatory strategies are taught. They compared healthy older adults' post-training changes in activation, following either repeated practice on tasks (alphanumeric equation judgments and visual detection tasks) under either focused attention (*single repeated*) or training in combining the two tasks under different conditions of attention priority (*divided variable*). In the latter condition, participants learned to control their attentional focus by exerting top-down regulation and by relying on their metacognitive abilities. *single repeated* training made participants faster and more accurate when asked to solve the alphanumeric equations under single-tasking and this was accompanied by reduced activation in the right inferior frontal gyrus, right middle frontal gyrus, left middle frontal gyrus, and in the left thalamus. This suggests increased efficacy of specialized regions with no qualitative change in the way the task was completed. This finding is coherent with the notion that repeated practice will result in decreased activation in brain regions that were active prior to training. In turn, the *divided variable* training increased activity in the right prefrontal cortex area 10 under dual-tasking conditions. As this is a region involved in orchestrating the basic executive functions needed to accomplish novel tasks and is critical for metacognition, it has been suggested to reflect the use of more active metacognitive and control capacities.

Neuroimaging as a Predictor of Training Response

Individuals differ in their response to cognitive training. One important question is identifying the factors that distinguish responders from non-responders, so that clinicians can determine who will benefit most from an intervention. Cerebral differences may contribute to individual differences in training effects. The performance gain following Space Fortress video game training that emphasized variable priority attention allocation was predicted by the pre-training volume of the dorsal striatum but not by pre-training volume of the hippocampus (Erickson et al., 2010). This result could be due to the role of the striatum in dopaminergic function; dopamine has been found to be involved in interindividual variability in cognitive aging (Li et al., 2008). Persons with greater dopamine availability might have more potential for training-related neuroplasticity, irrespective of the type of training provided.

An alternative explanation is that neurobiological predictors depend on the regions that are implicated by the training. For instance, Engvig et al. (2012b) reported that larger left hippocampal volume in persons with subjective cognitive decline was related to larger behavioral gain following a multimodal memory training program. Of note, they also found depression predicted post-training memory change independently from hippocampal volume and that the two combined factors explained almost 38% of the variance in training efficacy. Thus, the predictive value of the different brain regions might depend on their level of relevance to the training program. Training of episodic memory might be best predicted by hippocampal regions whereas training of attentional control might be predicted by the striatum, a region involved in executive control.

One hypothesis regarding transfer is that it will be found to the extent that there is overlap between the regions engaged in the training and those involved in the transfer task. This was supported by Dahlin et al. (2008) who trained younger and older adults with an updating training task. They assessed effect on a letter updating test and transfer on the n-back test, which implicates updating as well, and on the stroop tests which do not involve updating but require frontal lobe-mediated executive processes. In younger adults, all three tasks were found to activate a frontoparietal network prior to training but only the n-back and letter task showed a common left striatum activation. Thus no training effect was expected on the stroop task if transfer depended specifically on improvement of the striatum. Training was found to improve letter memory and there was transfer to the n-back, but not to the stroop task. Importantly, training increased activation in the same left striatal region that was activated by the letter and n-back task and this was found for the letter and n-back task but not for the Stroop task.

In a second experiment involving older adults in contrast to the prior study with young adults, they found a reduced training effect on the letter task and no transfer on the n-back task. They also found that older adults failed to activate their striatum prior to training and that the training-related increase in striatal activation was limited to the letter task. The authors conclude that the limitation in transfer following updating training in older adults might be due to their impaired striatal function.

Thus, there are indications that brain imaging can be used to predict both individual differences in training outcomes and also the extent of transfer expected from different training formats. Neuroimaging studies have suggested two brain regions—the striatum and the hippocampus—that seem to be implicated in the efficacy of cognitive training. One question is whether these are generic regions which would predict training and transfer whatever the type of training provided. For instance, Engvig suggested that adults with greater hippocampal volume might have a larger degree of brain plasticity and more potential for restoration or that those individuals have more reserve. However, these regions don't seem to correspond to generic regions as they are systematically related to training efficacy. Rather, their contribution appears to depend on the type of training provided, the hippocampus predicting efficacy of memory training, and striatum predicting executive training efficacy.

In summary, brain imaging provides key information regarding the impact of the environment on the brains of older adults with or without cognitive impairments. Studies investigating training-induced brain changes indicate that brain imaging is sensitive to training, that it can be used as a surrogate marker to detect clinically reliable effects, and that the regions that are modified by training are highly coherent with the nature of the intervention, involving brain areas that are reflective of the type of strategies that are learned. The studies indicate a cognitive neuroscience perspective that is not totally biologically determined. Undoubtedly, current models of age-related brain organization should be aware of studies of training-induced brain changes as these can provide a complex set of results to enrich models of cognitive and neural compensation and plasticity in older adults.

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CHAPTER

13

Executive Functions and Neurocognitive Aging

Patricia A. Reuter-Lorenz[1], *Sara B. Festini*[2], *and Tiffany K. Jantz*[1]

[1]University of Michigan, Ann Arbor, MI, USA [2]University of Texas at Dallas, Dallas, TX, USA

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OVERVIEW

Executive functions (EFs) play a fundamental, yet poorly understood, role in neurocognitive aging. The overarching goal of this chapter is to consider both sides of that statement. That is, we will review behavioral and neuroimaging evidence indicating the centrality of executive functioning to cognitive aging, and we will also delineate some of the major barriers or puzzles that challenge a coherent and thorough account of the role of EF in aging. Finally, we will

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consider how and to what extent declines in EFs affect typical day-to-day activities of older adults.

EFs are multifaceted control processes that regulate thought and behavior. While different taxonomies have been proposed to account for the range of processes that are "executive" in nature, EFs typically refer to a family of general-purpose mechanisms (i.e., updating, inhibiting, switching, working memory, prioritizing, sequencing), largely mediated by the prefrontal cortex (PFC), that are critical to other higher cognitive abilities including planning, reasoning, long-term memory, decision making, and problem solving. The implementation of EFs entails dynamic interactions among neural populations within and between the left and right frontal lobes themselves, along with circuits in other cortical areas, especially the parietal lobes, and subcortical regions, including the thalamus, basal ganglia, limbic system, midbrain, and the cerebellum. Thus, neuroanatomical considerations of EFs concentrate largely on the structure and function of the frontal lobes, however, frontal areas are critical nodes in a more complex network of cortical and subcortical regions that implement executive control (Fuster, 2013).

MEASURING EFs

Numerous tasks can be used to measure EFs and these can be divided into two general classes. One class includes *standardized neuropsychological instruments* that are often part of a larger test battery used to characterize the cognitive status of a given research population. Such EF measures include Trail Making (especially Trails B; see, e.g. Lezak, 2004), Wisconsin Card Sorting, Stroop (Stroop, 1935), measures of verbal fluency (e.g., COWT; Ivnik, Malec, Smith, Tangalos, & Petersen, 1996), Wechsler Digit Span, and Letter-Number Sequencing (Wechsler, 1997). Neuropsychological measures of this type have been used in a popular battery developed by Elizabeth Glisky and her colleagues to characterize healthy older adults in terms of the extent to which they display "frontal-executive" deficits, versus "medial-temporal-memory" deficits (Davidson & Glisky, 2002; Glisky & Kong, 2008; Glisky, Polster, & Routhieaux, 1995). The other class of measures includes *experimental tasks*, which are typically non-standardized, computerized tasks that analyze behavioral responses to specific stimulus manipulations. There are too many tasks of this type to list here, but common examples include the n-back (Kirchner, 1958), stop signal (Logan, 1994), anti-saccade (Hallet, 1978), AX-CPT (Braver et al., 2001), task switching (Rubinstein, Meyer, & Evans, 2001), and recent probes tasks (Jonides, Smith, Marshuetz, Koeppe, & Reuter-Lorenz, 1998).

While cognitive tasks are rarely "process pure," the impurity problem is especially relevant for measures of EF. As Miyake and Friedman (2012) point out, the target EF being measured by a task needs something to operate on—EFs are deployed in a cognitive context. To address this issue, one approach that both standardized and experimental measures of EF commonly employ is to compare a condition presumed to entail a specific executive demand to one that is otherwise identical but lacks the executive demand. For example, the Stroop task will include a baseline color naming condition without interference from color words, and the response time difference between baseline and color-word reading provides an index of susceptibility to interference. Similarly, in the n-back task, performance can be compared when participants have to hold and update information within working memory (i.e., during a 2-back task) to a condition in which they simply have to indicate if the stimulus is the same or different from a constant target stimulus (i.e., during a 0-back task). Further, a latent variable approach can be used to address the impurity problem with statistical methods that extract common variance across multiple tasks targeting the same putative EF (Hull, Martin, Beier, Lane, & Hamilton, 2008). For instance, McCabe, Roediger, McDaniel, Balota, and Hambrick (2010) explored the commonalities between performance on measures of mental control, mental arithmetic, verbal fluency, and the Wisconsin Card Sorting Test (WCST) by performing a confirmatory factor analysis to determine if and how well each task contributed to an underlying latent component denoting EF.

A number of different taxonomies or subtypes of EFs have been identified using these and other methods including dissociation procedures testing patients with localized brain damage, functional neuroimaging, and experimental task analyses. Although there is no consensus about which particular processes qualify as "definitive" EFs, there are several that emerge repeatedly in one form or another, especially in relation to cognitive aging. These are: interference control (inhibition), cognitive flexibility (task switching), and updating (Friedman & Miyake, 2004; Hull et al., 2008; Verhaeghen & Cerella, 2002). Working memory is often incorporated into notions of executive functioning although it is generally viewed as a system consisting of active storage or maintenance processes, that are closely aligned with executive control functions (such as updating, inhibiting, refreshing). Working memory is essential for goal maintenance, whereby actively held representations guide on-going and forthcoming behaviors in accordance with plans, context, and task relevance. Additional executive control concepts that have been especially important to cognitive aging include the distinction between proactive and reactive control (Braver, Paxton, Locke, & Barch, 2009), self-initiated processing (Craik, 1994), and monitoring operations (Ridderinkhof, Span, & Van Der Molen, 2002), all of which share the properties of being potentially domain general, higher-order processes that regulate and guide cognition.

EXECUTIVE DEFICIT THEORIES OF COGNITIVE AGING

One indication that EFs play a major role in understanding cognitive aging is the fact that at least four major theories place executive functioning front and center! Because these theories have been around for about 10 years or more in various renditions, they have been discussed extensively in other venues (Craik & Salthouse, 2011; Hofer & Alwin, 2008; Jurado & Rosselli, 2007). Nonetheless, they all continue to be tenable hypotheses that garner various forms of new support. Therefore, the next section briefly reviews the core ideas from each theory to provide a framework for interpreting more recent evidence about the behavioral and neural indices of EF discussed later in this chapter.

Inhibitory Deficit Theory (Hasher & Zacks)

Hasher, Zacks, and Bower (1988) and Hasher, Stolzfus, Zacks, and Rypma (1991) proposed that a core deficit in aging pertains to the ability to inhibit or suppress irrelevant or no-longer-relevant information. The theory was originally cast in relation to working memory and the considerable evidence that working memory capacity is reduced in older adults. Their view focused on the contents of working memory, emphasizing that inhibitory dysfunction left older adults with deficits in (i) preventing irrelevant information from entering working memory; (ii) deleting no longer relevant information from working memory; and (iii) restraining prepotent information from dominating in working memory. Inhibition is invoked to explain many aspects of perceptual and attentional selection, and efforts to identify a unitary or core inhibitory deficit in older adults that spans perceptual, memorial, and response domains have met with mixed success (Aslan, Bäuml, & Pastötter, 2007; Butler & Zacks, 2006; Camp, Pecher, & Schmidt, 2007; Kramer, Humphrey, Larish, & Logan, 1994; see for review Lustig, Hasher, & Zacks, 2007 or Lustig & Jantz, 2014). However, the idea that deficits in the ability to control interference, especially in relation to the contents of working memory continues to receive considerable behavioral and brain-based support (Aguirre, Gómez-Ariza, Bajo, Andrés, & Mazzoni, 2014; Gazzaley, 2011; Gazzaley, Cooney, Rissman, & D'Esposito, 2005; Machado, Devine, & Wyatt, 2009; Scullin, Bugg, McDaniel, & Einstein, 2011; Zanto, Hennigan, Östberg, Clapp, & Gazzaley, 2010).

Goal Maintenance Deficit (Braver & West)

Based on her pioneering research with single-unit recordings in awake monkeys, Goldman-Rakic (1995) proposed that the primary and overarching function of the PFC is the representation of task-relevant goals in the absence of support from external stimuli—in other words, working memory representations. Variants of this view have been advanced by Miller and Cohen (2001) and by Braver and West (2008), who specifically propose that aging is associated with the declining ability to actively maintain goal representations in working memory, due to neurophysiological alterations in the lateral PFC. Consequently, older adults are not able to adequately control top-down strategic processing, processing that is especially needed for tasks that involve conflicting perceptual or response demands. Braver and West also argue that a goal maintenance deficit can explain, or is at least compatible with, some aspects of memory decline evident in older adults, including deficits in associative binding (Naveh-Benjamin, 2000) and prospective memory (Henry, MacLeod, Phillips, & Crawford, 2004). Finally, Braver and West propose that effective goal maintenance is necessary for preparatory and flexible biasing of attention and action systems in dynamic environments—a process referred to as "proactive control," and contrasted with "reactive control," where an effort is made to respond correctively, after the fact, rather than in an anticipatory fashion. A variety of evidence from continuous performance tasks, as well as some memory tasks, suggests that proactive control is especially difficult for older adults (Czernochowski, Nessler, & Friedman, 2010; Dew, Buchler, Dobbins, & Cabeza, 2012; Paxton, Barch, Racine, & Braver, 2008).

Production Deficit Hypothesis

The production deficit hypothesis is fundamentally related to the proposal made by Craik and Byrd (1982) that older adults are impaired at self-initiated, effortful processing—deficits thought to be linked to reduced cognitive and neural resources that in turn affect the learning and memory abilities of older adults (see also Kausler, Wiley, & Lieberwitz, 1992). Although this hypothesis does not map well onto the specific taxonomies of EFs (e.g., inhibition, updating, switching, etc.), it corresponds with the broader view that the frontal lobes are critical for strategic processing and the corollary that strategic deficiencies may contribute to age-related memory decline (Kirchhoff, Gordon, & Head, 2014; Naveh-Benjamin, Brav, & Levy, 2007). More importantly, perhaps, the enhanced ability to identify the neurocognitive processes that underlie memory encoding and retrieval, made possible by brain imaging methodologies, has established the fundamental importance of engaging prefrontal circuitry for successful memory (Fletcher & Henson, 2001; Moscovitch & Winocur, 1992; Paller, McCarthy, & Wood, 1988) and the prevalence of age-related differences in prefrontal recruitment during mnemonic tasks (Craik & Rose, 2012; Maillet & Rajah, 2014).

Frontal Lobe Hypothesis of Cognitive Aging

In 1996, West published a highly influential paper that reviewed extensive behavioral and neuroscientific evidence supporting the hypothesis that declines in frontal lobe functions can explain a wide range of age differences in cognition. This hypothesis was grounded in earlier neuropsychological work based primarily on lesion studies that broadly compared the performance profiles of older adults to the types of deficits associated with damage to different brain regions (Albert & Kaplan, 1980; Dempster, 1992). As West pointed out, prior to his paper the major emphasis had been on inhibitory deficits, whereas his contribution broadened the explanatory scope of the frontal hypothesis of aging to acknowledge the heterogeneity of prefrontal subregions and the role of their representational abilities in controlling interference in attention and memory. One key tenet of this model is that deficits in frontally— mediated cognitive processes (i.e., EFs) should be the first and the earliest signs of cognitive aging to emerge across the lifespan—a prediction that is longitudinal in nature. A corollary of this prediction is that there will be time points, especially earlier in the course of aging, during which EFs are disproportionately affected.

A Current Perspective on Executive Deficit Theories of Cognitive Aging

The theories outlined above vary in the range of age differences they endeavor to explain, with the frontal lobe hypothesis of cognitive aging having the broadest reach. Overall these theories are not mutually exclusive and each is likely to have some piece of the truth about the nature of the cognitive deficits that can characterize older adults as a population. One crucial unknown, however, is whether there is one core executive deficit, such as impaired inhibition or working memory, that gives rise to other various manifestations of EF decline in cognitive aging. Some recent evidence pertaining to diminished resolution or clarity of working memory suggests this possibility (Basak & Verhaeghen, 2011; Peich, Husain, & Bays, 2013; Verhaeghen & Zhang, 2012), and is consistent with prior structural equation modeling indicating the centrality of working memory function to cognitive aging (Charlton et al., 2008; Hull et al., 2008). Nevertheless, it remains doubtful that a single core executive deficit could account for the wide range of neuroanatomical and neurofunctional data that has emerged over the past decade or the vast individual differences in trajectories of cognitive decline (Carlson et al., 2008; Mungas et al., 2005; Park & Reuter-Lorenz, 2009; Raz, Ghisletta, Rodrigue, Kennedy, & Lindenberger, 2010; Wilson et al., 2002). Furthermore, it is increasingly evident that EFs are fundamental to maintaining high cognitive function in older age, and that compensatory cognitive and neural processes may ameliorate other deleterious biological and functional effects of aging (Reuter-Lorenz & Park, 2014). In the following sections we will consider the lifespan trajectories of EFs, as well as the compensatory support that may be conferred by utilizing preserved executive abilities in older age.

DO EFs SHOW THE EARLIEST AND DISPROPORTIONATE DECLINE?

One of the core assumptions in EF theories of cognitive aging is that EFs will be the first cognitive abilities to decline as people age, and that EF dysfunction will be disproportionally greater than other aspects of cognitive impairment. The first assumption requires longitudinal evidence to assess the trajectories of cognitive change within individuals, however the latter assumption could potentially be addressed with cross-sectional work assessing whether age-related differences in EFs are greater than those in other cognitive domains. We consider the cross-sectional evidence first.

Cross-Sectional Evidence for Disproportionate EF Decline?

Verhaeghen (2011) specifically examined whether age-related EF deficits were larger than age-related declines observed in non-executive comparison conditions. Using a series of meta-analyses based on the Brinley plot approach to assess differential age effects, Verhaegen reached two important conclusions regarding measures of resistance to interference, task coordination, and task shifting. First, with respect to absolute age differences, the effects of age were reliable and universally larger on executive versions of the tasks, compared to their respective non-executive conditions. Second, overall these deficits were not disproportional to the age effects measured on the comparison tasks. In other words, for most tasks analyzed, a single linear model fit the data for both versions of the task, which argues against a specific EF deficit per se, above and beyond that observed in the non-executive tasks. This was true for commonly used measures of EF, like Stroop and Trail Making. Several tasks did show specific EF deficits, namely reading with distraction, dual-tasking, and global task switching (see also Verhaeghen & Cerella, 2002; Note that global switching costs are generally thought to reflect the additional load entailed in actively maintaining two sets of task goals at the same time). However, one concern is that these effects were relatively modest, and another is that these tasks are not among the neuropsychological measures of EF typically used in large-scale studies of aging.

In a further set of analyses based on correlations among aggregated data from 119 published studies, Verhaeghen (2011) sought to determine whether declines in EF could account for age-related variance in other aspects of complex cognition as reflected in measures of episodic memory, reasoning and spatial ability, and how the variance accounted for compared to that explained by processing speed and working memory. Consistent with prior research (Park et al., 2002; Salthouse, 1991, 2005), speed and working memory accounted for a larger portion of the variance than EF (resistance to interference and task switching), and accounted for no variance independently of speed and working memory. Taken together, these analyses based on hundreds of cross-sectional studies suggest that key EFs, resistance to interference and task shifting, while clearly impaired in older adults, are neither disproportionately impaired compared with other cognitive functions, nor do they account for age-related variation in performance on other measures of complex cognition.

Nonetheless, working memory continues to emerge as an aspect of EF that, while strongly affected by age declines in processing speed, may play a fundamental role in other aspects of cognitive decline. Furthermore, given the relative paucity of studies on other putative EFs such as updating (Fisk & Sharp, 2004; Pelegrina, Borella, Carretti, & Lechuga, 2012; Schmitt, Ferdinand, & Kray, 2014) and other forms of interference control in memory that are clearly affected by age (i.e., semantic interference, proactive interference, directed forgetting; Hedden, 2001; Hogge, Adam, & Collette, 2008; Titz & Verhaeghen, 2010), the possibility that aspects of EF decline contribute prominently, and disproportionately to cognitive aging remains viable.

Longitudinal Evidence for Earlier EF Decline?

Increasing sets of longitudinal data are emerging relevant to the question of whether EFs show an earlier onset of decline compared to other domains of cognition and whether there are specific executive declines or solely global changes. Longitudinal studies have revealed that both domain-general and domain-specific changes exist (Tucker-Drob, 2011).

Although some variance in task performance can be captured by a general cognitive variable, performance on specific tasks, including tasks that require executive abilities, can account for remaining variance. Goh, An, and Resnick (2012) examined longitudinal cognitive trajectories in the Baltimore Longitudinal Study of Aging and observed varying patterns of cognitive change. Longitudinal declines were observed in many executive tasks, including verbal fluency, digit span, alpha span, and Trails B. These tasks require executive skills such as inhibition, mental manipulation of information in working memory, semantic retrieval, and switching between rule sets. This study also documented longitudinal declines in long-term memory. However, other measures of short-term memory, chunking, and discrimination assessed by the California Verbal Learning Test, as well as conceptual abstraction and working memory capacity, did not exhibit declines. This discrepancy may be due to differences in the difficulty of each task, differences in the types of processing required by each task, differences in vulnerability to test–retest practice effects, as well as due to individual differences in the experience of cognitive changes over time. Moreover, this variability in the longitudinal data reflects that declines in EF are not always observed, and, accordingly, that disproportionate declines in EF are also not ubiquitous.

Indeed, inter-individual variability in longitudinal trajectories has been documented in multiple studies (de Frias, Dixon, & Strauss, 2009; Goh et al., 2012; Wilson et al., 2002). Pertaining specifically to EF, de Frias et al. (2009) found individual differences in 3-year longitudinal changes in inhibition, shifting, and updating. Certain individuals had greater stability in EF, and these individuals had better EF abilities overall. Thus, important insights into the aging process may ultimately depend on understanding why individuals differ so widely in their trajectories of change.

DO BRAIN REGIONS LINKED TO EF SHOW THE EARLIEST AND DISPROPORTIONATE DECLINE?

If EFs are most vulnerable to age-related decline, then we might expect that the neural substrates of EF would show the earliest and most robust indications of the adverse effects of aging. In this section we consider evidence that bears on this claim. First, however, we review evidence linking age effects on EF to specific neuroanatomical substrates. As noted in the overview to this chapter, regions of PFC are known to play critical roles in EFs, and the body of research establishing these links includes studies of brain–behavior relations in patients with focal brain damage (Baldo, Delis, Wilkins, & Shimamura, 2004; Davidson, Gao, Mason, Winocur, & Anderson, 2008; Yochim, Baldo, Kane, & Delis, 2009) as well as functional imaging studies of regional brain activity during the performance of cognitive tasks (Collette et al., 2005; Funahashi, 2001; Koechlin & Summerfield, 2007). However, it is also clear that regions of PFC interact extensively with other cortical and subcortical areas (Fuster, 1997), making the integrity of white matter pathways that mediate these interactions a critical player in the effectiveness of prefrontal control. Research on the effects of aging highlights the critical role of these pathways.

Aging and the Neural Substrates of EF

Relationships between EFs and prefrontal structure, including measures of cortical thickness and volume of frontal subregions, and white matter pathology, have been documented in normal middle-aged and older adult populations. White matter hyperintensities (WMH) appear as bright spots on MRI images of the brain, and older adults frequently exhibit more WMH than younger adults (DeCarli et al., 1995). WMH have been associated with various structural and functional brain changes, as well as increased clinical risk for stroke, dementia, and death (Debette & Markus, 2010). With regard to frontal lobe function, DeCarli et al. (1995) assessed WMH in adults free from other cerebrovascular risk factors and found evidence that greater levels of WMH were associated with reduced frontal lobe metabolism and worse performance on Trail Making Tests A and B (see also Tullberg et al., 2004). An early meta-analysis similarly related WMH and poor executive performance (Gunning-Dixon & Raz, 2000).

More recently, white matter integrity assessed using diffusion tensor imaging (DTI), has consistently revealed age-related declines in fractional anisotropy (FA) in the frontal lobes and links to EF decline (Grieve, Williams, Paul, Clark, & Gordon, 2007; Head et al., 2004; Kennedy et al., 2009; Salat et al., 2005). Low levels of FA reflect more disperse diffusion of water, which is indicative of decreased white matter integrity. For instance, Grieve et al. (2007) found evidence for a correlation between FA and EFs, such that lower FA values were associated with poor performance on the Trail Making task and a maze task (see also Brickman et al., 2006; Kennedy & Raz, 2009).

Critically, age-related cortical atrophy of PFC has also been linked to age-related EF impairment, sometimes in conjunction with white matter measures. In one early, widely-cited study Gunning-Dixon and Raz (2003) demonstrated that, in adults ranging in age from 50–86, both the volume of PFC and the integrity of underlying white matter (as indicated by quantification of WMH) predicted perseverative responses on the WCST (see also Kramer et al., 2007; Mungas, et al., 2005; Zimmerman et al., 2006). Consistent with this observation, Head et al. (2009) found smaller PFC cortical volumes to be associated with an increase in perseveration errors on the WCST. Measurements of other cortical regions did not share this predictive power.

A recent meta-analysis (Yuan & Raz, 2014) that includes 31 samples of participants with volumetric measures and 11 samples with measures of cortical thickness (total $N = 3272$ ranging in age from 18 to 85) confirms and extends this basic relationship, by showing that larger PFC measurements are associated with better EF performance. Although the effect sizes (as indicated by Cohen's d) were generally modest, the effects for WCST, interference, working memory, and digit span backward were all highly significant. Furthermore, measures of lateral PFC had the strongest relationship with performance. It is also noteworthy that bilateral PFC volumes have also been shown to predict the magnitude of EF decline over the course of 1 year in a non-demented older adult sample (ages 50–92; average age 73; Cardenas et al., 2011). A composite that included verbal fluency, Trail Making, and Stroop was used to measure EF, and decline was attributed largely to deterioration of white matter (Cardenas et al., 2011).

Taken together there is substantial evidence linking PFC volumes and measures of white matter degradation to levels of EF functioning in older adults. But are these indices of decline among the first to emerge over the course of late adulthood? We consider data relevant to that question in the next section.

Relative Degree and Onset of PFC Decline

Recent estimates of cortical volume reductions suggest a loss of approximately 0.02–0.03% per year, from about age 50 onward (Fjell et al., 2013). Of the age-related changes in brain structure that are commonly observed, structural changes in the frontal lobes have been thought to be the most dramatic (Brickman et al., 2006; Fjell et al., 2009; Grieve et al., 2007; Madden, Bennett, & Song, 2009; Raz et al., 1997; Salat et al., 2005), although there has also been considerable variability among studies due to a variety of methodological and sampling issues (Raz & Rodrigue, 2006). Moreover, the majority of studies to date are cross-sectional, and, thus, they can only document differences related to chronological age. To reveal differences due to aging itself, longitudinal studies are required to assess within-individual changes in brain structure.

With respect to white matter, Head et al. (2004) provide evidence for an anterior–posterior gradient, such that frontal regions exhibit lower levels of white matter integrity and more posterior regions exhibit greater white matter integrity. An anterior–posterior gradient is consistent with the frontal lobe hypothesis, and has been found more generally in a meta-analysis by Madden et al. (2009) (see also Brickman et al., 2006).

Similar effects have been observed in the patterns of gray matter loss with age. Jernigan et al. (2001) report that the frontal lobes had a disproportionate reduction in cortical gray matter compared to the rest of the brain. A longitudinal study by Resnick, Pham, Kraut, Zonderman, and Davatzikos (2003) similarly reported a reduction in cortical gray matter over time. The largest gray matter losses were observed in the orbital frontal gyrus, inferior frontal gyrus, cingulate gyrus, insula, and inferior parietal gyrus. Further, though gray matter changes were observed in several regions across the course of 6 years, atrophy of frontal regions was associated with significant functional decline (Nyberg et al., 2010).

However, as Fjell et al. (2009) point out, given the wide variation in structural results, it is difficult to draw firm conclusions about whether prefrontal regions are more adversely affected by healthy aging than temporal cortex and medial temporal lobe regions, for example, which are also vulnerable to degenerative processes, especially associated with Alzheimer's disease (Clerx et al., 2013; Heckemann et al., 2011; Jack et al., 1997). To address this problem, the Fjell team (2009) culled data from 883 participants drawn from six different samples ranging in age from 18 to 93 years, and analyzed structural images using identical preprocessing and thresholding procedures. While age-related thinning of cortical tissue was evident throughout the cortex, age effects across samples were strongest and most consistent in prefrontal regions, especially superior, lateral and medial prefrontal regions, which are typically associated with EFs. These results are clearly consistent with the frontal lobe hypothesis of cognitive aging. The authors point out however, that the anterior cingulate, a medial structure considered to be part of the frontal lobes, was relatively preserved. This region is thought to contribute to error monitoring, and aspects of executive control associated with response inhibition and performance on the Stroop task (Botvinick, Cohen, & Carter, 2004; Pardo, Pardo, Janer, & Raichle, 1990).

Further, in one of the most extensive longitudinal studies of brain structures to date, Pfefferbaum et al. (2013) examined trajectories of change over a period of up to 8 years across multiple cortical and subcortical regions in over 100 cognitively normal individuals ranging in age from 20 to 85 at the time of their first scan. While decline was widely evident and tended to accelerate in older age, volume reductions in lateral and medial prefrontal regions were greater than in other cortical areas, including lateral and medial temporal regions, which also showed prominent age-related declines.

Based on the anatomical evidence it would seem that the frontal lobes are especially vulnerable to volume loss and white matter insults with age, a core assumption of the frontal lobe hypothesis of cognitive aging. The anatomical evidence as a whole may be more consistent and compelling than the cognitive-behavioral results, at least with respect to the question of earlier and disproportionate decline. This difference in sensitivity should not be surprising, perhaps, given the challenges the field has faced with identifying core EFs, along with the great variation in tasks used to measure them. It also appears more generally that brain changes are likely to be measureable before cognitive changes in many domains (e.g., Mueller et al., 2005 regarding Alzheimer's disease; Raz et al., 2010; Raz & Lindenberger, 2011), suggesting that brain measures are more sensitive indicators of age-related decline than behavior. How then to reconcile the evidence for structural decline with what seems to be the many PFC-mediated strategic and compensatory processes engaged by older adults as revealed through functional brain imaging? We turn to that question next.

EFs AND PFC PROCESSES AS COMPENSATORY AND PROTECTIVE

Despite the structural indications that the frontal lobes are especially vulnerable to the adverse effects of aging, functional neuroimaging studies frequently reveal over-recruitment of the prefrontal regions in older adults, and some results have linked these effects to compensation and better performance in older adults (Cabeza & Dennis, 2012; Reuter-Lorenz & Cappell, 2008). That is, across a broad range of experiments measuring task-related activation with functional neuroimaging, older adults have been shown to activate frontal regions that are not active in younger adults performing the same tasks (Cabeza, 2002; Davis, Dennis, Daselaar, Fleck, & Cabeza, 2008; Gutchess et al., 2005; Reuter-Lorenz, 2002). Recently, Turner and Spreng (2012) used a meta-analytic activation likelihood technique to examine such age differences during executive tasks from 27 studies, resulting in a sample of 350 younger and older adults. They documented that activation was reliably greater in older adults in bilateral dorsolateral prefrontal cortex (DLPFC), supplementary motor cortex, and left inferior parietal lobule during working memory tasks. For tasks that required inhibitory control, older adults tended to showed greater recruitment of the right inferior frontal gyrus and the pre-supplementary motor area. Similarly, a recent meta-analysis by Maillet and Rajah (2014) comparing age-related activation during *successful* memory encoding showed greater activation for older adults in bilateral middle frontal gyri, bilateral superior frontal gyri, anterior medial frontal gyri, precuneus, and the left inferior parietal lobe, when encoding new episodic memories that they could subsequently remember. These converging data from multiple studies demonstrate that older adults appear to increasingly depend on PFC, and that different specialized frontal networks are recruited depending on the type of executive demands imposed by the task. Thus, even though the adverse effects of aging may selectively target the frontal lobes, functional neuroimaging evidence indicates, paradoxically, that age-related over-recruitment of frontal networks can be beneficial (Angel, Fay, Bouazzaoui, & Isingrini, 2011; Peelle, Chandrasekaran, Powers, Smith, & Grossman, 2013).

Some insight into the mechanisms underlying over-recruitment of PFC comes from studies that have varied task demands to determine the level of demand at which overactivation is evident in older adults, and to ask whether there might be some level of demand at which younger adults also begin to activate these additional regions. Several studies that varied working memory load in either an n-back task or an item recognition task demonstrate that older adults recruit additional regions of dorsolateral PFC at low to intermediate memory loads, whereas younger adults bring these areas on-line only at higher loads (Cappell, Gmeindl, & Reuter-Lorenz, 2010; Mattay et al., 2006; Schneider-Garces et al., 2010). Vallesi, McIntosh, and Stuss (2011) demonstrated this demand-related compensatory activation by varying the difficulty of a Go/No-Go task (low conflict versus high conflict), as well as by assessing performance on the first block of trials, while the task was still novel, versus performance on the second block of trials, after participants had been accustomed to the task with practice. Compared to younger adults, older adults over-recruited a fronto-parietal network during the highest task demand (i.e., during high-conflict trials in the first block). Furthermore, this additional recruitment of supplemental brain regions was associated with a lower error rate, providing yet another indicator that additional fronto-parietal engagement was compensatory.

However, greater neural recruitment is not always associated with better task performance. Individuals who show more activation also can have worse behavior. For example, older adults with greater activation of the superior frontal gyrus had lower hit rates and lengthened response times when performing a visual selective attention task (Solbakk et al., 2008). This inverse association between activation and performance may be due to the level of task difficulty. Although greater neural recruitment can be beneficial at lower levels of task demand, as demand increases available neural resources may be insufficient to support the computational requirements of the task. These ideas relating task demand to age difference in activation have been summarized in the compensation-related utilization of neural circuits hypothesis or CRUNCH proposed by Reuter-Lorenz and Cappell (2008).

Cross-sectional evidence also suggests that older adults engage control processes differently than young adults, with greater emphasis on reactive control, which is engaged at later stages of information processing, than proactive control, which can be considered more preparatory in nature. For example, while completing demanding control tasks, older adults show a late-stage over-recruitment of frontal regions, which may reflect a strategy shift that results in preserved, but slower and more rigid task performance (Velanova, Lustig, Jacoby, & Buckner, 2007). This so-called early-to-late shift (ELSA) of executive control strategies is also evident in the delayed functional connectivity of PFC and subcortical structures associated with memory (e.g., hippocampus), which may have important implications for maintenance of goals (Dew, Buchler, Dobbins, & Cabeza, 2012). Evidence from event-related potentials likewise suggests that older adults under-recruit control processes in response to a preparatory cue, but over-recruit in response to the target stimulus itself, thereby maintaining accurate performance, but at the expense of response speed (Kopp et al., 2014).

The importance of EF for maintaining cognition and effective performance more generally is evident in purely behavioral studies as well. Despite exhibiting age-related declines in executive functioning compared to their younger counterparts, those older adults who maintain higher levels of EF exhibit better behavioral performance. For instance, de Frias et al. (2009) found that better executive functioning was related to higher initial cognitive function and greater stability in cognitive function after a 3-year longitudinal assessment. Moreover, Chang et al. (2010) examined individual differences in EF and grouped individuals with mild cognitive impairment (MCI) into subsets of high and low performers based on Backward Digit Span and the Trail Making Test. MCI patients with higher executive functioning exhibited better performance on the Rey Auditory Verbal Learning Test, demonstrating the compensatory role preserved EF can play. In the same sample, Chang et al. (2010) further documented that prefrontal cortical thickness independently contributed to improved memory, above and beyond the medial temporal regions known to contribute to episodic memory.

Thus, collectively, data from cognitive-behavioral approaches and functional imaging methods demonstrate that individual differences in both behavioral and neural correlates of EF can be related to effective cognitive performance more broadly. Based on these data, efficient use of existing and supplemental executive abilities has become an important facet of models of cognitive aging, and the PFC often plays a key role in such compensation. The Scaffolding Theory of Aging and Cognition (STAC) model proposes that compensatory scaffolding in the form of supplemental neural recruitment, neurogenesis, or enhanced neural connectivity, for instance, can help overcome the neural challenges and functional deterioration associated with age-related biological and environmental risk factors such as genetics, stress, and vascular impairments (Park & Reuter-Lorenz, 2009). Moreover, Stern's (2009) cognitive reserve account similarly posits that those with higher protective factors experience less pronounced age-related cognitive decline. Many of these protective factors are associated with greater neural health and well-developed executive abilities, including higher IQ, more years of education, and higher occupational attainment (see also Tucker & Stern, 2011). These models of cognitive aging reflect the fact that differences exist in the way that individuals experience and respond to cognitive aging, and, notably, they are particularly informed by experimental evidence implicating prefrontal and executive compensatory processes. Individuals who maintain higher levels of executive functioning, and those who are able to recruit supplemental prefrontal neural networks to cope with increasing task demands, tend to fare better.

Given the importance of executive functioning to successful performance of everyday activities, any significant declines in EF will likely negatively impact daily life, regardless of whether EF shows a unique or disproportionate age-related decline. Sakai et al. (2012) found that older adults with lower executive abilities reported a higher frequency of driving errors, both nonhazardous (e.g., entering the incorrect lane in a roundabout) and hazardous (e.g., failing to notice pedestrians crossing the street). And, in this sample, reduced EF was also associated with declines in frontal gray matter. Moreover, Farias et al. (2009) found that longitudinal declines in EF predicted completion of daily activities independently from memory decline. Examples of daily activities that were tracked in this study include navigation on familiar streets, performance of household duties, and handling money, among others. Finally, using structural equation modeling, Vaughan and Giovanello (2010) report that a latent executive component was significantly related to performance of activities of daily living, and that, in isolation, task switching was the best predictor. From these studies it is clear that executive capabilities are important to maintain independence in daily life and that declines in EF have measureable everyday consequences.

EFs, THE FRONTAL LOBES, AND LIFELONG AGING

From the various lines of evidence reviewed in this chapter, it is apparent that prefrontal cortex and EFs play a central and complex role in neurocognitive aging, being adversely affected on the one hand, and a source of potential support and maintenance of effective cognitive and behavioral functioning on the other hand. Brain-based studies appear to be more sensitive than behavioral measures to selective and early decline of frontal cortex, while also revealing increased reliance on the functions they mediate in older adults. As noted, the inconsistency of behavioral measures may stem from shortcomings of the measures themselves, in addition to the challenge of defining EFs and isolating the contexts in which they are most likely to emerge.

To the extent that EFs and the prefrontal networks on which they depend provide a source of support and compensation in later years, it is essential to understand the lifelong processes that may bolster and expand the potential for executive compensation in later life. Longitudinal studies that document the trajectory of EFs from childhood through midlife and into old age are virtually nonexistent. The only lifespan functional imaging study to date suggests, by means of cross-sectional comparisons, that middle age is a point on a continuum that is intermediary between young adulthood and older age, and that overactivation of prefrontal and other cortical loci is evident by middle age (Kennedy et al., 2014). The potential longitudinal benefits of recruiting additional prefrontal sites are largely unknown. While it may be most beneficial to maintain a "youth-like" brain activation pattern into older age (Nyberg, Lövdén, Riklund, Lindenberger, & Bäckman, 2012), there is also evidence that older adults who show higher levels of PFC and hippocampal activity sustain high levels of memory performance over a 20-year period (Pudas et al., 2013).

Indeed, understanding individual differences in trajectories of executive and prefrontal functioning may be key to understanding cognitive aging. In the STAC model proposed by Park and Reuter-Lorenz (2009) prefrontal networks are hypothesized to serve a fundamental role in scaffolding functions, whereby they provide additional computational support when primary brain networks, which mediate task performance in younger brains, become less efficient due to aging. Their revised model, STAC-R (Reuter-Lorenz & Park, 2014), takes a lifespan, longitudinal perspective, according to which neural resources can be depleted or enriched by a variety of protective and risk factors throughout development. In this model protective and risk factors affecting an individual throughout developmental time not only influence brain health and the extent that cognitive function is enhanced and maintained across the lifespan but also influence the potential for scaffolding and recruitment of additional resources as brain efficiency declines in old age.

In closing, we should briefly acknowledge the additional relevant frontiers pertaining to EF and aging that are beyond the scope of this chapter. These include the important intervention work being done to enhance and sustain EFs using fitness and cognitive training regimens, the potential benefits of bilingualism on EF in older age, as well as new research directions in decision making, emotional control, and mindfulness in the elderly. It remains to be seen whether the theoretical perspectives about frontal function and aging reviewed herein can ultimately embrace these and other new developments. And if they do fall short, we can only hope that fresh ideas and critical new insights will emerge to unify our understanding of EF and the aging mind.

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CHAPTER

14

Social Interrelations in Aging: The Sample Case of Married Couples

Christiane A. Hoppmann[1] *and Denis Gerstorf*[2]

[1]Department of Psychology, University of British Columbia, Vancouver, Canada [2]Institute of Psychology, Humboldt University, Berlin, Germany

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INTRODUCTION

Socio-contextual models of lifespan development emphasize the notion that individual development is embedded in various layers of social contexts; starting from the most immediate social relationships that involve everyday interactions with close others such as romantic partners to more macro-level societal contexts that entail historically changing socio-cultural norms, for example regarding marriage (Baltes, Lindenberger, & Staudinger, 2006; Bronfenbrenner & Morris, 1998; Cairns, Elder, & Costello, 1996). The purpose of this chapter is to use the sample case of married spouses to illustrate how individual

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development is shaped by micro- as well as macro-level social factors. To do so, we start by elaborating why taking into account the perspectives of both partners significantly increases our understanding of the social dynamics and mechanisms that shape adult development and aging in three key domains: well-being, health, and cognitive functioning. In a second step, we will describe key methodological challenges inherent in couple research and discuss how these challenges may be overcome. In a third step, we will broaden our perspective and describe different socio-historical influences on marriage from a more macro-level perspective. In a final step, we offer thoughts and suggestions on further roads of inquiry that promise to take this body of research to the next level.

OVERVIEW OF EXISTING RESEARCH AND NEW TRENDS

Married couples are a unit of particular interest in aging research (Antonucci, 2001; Berg & Upchurch, 2007; Fingerman & Charles, 2010; Hoppmann & Gerstorf, 2014). Spouses typically share significant portions of the lifespan with one another, they live in the same environment, they have deep insights into each other's individual strengths and weaknesses, and they have a stake in each other's problems because unresolved problems (e.g., in the health domain) often have ramifications for the lives of both partners (Berg & Upchurch, 2007; Hoppmann & Gerstorf, 2009). These factors make it likely that spouses have many joint experiences and turn to each other for help, both of which increase the likelihood of dyadic interrelations in aging. Furthermore, married partners are biologically unrelated and thus allow us to study how psychological, social, physiological, and environmental processes operate in conjunction with the partner in shaping aging without having to factor in shared genetic make-ups that characterize, for example, aging siblings or parent–child dyads. As a consequence, married couples constitute an intriguing unit to study from the perspective of the social and behavioral sciences.

There is accumulating evidence from cross-sectional, long-term longitudinal, and daily life studies speaking to a close interplay between spousal functioning across key domains that are central to successful aging including well-being, health, and cognition (Bookwala & Schulz, 1996; Gruber-Baldini, Schaie, & Willis, 1995; Hoppmann, Gerstorf, Willis, & Schaie, 2011; Tower & Kasl, 1996). This work has filled a significant gap in the literature because it directly tested rather than theoretically assuming that spouses profoundly shape each other's aging outcomes. These findings are also novel because they demonstrate that a significant portion of well-recognized individual differences in aging across key domains of functioning is in fact related to the respective spouse. For example, recent time-sampling research examining situation-, person- and couple-specific variability in affect and collaborative problem-solving in older couples indicates that while the lion's share of variability was situation-specific, about 15–20% of the variability originated at the level of the person and another 7–20% of the variability was couple-specific (Hoppmann & Blanchard-Fields, 2011; Hoppmann & Gerstorf, 2013). This observation inevitably raises the question about possible underlying mechanisms.

In line with calls from lifespan scholars to extend individual-focused models of lifespan development to also "consider the intertwining behavioral stream of two or more individuals" (Baltes & Carstensen, 1999, p. 217) in shaping aging outcomes, we use the *collective* model of selective optimization with compensation (SOC) as a guiding framework to discuss different mechanisms that may help older couples to age successfully together. According to the collective SOC model, social others such as spouses often play a pivotal role in the choice of goals and tasks (selection) and also have a profound impact on the means to accomplish a chosen goal (optimization and compensation). For the purposes of this chapter, we specifically focus on how spouses may influence goal-relevant means. Hence, particular attention will be given to how spouses may *optimize* each other's development by creating a social context that strengthens individual resources and so leads to a situation where older adults can perform at their best and thrive. While a supportive spouse has a tremendous potential for optimizing aging outcomes, it is also important to recognize that there may be a point when optimization may no longer be possible. Hence, we will also discuss how spouses may be able to *compensate* for common age-related resource losses by offering new means when previously available means are lost (Baltes & Carstensen, 1999). It is inspiring to think about how spouses may help optimize each other's aging outcomes and compensate for aging-related losses, thus accomplishing together what might not be possible alone (anymore). However, it also needs to be recognized that not all such endeavors are going to be successful and so remind the field to also keep in mind that spouses can at times hamper each other's aging outcomes (Baltes & Carstensen, 1999).

In the following sections, we will review research on spousal interrelations in aging across three domains of functioning that are key to successful aging, namely well-being, physical health, and cognition and selectively highlight two potential mechanisms per domain through which spouses may optimize each other's aging outcomes and compensate for resource losses. We note that numerous studies have also documented evidence for spousal similarities across a number of further behaviors and psychosocial characteristics (Anderson, Keltner, & John, 2003).

Well-Being

Most research examining age-related changes in well-being has focused on the individual, which makes sense given the prominent role of subjective perceptions, evaluations, and experiences in shaping well-being (Diener, Tamir, & Scollon, 2006). Yet, there is an accumulating body of evidence that spouses' levels of well-being (or lack thereof) are interrelated (Bookwala & Schulz, 1996; Hoppmann et al., 2011; Tower & Kasl, 1996). This could be due to selective mating and compositional effects in marriage (Kenny, Manetti, Pierro, Livi, & Kashy, 2002). More importantly though, well-being also seems to wax and wane over time in association with the respective spouse (Hoppmann, Gerstorf, & Hibbert, 2011; Hoppmann et al., 2011). For example, using up to 35 years of longitudinal happiness information from couples participating in the Seattle Longitudinal Study, we have shown that spouses did not only report similar happiness levels at the beginning of the study. We also demonstrated that changes in happiness over time were associated between spouses as well (Hoppmann et al., 2011). We note that these spousal interrelations were considerably larger in size than those found among random pairs of women and men from the same sample (Figure 14.1). This means that adults married to a spouse whose happiness went up were more likely to also report higher happiness over time. Conversely, adults with spouses whose happiness went down, were also more likely to report lower happiness over time. Hence, although a number of fascinating questions need to be looked at in more detail (e.g., conditions under which age- and gender-specific effects emerge), these findings convincingly suggest that spouses can both improve and hamper each other's well-being. Motivated by conceptual notions from the collective SOC model (Baltes & Carstensen, 1999), we thus highlight potential mechanisms that may allow spouses to optimize their well-being and compensate for losses.

The basic idea behind spousal *optimization* of well-being is that one's partner may engage in

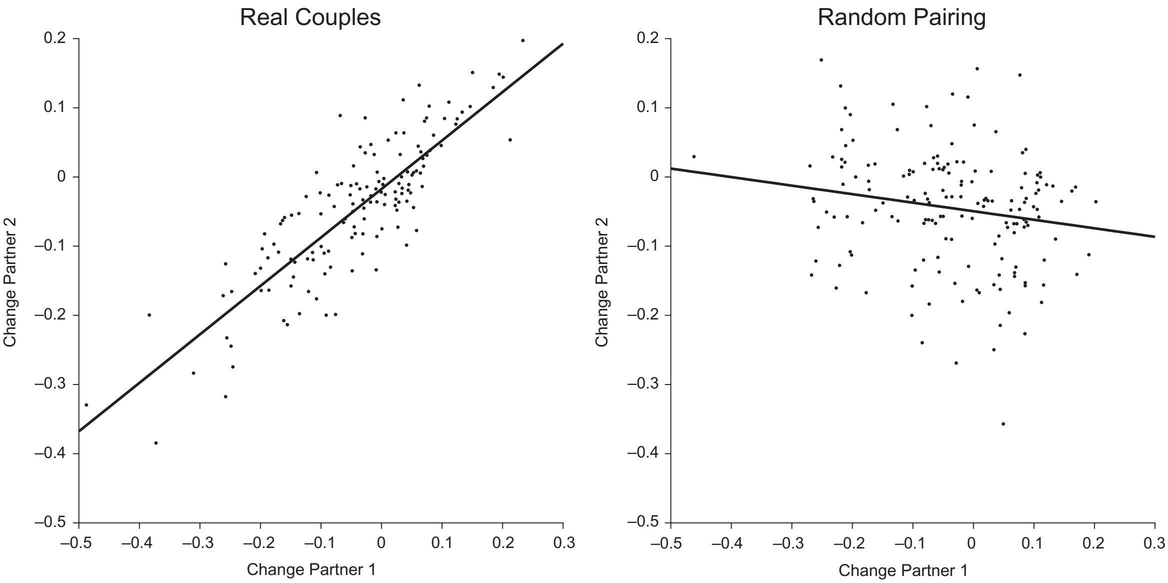

FIGURE 14.1 Social interrelations in how happiness changes over time using up to 35 years of longitudinal couple data from the Seattle Longitudinal Study: married couples (left panel) versus randomly paired men and women from the same couple data set (right panel). *For further details see figure 2 in Hoppmann et al., 2011.*

certain types of behavior that bolster well-being in old age. We selectively describe two potential mechanisms from the social psychological literature. For example, spouses may draw on each other for *self-affirmation* by bringing to mind the love and acceptance the partner has for the self (Murray, Bellavia, Feeney, Holmes, & Rose, 2001). So far, this line of work has been based on dating student couples. It would be intriguing to examine if spousal self-affirmation operates as a mechanism through which older spouses boost each other's self-esteem and well-being. Another interesting mechanism is *positive sentiment override* (Story et al., 2007). Specifically, in line with theoretical notions that older couples optimize the emotional climate within their relationship, it has been shown that older couples display more positive affectivity and that they also interpret their spouse's behaviors in more favorable ways than middle-aged couples (Levenson, Carstensen, Gottman, 1994; Story et al., 2007). This may not only be associated with favorable marital outcomes, but it could also contribute to the well-being of each individual spouse. Beyond the described examples, older adults may sometimes run into situations where spousal optimization is not enough or no longer possible. We therefore next turn to ways in which spouses may be able to promote each other's well-being when individual resources to do not suffice.

Older adults increasingly face situations where they are in need of help to compensate for individual resource losses. Hence, in contrast to optimization, *spousal compensation* entails specific mechanisms through which spouses may be able to offer new means to make up for previously available, but now compromised, resources. In line with the notion that two heads are better than one, a powerful way to overcome individual limitations may be to engage in *collaborations with the spouse*. For example, it has been shown that middle-aged and older adults who collaborate a lot with their spouse also report making better decisions when working together with their partner and enjoying their collaborations more than spouses who collaborate infrequently (Berg, Schindler, Smith, Skinner, & Beveridge, 2011). While spousal collaborations may be a powerful way to compensate for age-related losses with the potential to improve well-being, it also needs to be recognized that older adults may experience situations where the involvement of one's spouse may not be welcome. For example, *unasked-for support* has been shown to be associated with low affect quality in individuals (Smith & Goodnow, 1999). Taken together, there is substantial evidence for spousal associations regarding levels and changes in well-being in old age. However, despite some promising models from the social psychological literature, aging research is only just beginning to identify specific mechanisms through which spouses may optimize each other's well-being and compensate for resource losses.

Health

Health problems become increasingly common with aging (Spiro, 2007). Importantly, these problems often not only compromise the quality of life for the individual suffering from a particular disease, but often also have ramifications for significant others. In line with this notion, it has been shown that older adults' health is associated with the respective spouse on a variety of different health indicators, including functional limitations, blood pressure, and health behaviors (Hoppmann et al., 2011; Peek & Markides, 2003; Stimpson, Masel, Ruskin, & Peek, 2006). We selectively describe two potential mechanisms through which spouses may engage in optimization and compensation regarding each other's health. Recognizing the large literature on caregiving (Zarit & Reamy, 2013), we specifically focus on everyday life processes through which spouses can foster each other's health.

How can older adults *optimize* each other's health? The health psychological literature provides some promising avenues through which spouses may promote each other's health behaviors and how they can reduce stress responses. For example, it has been shown that *dyadic planning* promotes exercise in middle-aged and older prostatectomy patients after surgery (Burkert, Scholz, Gralla, Roigas, & Knoll, 2011). Furthermore, *spousal support* has been associated with increased everyday physical activity in a sample of older persons with diabetes (Khan, Stephens, Franks, Rook, & Salem, 2013). Another way in which spouses may promote each other's health and reduce physiological stress responses is *physical touch*. In fact, recent findings regarding the role of everyday intimacy have shown that something as little as a hug or a kiss may buffer the association between chronic stress and cortisol in the daily lives of middle-aged couples (Ditzen, Hoppmann, & Klumb, 2008). Furthermore, evidence using experimental paradigms demonstrates the potential of handholding or partner massage in alleviating partner stress in young adult samples (Coan, Schaefer, & Davidson, 2006; Ditzen et al., 2009).

In addition, spouses may also *compensate* for one another in important ways. For example, research focusing on associations between personality and health, a literature that has traditionally investigated samples of unrelated individuals, has recently been extended to a dyadic level (Lay & Hoppmann, 2014; Roberts, Smith, Jackson, & Edmonds, 2009). Interestingly, findings show that certain *combinations of traits* that had been consistently linked to negative health outcomes, such as neuroticism, can actually be beneficial if they are present in one's spouse, potentially because they help keep older adults out of harm's way (Lahey, 2009; Lay & Hoppmann, 2014; Roberts et al., 2009). For example, wives whose husbands were characterized by high conscientiousness combined with high neuroticism reported better health than other women, probably because these men were vigilant and diligent regarding health-related issues both for themselves and their wives (e.g., reminding their spouse about medications or exercise; Roberts et al., 2009). Furthermore, higher neuroticism in one's spouse has been linked to more favorable everyday problem–affect associations, possibly because spouses higher in neuroticism are more vigilant and prepare their partners to deal with everyday stressors, thereby compensating for aging-related losses (Lay & Hoppmann, 2014). This is interesting in light of potential age-related changes in personality. Hence, there is initial evidence on the potential of examining the important role of spousal optimization and compensation in the health domain.

Cognition

Spousal interrelations have been shown for a number of different cognitive abilities including memory, inductive reasoning, perceptual speed, and cognitive complexity in cross-sectional as well as long-term longitudinal studies (Gerstorf, Hoppmann, Anstey, & Luszcz, 2009; Gerstorf, Hoppmann, Kadlec, & McArdle, 2009; Gruber-Baldini, Schaie, & Willis, 1995). While these findings demonstrate that changes in cognitive functioning are linked among spouses, they also raise many questions regarding the underlying dyadic mechanisms. Research coming from an interactive minds or collaborative cognition perspective speaks to the potential of spouses to optimize cognitive performance and to compensate for cognitive losses in old age (Baltes & Staudinger, 1996; Dixon, 1999). Both perspectives emphasize the inherently social nature of cognition in terms of reciprocal influences between the cognitions of multiple individuals (interactive minds; Baltes & Staudinger, 1996) or the cognitive activity of multiple individuals working on a common task together (collaborative cognition; Dixon, 1999). The respective findings are encouraging because they have started to delineate specific conditions under which older couples may show similarly high collaborative performance as younger couples do despite well-documented age-related declines in individual cognitive performance, and they show how spouses may help compensate for individual cognitive losses in old age (Dixon & Gould, 1998; Rauers, Riediger, Schmiedek, & Lindenberger, 2011).

For example, spouses may be able to *optimize* cognitive performance by creating a *positive emotional climate* and by *counteracting* the vicious effect of anxiety-provoking *age stereotypes* that have been shown to undermine older adults' cognitive performance on a variety of different tasks (Chasteen, Kang, & Remedios, 2012; Levy, Zonderman, Slade, & Ferrucci, 2012; Murray et al., 2001). It would be interesting to examine whether the presence of a supportive spouse during a task that is known to activate negative age stereotypes leads to better cognitive performance than completing the same task alone.

In addition, older spouses may be able to *compensate* age-normative cognitive losses by engaging in spousal collaborations (Dixon & Gould, 1998; Ross et al., 2008). One key factor that has been shown to facilitate collaborative gains concerns effective *dyadic communication and familiarity*, in part because it allows older spouses to capitalize on their joint knowledge and expertise (Dixon & Gould, 1998; Margrett & Marsiske, 2002). To illustrate, Rauers et al. (2011) have shown that older adults who collaborated with their spouses needed fewer cues to guess a specific object than older adults who collaborated with age-matched unfamiliar partners. Importantly, older adults with relatively low fluid abilities were partly able to make up for their reduced performance when collaborating with their spouse as compared to working with a stranger (Rauers et al., 2011). Whether the opposite might also be true (i.e., one partner's poor cognition dragging down the other partner's cognition) remains to be tested.

Hence, effective communication and familiarity may represent pathways through which older couples are able to collaboratively compensate for an age-related loss of resources.

TOWARDS ADDRESSING METHODOLOGICAL CHALLENGES

At a very general level, research with older couples provides support for the notion that spouses play a key role in shaping each other's aging outcomes. However, an integration of these various lines of research remains challenging in part because of methodological issues. For example, long-term longitudinal studies have generated a substantial body of evidence that dyadic interrelations in aging trajectories exist, but these studies are limited due to their focus on individual-level measures (Hoppmann & Gerstorf, 2014). At the same time, there are interesting experimental paradigms (often developed for younger samples) that spell out specific dyadic mechanisms that have the potential to explain how the reported spousal interrelations in aging trajectories come about. Hence, one of the key challenges that future aging research with couples has to confront is to meaningfully integrate different methodological approaches. We will use the domain of everyday problem solving to provide an illustrative example.

Imagine the following scenarios of common everyday problems in old age: *Scenario 1.* An older man has been an avid runner for all of his life, but is increasingly having trouble with knee pain. His doctor tells him that he can either opt for knee surgery right away, recognizing that it will take a lot of hard work and a supportive environment to come back to where he is right now, or that he can stay away from activities that are hard on his knees such as running. He is having trouble weighing all the different pieces of information and worries about overburdening his wife if he goes in for surgery. *Scenario 2.* An older couple has been driving the same car for over 20 years and now it has finally broken down when the husband drove it to the mall. He is upset and does not even want to think about the larger issue of whether it is even worth fixing. *Scenario 3.* An older man has had a very close relationship with his son all along. However, since the birth of his grandchild, there have been tensions. He and his wife are trying to support the young family by looking after their grandson, but he is increasingly annoyed by an ever-growing list of instructions whenever they are babysitting. He does not want to start a conflict, but he is having trouble holding back his negative emotions.

The above everyday problems differ on many dimensions, including content domain, whether the problem is instrumental or social in nature, and in their emotional salience. Furthermore, all of these problems could be conceptualized as individual or joint problems and none of them has a right or wrong answer to them. Finally, these hypothetical problem scenarios all describe situations that are common in old age and yet, it is possible that a specific older adult experiences all of them or none of them in his or her daily life.

When trying to determine how older spouses can optimize each other's problem solving and compensate for resource losses when confronted with these problem scenarios or something similar, the researcher quickly finds himself or herself torn and unable to integrate two lines of research that are both relevant to the above-presented everyday problem-solving scenarios. On one hand, there is sophisticated *experimental* research showing that all of the above-mentioned problem characteristics matter and that older adults choose their problem-solving strategies in line with the characteristics of the problem (e.g., social vs. instrumental or high in emotional salience vs. low in emotional salience; Blanchard-Fields, 2007; Marsiske & Margrett, 2006). On the other hand, there is *time-sampling* research showing that older adults tend to approach their problems in idiosyncratic ways based on the goals they have or depending on their specific personality characteristics (DeLongis & Holtzmann, 2005; Hoppmann & Gerstorf, 2013). Importantly, these problem-situation and person-focused perspectives are not mutually exclusive, but they are rarely investigated together (see Newth & DeLongis, 2004, for an exception). We have shown—within the same sample of older couples—that there is substantial variability in individual and collaborative problem solving as related to problem-, person-, and couple-characteristics (Hoppmann & Blanchard-Fields, 2011). In other words, the same individual is likely going to solve all three problem scenarios in different ways based on their unique problem characteristics (e.g., instrumental vs. social), but s/he is also going to approach them in a consistent way that reflects his or her idiosyncratic goals and strategy repertoire (preference for individual vs. collaborative strategies) as well as the opportunities that are provided by his or her marriage (good communication style vs. not so good communication style). To move the field forward, we therefore propose that researchers examine both individual and spousal preferences for specific problem-solving strategies as well as how these strategies are tailored to problem characteristics. Doing this in a way that also allows for a combination and integration of daily life assessments and experimental paradigms would come with the important additional strength that problem solving is examined as older adults engage in their typical daily activities in their own environments, which maximizes ecological validity while also subjecting the respective mechanisms to rigorous experimental testing under controlled laboratory conditions within the same sample. For example, one might ask older couples in the lab to discuss strategies for solving ambivalent hypothetical problem scenarios that could be solved using individual or collaborative problem-solving strategies under high-stress versus low-stress conditions. One might predict that collaborations are particularly beneficial in high-stress situations. It would then be interesting to see if the respective lab findings have predictive validity for how the same couple approaches their everyday problems in response to high-stress/low-stress situations, whether that is related to spousal goals (which could be self-focused or shared), and how effectively spouses communicate the need for their partner to come in and help with a problem.

PSYCHOLOGICAL PROCESSES ARE EMBEDDED IN MACRO-LEVEL CONTEXTS

Theories focusing on more of a macro-level perspective draw attention to the fact that the above-described dyadic processes all occur in a larger societal context and that they are governed by historically changing social norms and expectations (Cairns et al., 1996; Helson & McCabe, 1994). Hence, different birth cohorts may encounter profoundly different expectations regarding the roles and behaviors within marriage (Settersten & Haegestad, 1996). For example, there are profound differences between generations in the likelihood to disengage from unsatisfying marriages as manifested in increasing divorce rates (United States Census Bureau, 2012). Another example may be changes in sexuality related to the introduction of Viagra (Marshall, 2006). In addition, social norms and expectations can differ between individuals belonging to the same birth cohort if they are part of different (sub)-cultures or religious denominations. For example, spouses may attach different meanings to their relationship and encounter different challenges in collectivist as compared to individualistic cultures, depending on their religious background (e.g., Catholic vs. non-Catholic), and whether they are married to a same-sex or an opposite-sex partner (Balsam

& A'Augelli, 2006; Diener, Gohm, Suh, & Oishi, 2000; Mock & Cornelius, 2007; Robles, Slatcher, Trombello, & McGinn, 2013). Hence, although our focus in this chapter is on understanding the psychological processes that tie together aging in spouses, we also have to recognize the often considerable impact of such macro-level forces.

For example, in light of macro-level changes in divorce rates, it is quite possible that older couples belonging to the Baby Boomer generation will be less able to bank on long histories of joint experiences when collaborating on everyday problems in old age as compared to earlier-born cohorts of older couples who often have been married for 40 years by the time they reach retirement age. At the same time, it is also possible that earlier-born cohorts vary more in their relationship quality and communication style, whereas the aging Baby Boomers might only stick to high-quality relationships and therefore be better positioned to collaboratively solve everyday problems in old age. Furthermore, changing gender roles may lead to more egalitarian collaborations and fewer gender differences in emotional transmissions (for an overview, see Joiner & Katz, 1999) among the aging Baby Boomers as compared to earlier-born cohorts.

FUTURE DIRECTIONS AND CHALLENGES

This chapter provided an overview of previous research on social interrelations in aging using the sample case of married couples. Drawing on collective extensions of the model of SOC, we have highlighted specific mechanisms that may help us better understand how spouses can optimize each other's aging outcomes and compensate for individual resource losses. In closing, we would like to highlight some remaining challenges and lay out promising areas of inquiry that would move this line of research to the next level.

Capturing Processes that Occur on Different Timescales

Developmental scientists have long called for the need to link developmental processes that occur at different levels of abstraction and along different timescales (Bronfenbrenner & Morris, 1998; Nesselroade, 1991). Specifically, combining repeated daily life assessments that capture processes that unfold on a timescale of hours or days with assessments of long-term longitudinal change that occur over years or even decades would represent a quantum leap in couples research because it would help address key questions such as "Are the fluctuations in behaviors and feelings that can be captured using daily life assessments meaningful and do they predict long-term outcomes?" Initial evidence from samples of unrelated individuals indicates that the answer may very well be "yes" (for more extended discussion, see Gerstorf, Hoppmann, & Ram, 2014). For example, we, and others, have shown that across different domains of functioning (e.g., affect quality, cognitive processes, and goal pursuit) daily life processes and short-term variability are significantly associated with long-term health outcomes including mortality hazards (Hoppmann, Gerstorf, Smith, & Klumb, 2007; MacDonald, Hultsch, & Dixon, 2008; Piazza, Charles, Sliwinski, Mogle, & Almeida, 2013). Apart from applying these research designs to the study of social interrelations in couples, it also remains to be tested what the more intermediate processes might look like. Using an example from the field of stress and aging (Figure 14.2), it will be intriguing to examine (i) if having a spouse who reports high negative affect in daily life is associated with high cortisol outputs over and above one's own levels of negative affect during a typical week (timescale of days), (ii) if having high cortisol outputs during a typical week is associated with poorer glucose regulation (timescale of months), and (iii) how this ultimately increases the risk of

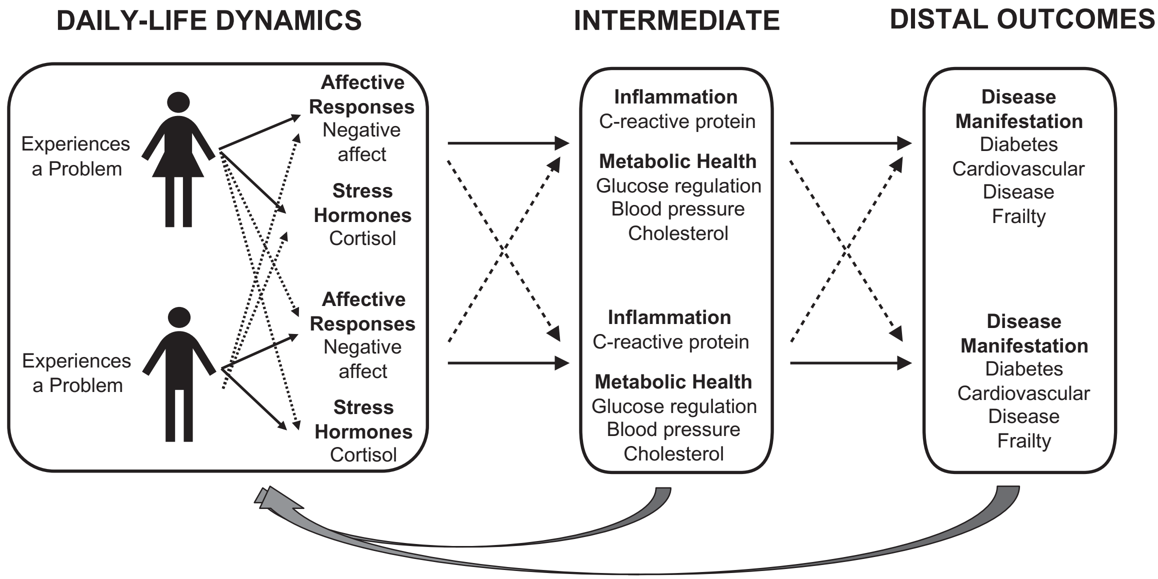

FIGURE 14.2 Working model of how multiple timescale inquiry would help us better understand the socially interrelated nature of long-term development. *Adapted from Hoppmann & Gerstorf, 2014*.

developing stress-related diseases such as diabetes (timescale of years).

Integrating Between-Couple and Within-Couple Perspectives

Another highly informative avenue for future inquiry would be to move the study of social interrelations in aging from a between-couple perspective to a within-couple perspective. For example, sizeable correlations between spouses in both levels of and long-term longitudinal changes in a variety of different indicators of physical and mental health suggest that individual change trajectories are more similar to the respective spouse than to other randomly matched partners from the same sample (Hoppmann et al., 2011). However, such similarity does not preclude the possibility that there are also meaningful and in part considerably sized health and well-being differences within a given marriage. In fact, findings from the Household, Income, and Labour Dynamics in Australia (HILDA) survey have pointed to substantial discrepancies in mental health of more than three-quarters of a standard deviation between partners within a given married dyad that remained stable over 9 years (Gerstorf, Windsor, Hoppmann, & Butterworth, 2013; see Figure 14.3). It is upon future research to delineate the specific conditions under which such spousal discrepancies are maladaptive (e.g., associated with elevated risks for marriage dissolution) or adaptive (e.g., serving developmental or relationship functions). For example, drawing from conceptual notions such as the collective SOC model, one could argue that a certain degree of spousal differences—if kept within certain bounds—can be adaptive because those discrepancies are a necessary precondition to invoke the help of one's partner during times of need in order to optimize one's own health or to compensate for resource losses.

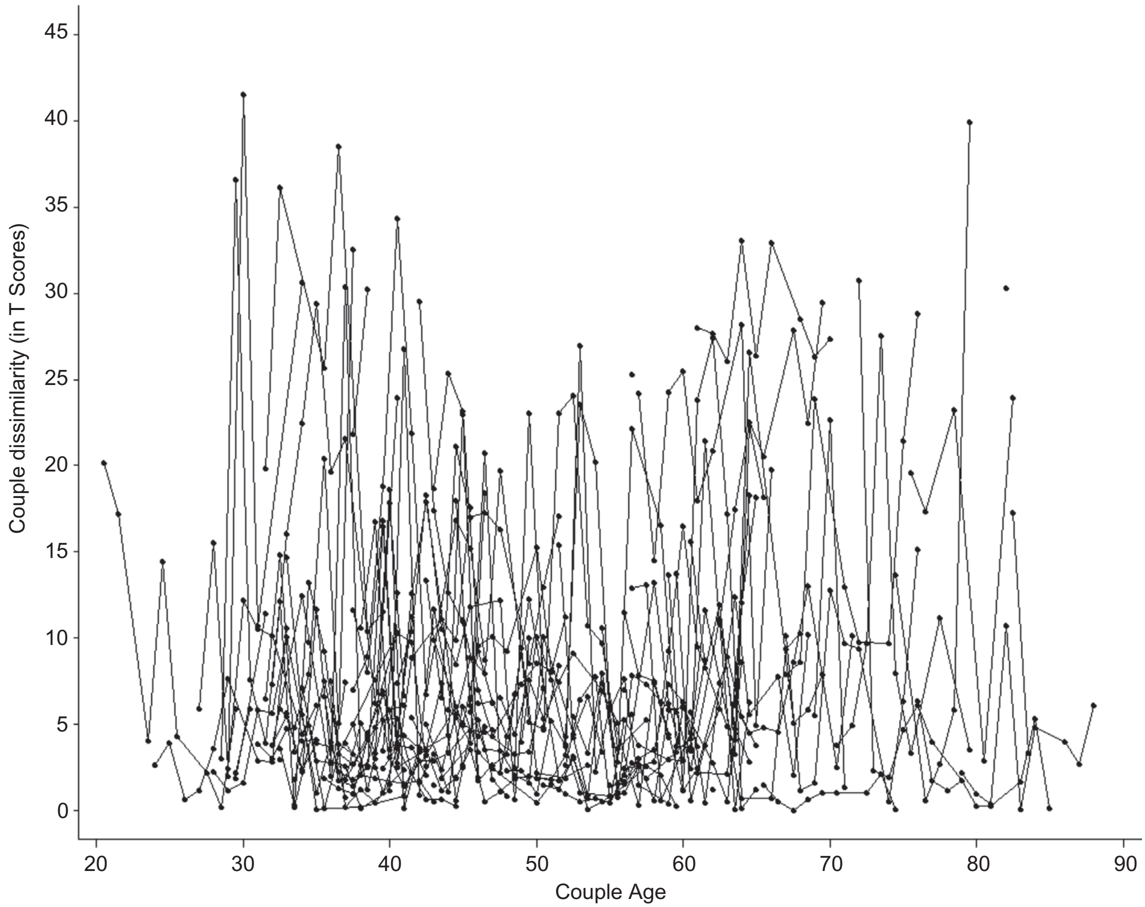

FIGURE 14.3 Within-couple similarities in mental health across couples participating in the HILDA survey. *For further details see figure 3 in Gerstorf et al., 2013.*

Applied Significance

There are multiple ways in which findings from couple studies could be applied to benefit the health of aging spouses. For example, it has been shown that holding the hand of a romantic partner alleviates stress in young couples (Coan et al., 2006). It has further been demonstrated that receiving a hand massage by a health professional prior to surgery reduces anxiety and blood pressure in cataract patients (Kim, Cho, Woo, & Kim, 2001). It would therefore make sense to explore if something as little as a 5-min hand massage by a spouse could reduce the stress associated with invasive medical procedures in old age. Furthermore, it would be highly informative to recruit spouses to provide assistance with the monitoring of clinically relevant symptoms that are outside of the awareness of a patient. For example, Swetter et al. (2009) have demonstrated that female spouses of patients with invasive cutaneous melanoma (skin cancer) had higher melanoma awareness than their husbands and that the majority of spouses played a key role in patient skin self-examination. The potential for involving spouses in health monitoring is not limited to cancer. It may also be very useful to educate and recruit spouses to help with the monitoring of other types of symptoms that are hard to detect by the affected person, such as dropping blood sugar levels in persons with diabetes or the emergence of memory problems.

Social Interrelations Beyond Marital Dyads

This chapter used the sample case of married couples to spell out a number of different mechanisms that may link the developmental trajectories of closely related individuals. While married couples offer valuable insights into the social contours of aging, they are but one specific unit. It is similarly important to examine social interrelations in other social units including but not limited to parents and their adult children or grandchildren, friendship dyads, aging siblings, or professional relationships between nurses and patients (Baltes & Zerbe, 1976; Bengtson, Giarrusso, Mabry, & Silverstein, 2002; Fingerman & Birditt, 2011; Giles & Gasiorek, 2011; Strough, Berg, & Meegan, 2001). The promise of doing so is supported, for example, by previous research from unrelated individuals suggesting that parental evaluations of how their adult children turned out are an important source of well-being (or lack thereof) in old age (Ryff, Lee, Essex, & Schmutte, 1994).

CONCLUSION

This chapter points to the importance of extending aging research to include the perspectives of multiple co-developing individuals. Such an extension holds great promise for the identification of processes through which older adults might be able to embark on more favorable aging trajectories by virtue of optimizing goal-relevant means and compensating for resources losses. Moving forward, it will be important to integrate different research designs into the same study to facilitate the integration of findings emanating from different research traditions and to spell out the mechanisms that facilitate successful aging in units of one plus one individuals.

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CHAPTER

15

Age Differences in the Connection of Mood and Cognition: Evidence from Studies of Mood Congruent Effects

Bob G. Knight[1,2], *Sarah Rastegar*[2], *and Seungyoun Kim*[1]

[1]School of Gerontology, University of Southern California, Los Angeles, CA, USA [2]Department of Psychology, University of Southern California, Los Angeles, CA, USA

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INTRODUCTION

The mood–cognition linkage is a key element of the theories underlying cognitive behavior therapy, one of the most well-established psychological therapies with adults of all ages for depression and anxiety. In this chapter, we review current theories and research on age differences in the effects of mood on cognition, with particular attention to mood congruence effects as a way to explore age differences in the mood–cognition linkage when moods change from usual homeostasis to a more negative tone. First, we review theories of mood-congruent cognition and conceptual and methodological issues in the study of mood-congruent cognition. Next, we present evidence for the mood–congruence phenomenon, comprised of lab-based research primarily conducted with younger populations. We then review the research on age differences in the mood–cognition linkage, and discuss potential implications of this literature for adaptations of theory, assessment, and therapeutic intervention with older adult clients.

DEFINITION AND THEORIES OF MOOD-CONGRUENT COGNITION

The terms *mood*, *emotion*, and *affect* all refer to the same mental states that arise spontaneously and generally involve subjective experience, physiological reactions, and behavioral components (American Heritage Dictionary, 2004/2009). We mainly use *mood* in this chapter because of our primary focus on mood-congruent cognition, in some instances we use *emotion* as a synonym when *mood* would be linguistically awkward. Reference to *clinical disorders* refers to diagnosed mental health disorders with depressed or anxious mood as a key component. *Clinical levels of mood* refer to distinction based on duration and intensity, usually indicated by high scores on a screening test. *Mood congruence* refers to the finding that current mood state biases the processing of environmental stimuli, favoring processing efficiency for similarly toned emotional material relative to neutral or emotionally incongruent information (Blaney, 1986). As examples, individuals who experience sadness, either transiently or at clinical levels, are expected to more readily attend to, store, and retrieve depression-relevant information, happy individuals, positive information, and anxious individuals, threat-related information.

Emotion Theory and Mood Congruence in Young Adulthood: Associationist and Schema Models

Bower (1981) provided an early conceptual model of the mood-congruent effect, describing mood-congruence findings within an associative network theory of emotion and memory. Bower's perspective had its origins in the connectionist frameworks used by many cognitive psychologists during the 1970s to model memory (Bower, 1998). The central premise of Bower's associative network model of emotion is that memory is organized in a network of associative nodes. These nodes are idiographically linked by conceptual and perceptual features based on past experiences and learning (Bower, 1998). Within a network, the activation of any one node (via external stimuli or internal memory) may spread, or propagate, to other connected nodes based on the strength or intensity of the activation (Bower, 1981). Connections that are activated are easier to retrieve; in contrast, information in nodes not activated within a context will not be as readily available (Bower, 1981). Finally, connections that are repeatedly activated are thought to be strengthened, and thereby made more efficient (Bower, 1981, 1998).

Within this model, the presence of a mood state activates the corresponding emotion node (e.g., sad), spreading automatically to related thoughts, physiological responses, and memories (Bower, 1981; Matt, Vasquez, & Campbell, 1992). Thus, mood-congruent information is expected to receive increased processing at both encoding and retrieval due to its connection to activated emotion nodes, while mood-incongruent information (of dissimilar valence or neutral) would be less accessible or potentially inhibited (Bower, 1981; Matt et al., 1992). The consequence of repeated mood exposures is also evident: those more frequently, intensely, or elaborately experiencing an association between a mood state and other internal representations will have strengthened connections between these nodes and more readily access these internal representations than those who have less experience with the mood state (Matt et al., 1992). In this way, Bower's (1981) application of network theories to emotional memory projects beyond current mood state to assert that those who frequently experience a mood (e.g., sadness in depressed individuals), might undergo even more pronounced effects of a mood-congruence due to strengthened mood-relevant associative networks (Bower, 1981).

Bower's model (1981) of mood-congruent memory and information-processing is similar in many respects to Beck's schema activation theory in clinical disorders (Beck & Clark, 1997; Clark, Beck, & Alford, 1999). Beck's cognitive models of clinical disorders like anxiety and depression also assume that the activation of internal cognitive structures (here called *schemas*) within the context of a mood state leads to biased processing via changes in the accessibility of different types of valenced information (Clark et al., 1999). Schemas may have varying complexity, depending on how detailed and interconnected concepts and experiences are within the representation structure (Clark et al., 1999). In everyday sad mood or in the context of clinical depression, mood-congruent information within the affective schema becomes activated, allowing for facilitated attentional and memory processing, particularly if the information is personally relevant to the individual (Clark et al., 1999). Whether conceptualized as nodes or schemas, the basic assumptions of Bower (1981) and Clark et al. (1999), suggest that moods are internally represented in associative networks that connect them to affectively congruent cognitions. In this way, mood state is expected to initiate the activation of mood-congruent processes and information within the cognitive structure, increasing both access and resources devoted to mood-related information and possibly diminishing the availability of incongruent information.

While network and schema activation models are the most frequently referenced theories explaining mood-congruent effects, others have suggested that emotional information-processing biases can more accurately be explained by the goal relevance of the material, than by simple matching between the stimuli and the mood state (for a discussion, see Levine & Edelstein, 2009). Goal relevance models hold that information related to goal attainment receives more cognitive resources, via increased attention and memory processing, independent of its affective valence. According to evolutionary and biological perspectives, discrete mood states are thought to inherently involve different goal tendencies (e.g., detecting and avoiding threat in fear, coping with loss in sadness; Levine & Edelstein, 2009). From this viewpoint, mood-congruent biases occur not because of a valence match between the stimuli and the mood per se, but because similarly valenced stimuli tend to relate more to the goals of a given mood than do non-valenced or opposite-valenced materials and are therefore more salient (Levine & Edelstein, 2009).

An important implication of this model, and one that follows discrete emotion theories (Levine & Pizarro, 2004), is that information-processing biases should be based on the specific mood states; for example, those in fearful moods should show biases to threat-relevant information more than generally negative stimuli, and those in sad moods would be predicted to show preferential attention to loss more than threats to safety (Levine & Edelstein, 2009). While a comparison of the literature examining the support for associative network versus goal relevance models of mood-congruent information processing is beyond the goals of this chapter, the possibility that goal relevance may be operating to produce mood-congruent effects is important to consider, particularly as we move into our discussion of research comparing mood-congruent biases across the adult lifespan.

Emotion Theory and Aging: The Positivity Effect and Its Limits: SST and SAVI

There is a theoretical foundation for a greater link between mood and cognition in older adults. While some general cognitive processes have been found to decline with age (e.g., reduced associative memory, slowed processing speed; Naveh-Benjamin, 2000; Salthouse, 1995), it has been recognized for some time that in normal aging mood-related cognition is often relatively preserved. Older adults generally show smaller losses in attention and memory for emotional material than for neutral stimuli. In addition, relative to younger individuals, older adults generally engage less with negatively valenced material and sometimes more with positive material (Mather & Carstensen, 2005).

This change in processing away from negative and towards positive information is a part of Socioemotional Selectivity Theory and constitutes the "positivity effect" in late life (Carstensen, Fung, & Charles, 2003). According to Carstensen and her colleagues, older adults perceive a more limited future due to the increasing salience of their mortality and are motivated by this shortened time perspective to prioritize meaning and well-being goals (Carstensen et al., 2003). This motivational shift acts as the mechanism for the age-related increases in the ratio of positive to negative information attended to, rehearsed, and accessed by older adults (for reviews, see Carstensen et al., 2003; Charles & Carstensen, 2009; Mather & Carstensen, 2005).

From this perspective, older adults' increased motivation for positive mood regulation propels attention and memory biases that produce the positivity effect. The positivity effect literature argues that healthy older adults' bias towards positive information may, in part, be accomplished using proactive management of stressful situations when feasible or by devoting more processing resources to mood regulation, for example, by modulating attention and encoding processes to prioritize positive stimuli (Carstensen et al., 2003).

Though a large literature demonstrates positive information-processing biases in aging individuals, not all older adults demonstrate the positivity effect. The Strength and Vulnerability Integration model (SAVI; Charles, 2010) has suggested limitations to the positivity effect, noting that older adults' positivity bias is nullified both under short-term stress and, to an even greater extent, under the pressure of chronic stressors commonly associated with later life (e.g., chronic illness, grief, caregiving). Thus, when high levels of negative mood are experienced, older adults may perform similarly, or even less successfully, in maintaining well-being than younger adults (Charles, 2010). In this chapter, we review the literature on mood congruence effects first in younger adults and then in older adults in order to explore age differences in the mood congruence effect and thus age differences in reactions to change in mood as contrasted with the positivity effect account of age differences when older adults are maintaining homeostasis via emotion regulation.

CONCEPTUAL AND METHODOLOGICAL ISSUES IN THE STUDY OF MOOD-CONGRUENT COGNITION

A number of different methodological and statistical approaches have been used to study mood-congruent cognition. Before we begin our discussion of the relevant literature, it is worth clarifying some empirically significant distinctions within the area. Research testing the mood congruence effect can take multiple forms, depending on the mood context in which valenced material is presented and recalled. The most commonly used paradigms in the study of mood congruent effects involve presenting emotionally valenced and neutral stimuli to individuals who have either been induced to feel a mood or are expected to present with the mood due to a clinically significant mood disorder as compared to controls (Fox, Russo, Bowles, & Dutton, 2001; Rinck & Becker, 2005). To assess mood-congruent memory, participants are later asked to recall this information when in a similar mood (Russo, Fox, Bellinger, & Nguyen-Van-Tam, 2001). Based on network and schema models, information that is mood-congruent at both encoding and retrieval should show the most prominent mood-congruent biases due both to more elaborated cognitive connections and to increased activation of these connections at search (Matt et al., 1992). However, in theory, the mood at encoding need not match the mood at retrieval to demonstrate mood-congruence (Watkins, Mathews, Williamson, & Fuller, 1992).

Another important consideration in the study of mood-congruent cognitive processes is what type of evidence constitutes "mood-congruence." That is to say, a number of memory and attention patterns have been used to support the existence of mood-congruent biases across research studies. In studies looking at mood-congruent memory in depressed mood, increases in both recognition and recall for negative stimuli as well as decreased recognition and recall for positive stimuli in sad or clinically depressed participants relative to control participants has been taken to indicate mood-congruent processing (Direnfeld & Roberts, 2006).

Multiple definitions of mood-congruence have arguably been even more problematic in studies of mood-congruent attention. Here, evidence of mood-congruent attentional biases in the context of negative mood states has been defined by researchers in numerous ways, including faster reactions to negative targets (facilitated attention; Bradley, Mogg, Falla, & Hamilton, 1998; MacLeod, Mathews, & Tata, 1986; Mogg & Bradley, 2002; Mogg, Bradley, & Williams, 1995), longer engagement with negative information (impaired disengagement; Amir, Elias, Klumpp, & Przeworski, 2003; Fox, Russo, & Dutton, 2002; Yiend & Mathews, 2001), and reduced attention to positive information (Erickson et al., 2005) relative to controls.

To make matters more complex, the basis of comparison for attentional bias in studies has varied, with some studies using a within-subjects design to assess mood-congruence (in which attention to or retrieval of negative information is compared relative to the positive information responses for participants within a certain group), and others using between-subjects analysis (comparing positive and negative information processing of those in neutral or positive mood states to those in negative moods; for a discussion, see Bar-Haim, Lamy, Bakermans-Kranenburg, Pergamin, & van IJzendoorn, 2007).

Finally, while the majority of studies have compared valenced (negative and/or positive) to neutral stimuli when calculating the magnitude of positive or negative cognitive biases, some studies have compared responses to negative and positive information directly in order to calculate bias scores, obscuring directionality by potentially confounding bias towards one valence with bias away from the other (Mathews & MacLeod, 1985). An in-depth comparison and discussion examining differences in mood-congruent processing bias by operational definition is beyond the purview of this chapter. Instead, we adopt the various definitions in our discussion of the literature, indicating whenever possible the approach taken by researchers in a given protocol.

How to measure mood itself is a fundamental issue in this area. Assessment of mood is quite challenging because it is considered as a multidimensional construct consisting of cognitive (subjective experience), neurophysiological (bodily symptoms), and behavioral expression (Scherer, 2001). Appropriate measures are needed for each dimension (Edelstein & Segal, 2011). Multifaceted aspects of mood require comprehensive assessment of mood, and the use of multiple methods has been strongly recommended in mood study (Eid & Diener, 2006; Haynes & O'Brien, 2000).

In a typical experiment to explore mood–congruent cognition, a particular mood state is induced (happy, sad, or anxious) and the induced mood state is usually confirmed by a self-report method. The subjective experience of mood is considered an important aspect of mood, and self-report is the most frequently used method of measurement. Questionnaire-based measures of mood (e.g., Beck Depression Inventory, Profile of Mood States) have been widely used as self-report measures of mood.

Mood also involves diverse physiological reactions in response to mood-eliciting stimuli. For example, systolic blood pressure changes when watching happy and sad emotion-eliciting film clips. These physiological changes are controlled by the autonomic nervous system (ANS), and a number of techniques have been developed to assess the physiological component of mood (Edelstein & Segal, 2011). Several studies have employed these methods in measuring physiological reactivity in response to emotional stimuli and emotion events (Langley et al., 2008; Tsai, Levenson, & Carstensen, 2000).

Affective neuroscience has focused on investigating how emotions are represented within the brain to explore the nature of emotion–cognition interactions. Historically, the limbic system (e.g., amygdala, prefrontal cortex, and the anterior cingulate) was known as the most important brain area associated with emotion and mood. Advances in technological developments in the functional imaging of the brain have accelerated neurological mood study, and diverse techniques (e.g., PET, fMRI, EEG, MEG) have been used to measure neural correlates of mood.

Traditionally, there are two major conceptualizations of the structure of mood (emotion). The discrete emotions approach assumed that there are some emotions that are basic or primary and that have distinctive neural structures and physiological response patterns, such as anger, fear, and happiness. The dimensional approach proposed that emotions are better described by their positions in a two-dimensional space formed by the dimensions of valence (positive–negative), and arousal (calm–excited) with others using a two-dimensional space with positive and negative valence as the axes. Edelstein and Segal (2011) found that researchers from the two approaches focus on different aspects of mood, use different methods to assess mood, and may study different species to address questions. As both perspectives have been supported by evidence, it is difficult to determine whether the discrete emotion approach or the dimensional approach provides a more accurate view on the structure of mood, and it is beyond the purpose of this chapter. We have included both perspectives on the structure of mood in our discussion of effects of mood on cognition.

EFFECTS OF PERSONALITY FACTORS ON EMOTION AND COGNITION INTERACTION

A good deal of previous research has suggested that personality traits influence mood and cognition interaction. Fox (2008) suggested three ways in which personality traits might influence cognitive bias. First, personality traits directly affect cognitive bias, second, personality traits modulate mood states that, in turn, influence cognitive processing. Lastly, the interaction between personality traits and mood states affects cognitive bias. For example, Rusting (1999) found that persons high in extraversion and positive affectivity tended to retrieve positive memories and made positive judgments. Those high in neuroticism and negative affectivity retrieved negative memories and made negative judgments. Interaction between personality traits, mood, and cognition is an important issue in studies of mood-congruent cognition, because personality traits influence mood congruent cognition (Rusting, 2001).

Personality has long been seen as an important influence on emotional well–being, which in turn influences cognition. A classic expectation is the link proposed by Gray (1991) between moods and the behavioral activation system in the brain, typically associated with extraversion and positive emotions and the behavioral inhibition system associated with neuroticism and negative emotional states. However, in a meta-analysis, DeNeve (1999) found that while these correlations held, other personality traits were more influential, including those directly related to emotional tendencies such as stability and tension; those related to relationship enhancement, and those related to the way people explain life events such as control and repressive-defensiveness.

The age effects on the connection between personality and emotions is unclear however. Ready, Åkerstedt, and Mroczek (2012) reported stronger connections between neuroticism and negative mood among middle-aged and older compared to younger adults. Ready and Robinson (2008) found weaker connections among four of the Big 5 personality factors in older adults than in younger adults, excluding openness to experience. Javaris et al. (2012) found conscientiousness associated with recovery from negative emotional stimuli in middle-aged but not in older adults. Pearman, Andreoletti, and Isaacowitz (2010) found agreeableness but not age was related to recovery from physiological reactivity to sad pictures. Thus, while there is evidence for influence of personality on the mood–cognition linkage and certainly on mood itself, age differences with regard to this connection are unclear at present and need further systematic study.

MOOD-CONGRUENT EFFECTS ON COGNITION: ADULTHOOD

Mood-congruence Effects in Depression: Memory and Attentional Bias

The interaction between depressed mood and cognition has been studied extensively over the past 30 years (for a review, see Gotlib & Joormann, 2010). In fact, a number of widely held theories of depression posit that biases in information processing affecting memory, attention, and interpretation, not only are present in depressed mood, but play an active role in sustaining it (Bower, 1981; Barlow, 2000; Clark et al., 1999). Cognitive-behavioral therapy (CBT), is presumed to operate by changing negative biases in cognition in order to break the negative mood–cognition linkage. Weakening of the association between negative mood and negative thoughts through therapy, in turn, is thought to reduce depressive symptoms by minimizing the influence of negative mood-congruent schemas on affect (Beck, Rush, Shaw, & Emery, 1979; Gotlib & Joormann, 2010).

Research on the effects of mood state on cognition reveals two patterns of cognitive correlates with depression. Neuropsychological studies have suggested global deficits in cognitive abilities for those with major depression as compared to control samples (McClintock, Husain, Greer, & Cullum, 2010). The performance of individuals with depression is marked by difficulties with attention and memory tasks that require increased cognitive effort and have less task-inherent structure (e.g., semantically unrelated materials, free recall tasks; Gotlib & Joormann, 2010). A second line of research has looked at the relationship between depressed mood and emotional cognition, which we focus on below. This work suggests a more variable relationship between depression and emotional attention and memory, pointing to both deficits and enhanced abilities by valence depending on whether the material is mood-congruent or mood-incongruent (Gotlib & Joormann, 2010).

To date, there is significant evidence for mood-congruent memory biases in depressed mood. While not all research has shown the effect (Banos, Medina, & Pascual, 2001), a preponderance of studies have shown that individuals with depression or sad mood exhibit preferential recall for negative relative to neutral or positive material (for reviews, see Gotlib & Joormann, 2010; Mathews & MacLeod, 2005). This is in contrast to individuals without current depressed mood, who tend to demonstrate either a general emotional salience effect in memory, in which positive and negative information is remembered about equally, both better than neutral information (Murphy & Isaacowitz, 2008), or a positivity bias in memory, in which positive information is favored relative to negative information (Matt et al., 1992). While not always the case, mood-congruent memory biases for negative information in depressed mood appear to be most consistently seen in explicit, unsupported memory, such as free recall tasks (Gotlib & Joormann, 2010).

Mood-congruent memory biases for those in depressed moods have also been demonstrated in autobiographical memory retrieval. In addition to reductions in memory specificity (Williams et al., 2007), depressive symptomatology has been linked to the increased accessibility of negative autobiographical memories and decreased retrieval of positive personal memories in dysphoric relative to nondysphoric individuals (Joormann & D'Avanzato, 2010; Lyubomirsky, Caldwell, & Nolen-Hokesema, 1998).

The evidence for mood-congruent biases in implicit (e.g., lexical decision and word fragment completion tasks) and less difficult memory tasks, such as recognition, appears to be more mixed. Some have suggested that mood-congruent memory biases in depression may be conditional upon elaborative processes, which could occur through rumination, a common cognitive component of depression (Watkins, 2002). However, a large-scale meta-analysis of implicit cognitive biases suggests an effect size for memory favoring negative information in depressive mood somewhat larger than that seen in explicit memory tasks with clinical and induced depressed persons in the Matt et al. (1992) study ($r=0.13$, $P<0.0001$, approximately equivalent to $d=0.26$; Phillips, Hines, & Thorsteinsson, 2010).

It is worth noting that negative mood is not only associated with increases in hits for negative information, but also in higher false memory rates for intrusions that match the mood condition. Individuals who have undergone a negative mood induction have been shown to demonstrate false recognition of negative lures more than those in a neutral or positive condition (Ruci, Tomes, & Zelinski, 2009). The same pattern of findings has also been seen in those with major depressive disorder (MDD) relative to controls (Howe & Malone, 2011). Relating these findings back to associative theories on mood-congruent cognition, it appears that the activation of sad mood-congruent information in cognitive networks may lead to an increased readiness to falsely identify negatively valenced non-target stimuli, at the same time as it benefits accurate retrieval of previously encountered mood-congruent negative information.

In addition to effects on memory, there is growing evidence for attentional biases to negative material in depressed mood. Based on initial findings in the field (MacLeod et al., 1986), it had been presumed that depressed mood did not significantly affect attention allocation, as anxiety had been shown to do (Mathews & MacLeod, 1994). However, more recent evidence using measures of divided attention, such as the dot-probe task, suggests that mood-congruent biases in attention may be evident in depressed mood. It seems that mood-congruent attentional biases towards negative stimuli (vigilance) in depressed mood may be discernible with longer, supraliminal stimulus duration exposures of valenced stimuli (i.e., when individuals are allowed greater time to engage in elaborative processes; Eizenman et al., 2003; Koster, De Raedt, Leyman, & De Lissnyder, 2010).

Eye-tracking studies also point to attentional biases in depression. It seems that dysphoric individuals do not orient to visual stimuli any differently than nondysphoric subjects: when presented with simultaneous images (one valenced and one neutral), both groups have been shown to shift attention toward positive and away from negative information relative to neutral images (Caseras, Garner, Bradley, & Mogg, 2007). However, dysphoric and depressed individuals spend a greater proportion of time maintaining attention to negative visual stimuli than healthy controls (Caseras et al., 2007; Eizenman et al., 2003; Kellough, Beevers, Ellis, & Wells, 2008), and may be slower to disengage attention from depression-related images (Sears, Thomas, LeHuquet, & Johnson, 2010).

Taken together, the majority of research on mood-congruent information-processing biases in clinical depression and sad mood indicates the presence of explicit and implicit retrieval biases favoring negatively valenced target stimuli and autobiographical recall. Though evidence is less extensive for attention, literature supporting the existence of increased processing of negative information in depression has emerged, suggesting that the magnitude of mood-congruent attentional biases may be similar to that of mood-congruent memory effects observed in depressed mood.

Mood Congruence Effects in Anxiety: Memory and Attentional Biases

As in depression, cognitive theories of anxiety disorders link biased attentional, and to a lesser extent memory, processes in the development and perpetuation of anxious mood state (Beck & Clark, 1997; Eysenck, 1992; Mathews & Macleod, 1994). Anxious mood state has been hypothesized to be associated with hypervigilance, in which individuals more readily detect and engage with threat-related information in their environment (Barlow, 2000; Beck & Clark, 1997). Anxious cognitive biases are also thought to involve delayed disengagement from cues and stimuli associated with threat, resulting in a net increase in stimulus-driven attention towards threat (Eysenck, Derakshan, Santos & Calvo 2007; Fox et al., 2002). Moreover, the increased attention allocation to threat-related stimuli in anxiety is thought to come at the expense of goal-directed task completion, particularly when the information to be processed is neutral (Eysenck et al., 2007). It has been suggested that when this threat-focused processing style becomes chronic, it, in part, promotes the development of a feedback loop in which the world is perceived as dangerous, and pathological coping strategies are more likely to be enacted, including avoidance and worry (Barlow, 2000). Mirroring depression, the cognitive biases accompanying clinical anxiety are postulated to drive and perpetuate the disorder.

Of note, studies examining mood congruence in anxiety most commonly have compared those who score high on trait anxiety measures to those who score lower on these assessments. Relative to work done on depressed mood, there appears to be somewhat less research examining the effects of clinical anxiety (e.g., generalized anxiety disorder, GAD) or induced anxiety on memory and attention. The heterogeneity of clinical diagnoses within the anxiety disorders category may also complicate the study of mood-congruent processing. Unlike the spectrum of unipolar depressive disorders, which involve varying levels of sad mood, anxiety disorders vary rather broadly in the content and specificity of perceived threats. In the revision of psychiatric disorders reflected in the DSM 5, trauma and stress-related disorders have become a separate category as have obsessive compulsive disorders (OCDs; American Psychiatric Association, 2013).

For example, while GAD is characterized by diffuse worry in a variety of contexts, OCD and specific phobias, by definition, are related to fear of clearly defined, specific entities (e.g., fear of contamination or spiders; American Psychiatric Association, 2000). From the standpoint of the schema and network theories of mood-congruent processing presented earlier, what is truly "mood-congruent" stimuli should differ quite markedly from one type of anxiety disorder to another depending on the type of information most strongly linked to the anxious mood state in the network (Radomsky & Rachman, 1999). In our review of the literature, it appears that some anxiety researchers are more attentive to the possible effects of stimuli relevance on mood-congruence than others. Therefore, while we believe examining differences in the type of threat stimuli most salient to individuals should be given more detailed consideration in future research, in the discussion that follows, we focus largely on mood-congruence findings in the context of nonspecific trait and state anxiety and do not distinguish between the specific types of threat-related stimuli used.

Despite the fact that many of the diagnoses subsumed under the category of anxiety disorders present and are classified by heightened memory for threatening events (e.g., flashback memories of trauma events in posttraumatic stress disorder (PTSD), panic attacks in panic disorder (PD); American Psychiatric Association, 2000), the evidence for mood-congruent memory in anxious mood is not as consistent as that demonstrated for memory biases in depression (Coles & Heimberg, 2002). In fact, it had previously been posited that anxiety promotes attentional, but not memory biases (Mathews & MacLeod, 1994; Williams, Watts, MacLeod, & Mathews, 1997).

Findings on whether anxiety leads to mood-congruent memory have been mixed. Some studies find no threat-related or negative explicit memory biases in generalized anxiety (Bradley, Mogg, & Williams, 1995), social phobia (Rinck & Becker, 2005), or induced anxiety (Foa, McNally, & Murdock, 1989). A descriptive review of the literature on mood-congruent memory in anxiety disorders found varying support for explicit memory biases by type of diagnosis, with compelling evidence for explicit biases only in PD, and to a lesser extent PTSD and OCD, but not in GAD or specific phobia (Coles & Heimberg, 2002). Implicit memory biases, however, were more consistent across these anxiety disorders (Coles & Heimberg, 2002). As acknowledged by the authors, the relatively limited number of studies in each diagnostic category, as well as the wide variation in the nature of stimuli used, limits the conclusiveness of these findings (Coles & Heimberg, 2002).

Attentional biases in anxiety have been extensively explored. In 2007, Bar-Haim, Lamy, Bakermans-Kranenburg, Pergamin, and van IJzendoorn (2007) completed a meta-analysis of 172 studies examining threat-related attentional bias in over 2000 anxious individuals as compared to over 1500 nonanxious control participants. Results of this study showed that across a number of experimental paradigms, including emotional Stroop, dot-probe, and spatial cuing tasks using both subliminal and supraliminal stimulus presentations, attentional biases favoring threat-related stimuli were present in anxious individuals with a moderate effect size ($d = 0.45$, $P < 0.01$; Bar-Haim et al., 2007). Despite adequate power, the attentional bias to threat stimuli in nonanxious controls was near zero and non-significant ($d = -0.007$, $P = 0.85$), suggesting similar biases favoring threat-related information do not exist in those without clinical or elevated anxiety levels (Bar-Haim et al., 2007).

In this meta-analysis, attentional threat-related biases appeared to exist for clinically, trait, and state anxious individuals (Bar-Haim et al., 2007). Within-subject attentional biases favoring threat-relevant information were significant across studies for those experiencing clinical levels of anxiety ($d = -0.45$), high trait anxiety ($d = 0.38$), and those assigned to groups on the basis of state anxiety levels ($d = 0.65$; Bar-Haim et al., 2007).

To understand the temporal dynamics of attention in anxious individuals, the time course of attentional deployment in anxiety for facilitated engagement and impaired disengagement in attention has been studied extensively. A widely held perspective is that highly anxious individuals demonstrate sequential attentional stages, such as orienting rapidly to threat, facilitated engagement with threat once detected, impaired disengagement from threat, and lastly, attentional avoidance by focusing away from the threat (Fox et al., 2001; for a review and model, see Ouimet, Gawronski, & Dozois, 2009). This pattern is consistent with the "vigilance-avoidance" hypothesis, which suggests that anxious individuals first engage more strongly with, and then more reliably avoid, threat-relevant material as compared with nonanxious persons (Mogg, Bradley, Miles, & Dixon, 2004).

Facilitated orientation to and engagement with threat information in anxiety is generally seen at short, or subliminal, stimulus presentations and fades at longer durations, while dot probe tasks have largely found evidence for impaired disengagement at longer, supraliminal presentations (for reviews, see Cisler & Koster, 2010; Ouimet et al., 2009). However, the results of a study by Koster, Crombez, Verschuere, Van Damme, and Roelf Wiersema (2006; Experiment 1) using a modified cuing task indicated that high trait anxious individuals show attentional bias in both facilitated engagement and impaired disengagement in the early stages of image presentation (100 ms) and avoidance at later stages (200–500 ms). Others have found that those induced to feel anxious show delayed disengagement from threat stimuli even at longer durations relative to nonanxious controls (600 ms; Fox et al., 2001). Attentional avoidance of threat stimuli in anxious individuals has been shown to begin at display times of 500 ms (Onnis, Dadds, & Bryant, 2011) or longer (Mogg et al., 2004). While these results generally support the sequential attentional pattern described above, there appears to be some overlap in timeframes, particularly in delayed disengagement and avoidance.

While mood-congruent memory effects are less clear in anxiety than in depression, attentional bias to threat is well-established for anxiety. Persons with clinical anxiety disorders and those with high trait and/or state anxiety orient more readily to potential environmental threats as they first appear, take longer to disengage attention from them, but then are more likely to show avoidance at longer time intervals. While the exact time course of these bias changes is still a matter for debate among researchers, the overall order of these attentional stages in anxiety appears to be consistent across studies, involving facilitated orientation and engagement, delayed disengagement, and ultimately avoidance.

MOOD-CONGRUENT EFFECTS ON COGNITION: OLDER ADULT POPULATIONS

Depressed Mood and Congruent Cognition in Older Adults

The limited research that exists on the relationship between sad mood and emotional cognition indicates that older adults may be as vulnerable as younger individuals, if not more so, to the effects of sad mood-congruent memory and attention. This research has involved older adults selected for depressive symptoms as well as those experiencing transient depressed mood. As with younger adults, procedures to induce specific mood states (e.g., sadness) have been shown to be effective with older populations, and may serve as a laboratory-based analogue to clinical disorders such as depression (Fox, Knight, & Zelinski, 1998; Levenson, Carstensen, Friesen, & Ekman, 1991).

Ferraro, King, Ronning, Pekarski, and Risan (2003) used mood manipulation to study the effects of age and induced mood on an implicit memory test (a lexical decision task) involving emotional stimuli. Older and younger adults were randomized to one of two mood-induction conditions: sad or happy (Ferraro et al., 2003). Following a music-based induction, participants were shown words presented on a computer screen one at a time (Ferraro et al., 2003). Words were from one of three categories: sad, happy, and pseudowords (i.e., nonwords; Ferraro et al., 2003). Subjects were asked to identify as quickly as possible whether each target was an actual word using response buttons, with both accuracy and response times tracked. While there was no effect of mood state on stimulus identification accuracy, Ferraro et al. (2003) found a mood group by stimulus valence interaction across age groups for response times. Individuals induced to feel happiness responded faster to happy as compared to sad words, while sad-induced participants responded faster to sad, relative to happy, targets. Citing Bower's (1981) network model of emotional processing, the authors interpreted the faster response times to mood-congruent targets to be indicative of mood-congruent lexical processing (Ferraro et al., 2003). The results of this study suggested that mood state influences older adults' information processing in ways comparable to younger adults; however, mood-congruent effects were limited in this experiment to a single measure (a lexical decision task).

Randomizing older and younger adults to either a sad or neutral mood manipulation, Knight, Maines, and Robinson (2002) also found that older and younger adults in the sad condition demonstrated mood-congruent memory effects, but that these effects varied by age group and task type. In this study, older and younger adults randomized to one of the two mood conditions completed a variety of cognitive tasks designed to assess mood-congruent memory and interpretative biases, including word, text, and autobiographical recall tasks with valenced material and a lexical ambiguity task involving spelling ambiguous (sad-neutral) homophones. Across the word list immediate recall and lexical ambiguity tasks, a main effect of age on identification of negatively valenced words was observed, with older adults recalling and spelling fewer negative words overall than younger adults, consistent with a positivity bias (Knight et al., 2002).

However, among those in a sad mood, older and younger individuals in this study demonstrated mood-congruent biases. As evidenced by a main effect of mood induction group, but no significant age by induction group interaction, older and younger groups induced to feel sad prior to learning a word list demonstrated subsequent mood-congruent recall at a delay, recalling a higher proportion of negatively valenced words relative to age-matched peers in the neutral induction condition (Knight et al., 2002). Older and younger adults in a sad mood were also significantly more likely to retrieve a negative autobiographical memory when prompted to recall an event from their past than controls (Knight et al., 2002). This finding suggests that longer-term memory (e.g., for material after delay) may be particularly susceptible to sad mood-congruent biases across age groups, in line with those who have suggested that elaborative processes are an important component of depressed mood-congruent cognitive biases (Watkins, 2002).

Of interest, the effects of mood-congruent memory appeared to be more pervasive in the older participant group in this study. In addition to mood-congruent word recall at a delay, older adults randomized to the sad induction group demonstrated reduced memory for positive words at immediate recall relative to controls (31% of all words retrieved being positive targets in the sad induction group vs. 46% positive word targets in the neutral induction group), a difference not observed in younger participants (42% positive word hits in both groups; Knight et al., 2002). Older adults also evidenced mood-congruent implicit memory as seen in their performance on a lexical ambiguity task, with those in the sad group generating more negatively valenced homophones than peers in the neutral group; younger adults, however, showed an equivalent frequency of negative meanings attributed to ambiguous homophones across induction groups (Knight et al., 2002).

In a replication and extension of the Knight et al. (2002) study conducted with healthy older and younger adults, older adults in a sad mood induction group demonstrated mood-congruent recall for recent autobiographical memories, more frequently recalling negative memories when prompted to retrieve a personal event from a week ago as compared to older adults in a neutral group (Knight, Kellough, & Poon, 2011). Surprisingly, younger adults in this project demonstrated the opposite effect. Younger individuals in the sad induction group were less likely to recall a sad memory from the prior week as compared to those in the neutral condition, indicative of mood-incongruent memory, possibly to promote mood repair. Again, a main effect of age group suggestive of a positivity effect was seen for distant memories (high school events), such that older individuals recalled fewer sad high school memories than younger adults across induction groups. Taken together the work by Knight and associates suggests that older adults' may show mood-congruent memory biases, explicit and implicit, across more domains than younger adults, suggesting that the effects of mood on emotional cognition in older adults may be more extensive.

The few additional studies of depressed mood-congruent memory with older clinical populations support the results found by mood induction research. Two studies have examined the effects of depressive symptomatology on autobiographical memory in individuals over 60 years old. In the first, individuals were classified as positive for clinically significant depressive symptoms (defined as scoring at or above 16 on the Center for Epidemiologic Studies—Depression; CES-D; Radloff, 1977), or, below this threshold, as controls (non-clinically significant depressive symptoms; Serrano, Latorre, & Gatz, 2007). All participants completed the Autobiographical Memory Test (AMT; Williams & Broadbent, 1986) which prompted individuals to retrieve specific past events based on both valenced (positive, negative) and neutral cue words within a 30-s timeframe (Serrano et al., 2007). Memory responses across prompts were subsequently coded for valence (positive, negative, neutral), specificity (specific or general), and frequency of omissions by prompt type. The effects of group membership on memory valence indicated a pattern of results supporting mood congruence in autobiographical memory retrieval.

While older participants with clinically significant depressive symptoms and those without displayed a positivity preference in memory retrieval, providing more positive memories than negative memories across cue types, the magnitude of this positivity effect was moderated by group membership such that depressed individuals displayed a less pronounced bias for positive information than nondepressed individuals (Serrano et al., 2007). The relationship between depressive symptomatology (CES-D score) and the magnitude of positive bias was linearly related, with increasing depressed mood related to decreasing retrieval of positive relative to negative memories ($r = -0.27$), driven by an increased negative memory retrieval in depressed participants as compared to controls (Serrano et al., 2007). In addition, depressed individuals recalled significantly more negative memories than those who were not depressed (Serrano et al., 2007). Omissions by cue valence also suggested a memory bias. Non-depressed older participants were more likely to fail to provide a memory for a negative cue word in the allotted timeframe than they were to supply a positive cue, whereas depressed older adults were more likely to demonstrate omissions to positive cues and less likely to have omissions to negative prompts than controls (Serrano et al., 2007).

In a similar study, Ricarte et al. (2011) selected older adults from a primary care outpatient clinic, comparing those meeting diagnostic criteria for MDD to age-matched peers in their performance of valenced cues from the AMT. In contrast to Serrano et al. (2007), this study did not find evidence of an overall positivity effect in either the MDD or control groups (Ricarte et al., 2011). Instead, older MDD participants retrieved more memories for negative than positive cue words, whereas older nondepressed individuals exhibited no bias to either valence, retrieving a statistically equivalent number of memories for both positive and negative cues (Ricarte et al., 2011). The results of this later study supplement those found by Serrano et al. (2007), suggesting that a depressive memory bias favoring negative autobiographical memories may be even more prominent in older individuals meeting clinical criteria for mood disorder than those with elevated symptoms alone.

Mood-congruent Attention in Sad and Depressed Mood

Additional laboratory research has suggested that sad mood also influences emotional attention in normal older adults. Poon and Knight (2009) conducted a 2 × 2 design, experimentally inducing both mood (sad vs. neutral) and old-age schema (activated vs. non-activated) among a sample of community-dwelling older adults. The authors examined the effects of condition assignment (mood and old-age schema) on response times to a computerized Stroop task involving physical-symptom, aging-related, and neutral words. Mood was manipulated using an autobiographical writing exercise with a sad or neutral prompt and maintained with music, while old-age schemas were activated using aging-related questions versus non-aging-related general questions (Poon & Knight, 2009). Results indicated that older adults in the control condition (neutral mood, non-activated old-age schema) displayed an attentional bias away from symptom-related (e.g., pain, fatigue) words compared to those in a sad mood or those whose old-age schema was activated (Poon & Knight, 2009), indicating older adults' avoidance of such negative words under normal (i.e., non-emotional) conditions consistent with the positivity effect (Mather & Carstensen, 2005).

Of interest to our discussion, mood exerted a large effect on attention, such that those randomized to a sad induction group focused more on symptom-related words than those in the neutral mood condition ($\eta^2 = 0.47$; Poon & Knight, 2009). In addition, mood interacted with old–age schema activation to exert a net attentional bias toward symptom-related words, with longer within-subject reaction times to symptom than neutral words. The main effects of mood, as well as the interaction of sad mood state with old-age schema, on increased attention to negatively charged symptom words supports the theoretical assumptions of mood-congruent attention. These findings suggest that the activation of an emotional cognitive network or schema via a given mood state may facilitate attentional processes with similarly valenced targets in older adults (Beck & Clark, 1997).

To our knowledge, only one other study has examined attention to emotional information in younger and older adults after negative mood induction. Isaacowitz Toner, Goren, and

Wilson (2008) randomly assigned healthy older and younger participants to positive, negative, and neutral mood inductions and then monitored participants' visual attention for valence (happy, angry, afraid, sad) with neutral face pairs using eye-tracking. The results of this study indicated that older and younger adults induced to feel positive, negative, and neutral mood states showed divergent attentional patterns by age group (Isaacowitz et al., 2008). While younger adults who were induced to feel positive or neutral mood showed increased fixations towards happy as opposed to neutral faces, older adults who were in the positive or neutral condition did not show evidence of such a preference (Isaacowitz et al., 2008). Older adults induced into a negative mood, however, showed a mood-incongruent attentional bias, with an attentional preference away from sad and angry and towards happy faces, while younger adults in the negative mood group showed mood-congruent biases towards angry and afraid faces (Isaacowitz et al., 2008). The authors interpreted this finding as consistent with a motivational account as in socioemotional selectivity theory, which posits that the positivity effect in older adults represents efforts at emotion regulation. In contrast, younger adults are predicted to be motivated to gain information, particularly as such data might provide information on the antecedents and consequences of their emotions. The results of Isaacowitz et al. (2008) suggest that younger adults show mood congruence in early phases of attention whereas older adults in a sad mood show mood incongruence (possibly due to efforts at mood repair).

Findings regarding the effects of sad mood induction on emotional attention are mixed, with some finding mood-congruent attentional biases in older adults experiencing transient sad mood (Poon & Knight, 2009), and others showing that the effects of sad mood may drive older adults to mood-incongruent biases differing from the mood-congruent effects seen in younger adults (Isaacowitz et al., 2008). The methodological differences in the studies may account for these differences. The Stroop task in the Poon and Knight study measures the mood effects by the slowing of response to the intended task resulting from the implicit attention to the meaning of the words, presumed to be an automatic process. Isaacowitz et al. used ratio of eye fixations over 4-s stimulus exposures as the method. As will be seen in the next section on anxiety, that timeframe would be ample for initial attention to face stimuli to shift from vigilance to avoidance using a dot probe task with facial stimuli (Lee & Knight, 2009). There also were differences in responses to verbal versus facial stimuli in the Lee and Knight study.

Taken together, results of these studies generally confirm positivity effects for older adults not experiencing sad mood, but show that when older adults become sad or depressed, they are frequently susceptible to mood-congruent effects, particularly for memory. In our own laboratory studies, we have repeatedly seen mood-congruent effects in older adults at lower mean levels of depressive symptoms (as measured by the CES-D), as well as evidence suggesting that older adults experience these effects on a wider variety of tasks than younger adults (Knight et al., 2002, 2011). While more research on the topic is needed, the data that exist suggest that older adults experiencing sad mood may be as vulnerable, if not more so, to mood-congruent memory and interpretative processes across contexts, but potentially less susceptible to depressed mood-congruent attention.

Anxious Mood and Congruent Cognition in Older Adults

The effects of anxiety on emotional processing in older adults may be more complex and distinct from younger adults than those of depressed mood for several reasons. For one, when anxious, older adults appear to focus on different types of threat than younger adults.

In terms of the content of worry, older adults tend to focus less on social threats and more on health threats, while younger adults display the opposite pattern (Ladouceur, Freeston, Fournier, Dugas, & Doucet, 2002; Lindesay et al., 2006). Secondly, the prevalence of specific types of anxiety disorder may change with age, with older adults less likely to experience panic disorder and PTSD and relatively more likely to experience GAD (Wolitzky-Taylor, Castriotta, Lenze, Stanley, & Craske, 2010). Finally, while attentional processing for neutral information has generally been found to be reduced in older relative to younger adults, especially with regard to selective attention and inhibition of task-irrelevant stimuli (Gazzaley, Cooney, Rissman, & D'Esposito, 2005; Rogers & Fisk, 2001), selective attention to threat stimuli in anxious older populations has only been studied recently. As in younger adults, the limited research on mood-congruent cognition in anxious older adults has focused largely on the impact of anxiety on attention, and not memory, for emotional material.

Fox and Knight (2005) examined the effects of both state anxious mood (assessed after a neutral or anxious mood induction) and trait anxiety (low or high relative to the median split), each measured using the Spielberger State Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983), on selective attention to threat in healthy older adults. Attentional biases to threat were determined by response latencies to neutral versus physical- or social-threat words in computerized versions of an emotional dot-probe and emotional Stroop task (Fox & Knight, 2005). The results of this study suggested that anxious mood state contributed to threat-relevant attentional biases in older adults: a main effect of mood induction group was observed such that older individuals experiencing induced anxiety had an attentional bias toward threat information in the dot probe task, while older adults in the neutral group exhibited a tendency to avoid threat.

Surprisingly, on the emotional Stroop, the anxiety induction only contributed to slowed response latencies for threat-relevant words in older adults with low, but not high, trait anxiety levels (Fox & Knight, 2005). These findings run counter to the increased vulnerability to attentional biases for threat thought to occur in those with high trait anxiety induced to feel anxious (Eysenck, 1992). A speculative explanation offered was the possible effect of experience in high trait anxious older adults: older individuals who are highly reactive to anxiety have had many opportunities to practice functioning while anxious, and, as a result, may more effectively use mood regulation strategies in completing the more complex Stroop task. This would also agree with the time course of attentional biases in anxiety, in which, at longer stimulus durations, highly anxious individuals display a pattern of attentional disengagement (i.e., avoidance) with threat stimuli not seen in those low in anxiety (Derryberry & Reed, 2002).

Lee and Knight (2009) recruited nonclinical samples of younger and older adults who were then stratified as low, moderate, or high in self-reported trait anxiety by scores on the STAI. Attentional bias was measured using a dot probe task with negative-neutral stimulus pairings of faces (sad–neutral, angry–neutral), pictures (high threat–non threat), and words (negative–neutral), all presented either subliminally (20 ms exposure for younger adults; 50 ms for older adults) or supraliminally (1500 ms exposure). The use of both subliminal and supraliminal stimuli presentations in this protocol allowed for an analysis of the time course patterns of attentional bias. Lower attentional bias scores for negative- or threat-related material in a subliminal relative to a supraliminal presentation would be indicative of an avoidant-vigilant response, whereas the reverse pattern (lower attentional bias scores for supraliminal relative to subliminal) would suggest a vigilant-avoidant attentional pattern.

Results indicated that high-anxiety older adults attended less to subliminally presented negative words and gave more attention to supraliminal negative words (avoidant-vigilant pattern; Lee & Knight, 2009). For faces, a main effect of age was found such that older adults across anxiety levels showed a vigilant-avoidant response to angry faces. Only older adults with moderate anxiety, however, showed the same pattern with sad faces. Surprisingly, younger adults did not display attentional biases for threat across any of the three stimuli types. The broad effects of anxiety on attention in older, but not younger, adults observed in this study again suggest that older adults may be more susceptible to mood-congruent cognitive processes and at lower trait anxiety scores than found in the younger adults.

Taken together, it seems that older participants may be susceptible to anxiety-related attentional biases at both the early and late stages of stimulus engagement, depending on the type of stimuli. The rapid detection of anger in faces has been shown to be preserved with age (Mather & Knight, 2006), and may explain older adults' vigilant-avoidant pattern for this type of stimuli: we speculate that older adults' attention is captured by angry faces, shown by early attentional bias to stimuli, but avoidance at longer presentations may represent a coping strategy to down-regulate negative emotions.

In summary, the laboratory work done so far implies that older adults display attentional bias to threat at least as readily as younger adults. As with the work on depressed mood, there are indications that older adults show mood-congruent attentional bias effects at lower levels of self-reported anxiety than younger adults (Lee & Knight, 2009), though the reasons for these differences are unknown. Research disentangling the time course of attentional bias in older individuals remains scarce.

IMPLICATIONS FOR THEORY AND RESEARCH ON AGE DIFFERENCES IN THE MOOD–COGNITION LINKAGE

On the whole, the mood-congruence literature to date points to the mood–cognition linkage being maintained into later life with mood-congruent memory and attentional bias to threat being present in older adults whose moods have changed in a negative valence direction either in lab manipulation or due to influences in their own lives (e.g., those with clinical disorders or with high trait negative mood). Taken with the positivity effects noted in the control conditions, these findings support the SAVI model's account of positivity effects in older adults, but with those effects disappearing or reversing under stress conditions. There is some indication in the small literature on the mood–cognition linkage in older adults that the effects may be more pervasive in older adults (affecting more cognitive processes and operating when young adults do not experience the effects) and may operate at lower levels of self-reported state distress. These findings need further exploration in research.

The persistence of the mood–cognition linkages themselves into later life suggests the importance of theoretical developments that can integrate the associationist and schema accounts of that linkage with the SAVI model's account of positivity effects and their limits. That integration would be useful for understanding age differences in emotion regulation and also in understanding the psychopathology of late life. While developing such a theoretical integration is beyond the scope of this chapter, there are a number of questions suggested by this line of research that can be addressed in future research and that would help guide theory development. What are the circumstances that break through the positivity effect and the generally better emotion regulation shown by older adults? Why do effects of mood on cognition appear at lower measured levels of negative mood in older adults? While laboratory research participants and most people in natural settings recover from negative mood states and the associated cognitive effects, why do some people get stuck in the mood–cognition linkage and develop clinical depression or anxiety?

We also note that there are methodological differences among studies that yield important differences in the mood–cognition linkage for both young and old adults. The choice of materials matters with faces and verbal material often leading to different results, for example. Future research should explore these differences more systematically and help develop an understanding of the underlying mechanisms for emotional responding to visual stimuli, especially faces, and to verbal material. There are intriguing hypotheses advanced about the evolutionary priority of recognizing emotion in faces, for example, and for the development of changes in the semantic network of words, as words and moods are repeatedly associated over time. These hypotheses are more often advanced in "Discussion" sections rather than being the focus of theory and systematically tested hypotheses.

The timing of the measurement of the linkage is important. Well established in anxiety, and possibly in depressed mood as well, there are shifts from vigilance to avoidance and vice versa that occur on a timescale of tens of milliseconds to seconds. Systematic investigation of the time course of these shifts and understanding their meaning for emotion regulation may well be key to advancing understanding in this area.

IMPLICATIONS FOR PSYCHOLOGICAL INTERVENTIONS WITH OLDER ADULTS

Older adults appear to show the effects of depressed mood and of anxiety at lower measured levels of these moods than younger adults (Knight et al., 2002; Lee & Knight, 2009). Experts in mental health and aging have argued for years that different criteria may be needed for the assessment of depression in older adults, with lower cut-off scores on screening measures developed with younger populations. For example, Allen-Burge, Storandt, Kinscherf, and Rubin (1994) using more inclusive criteria for commonly used depression scales, reported that 15% of older women and 28% of older men diagnosed with unipolar depression on an inpatient geropsychiatry unit would be miscategorized as non-depressed if they had applied traditional thresholds developed for younger groups. There have also been calls for more attention to the importance and greater prevalence of minor as compared to MDD in older adults (Meeks, Vahia, Lavretsky, Kulkarni, & Jeste, 2011). While certainly not conclusive, we would argue that the finding of similar negative cognitive biases at lower measured levels of depressed mood and anxiety support the assertion that older adults may be experiencing similar degrees of symptomatology at lower self-reported scores on mood measures.

The existence of mood-congruent biases in older adults has both theoretical and practical implications for psychological intervention with older individuals. One of the most effective psychosocial treatment approaches for late-life depression and anxiety is CBT (Ayers, Sorrell, Thorp, & Wetherell, 2007; Scogin, Welsh, Hanson, Stump, & Coates, 2005; Wolitzky-Taylor et al., 2010). As described before, CBT, and other cognitively based therapies, are based on the premise that mood and cognitive patterns are inherently linked, such that negative mood precipitates negative information-processing biases and vice versa. Cognitive therapies are thought to work by "undoing" these links, teaching individuals to attend to and interpret information in a less negatively biased and more emotionally neutral, or realistic, manner (Beck et al., 1979).

Based on the proposed mechanism, cognitive therapies should only be effective in those who demonstrate negative mood-cognition coupling. Given the positive results of outcome studies for CBT with older adults, it is not surprising that research on mood-congruence effects confirms that older adults with depressed mood and those experiencing high levels of anxiety show similar cognitive-emotional patterns to those observed in younger adults. There are, however, potential age differences in mood-congruence effects that could be informative for thinking about psychological assessment and intervention with older adults.

While cognitive-behavioral interventions have long been shown to improve mood in older adults with mood disorders (for a review, see Scogin et al., 2005), recent research suggests that general information-processing training may also be a promising therapeutic intervention for older adults. For example, Mohlman (Mohlman, 2005; Mohlman & Gorman, 2005) has reported that adding cognitive training aimed at improving executive functioning improves response to CBT in older adults. Mohlman has mainly conceptualized this approach as enhancing the ability to perform the cognitive work (e.g., complex reasoning) involved in CBT. We would suggest that the executive functioning training itself may improve depression and anxiety symptoms by enhancing older adults' control over memory retrieval and attentional search processes so that the positivity effect can reassert itself. Mather and colleagues (Kryla-Lighthall & Mather, 2009; Mather & Knight, 2005) have demonstrated that the positivity effect only emerges in those with a certain level of executive functioning and attentional capacity, even in normal (i.e., not depressed or anxious) older adults. Thus, improving the overall cognitive functioning of older individuals may have downstream effects on mood regulation and well-being. Future research should specifically test the effects of general cognitive training on subsequent emotional biases in older populations experiencing depression or anxiety.

In addition, therapeutic interventions directly targeting mood-congruence cognitive biases have been developed. In the last decade, researchers have begun to harness the same tasks used to assess mood-congruent cognitive biases (e.g., visual dot probe tasks) in order to attempt to alter these biases (for a review, see MacLeod & Mathews, 2012). This type of intervention is often referred to as attention training, or more broadly, cognitive bias modification (Hallion & Ruscio, 2011). A number of studies have found that by having participants engage in a modified dot-probe task in which the target always replaces positive stimuli, individuals experiencing high levels of stress and anxiety can develop a positive attentional bias on this task, a change that is associated with symptom improvement (Amir, Beard, Burns, & Bomyea, 2009; Dandeneau, Baldwin, Baccus, Sakellaropoulo, & Pruessner, 2007; Hazen, Vasey, & Schmidt, 2009) which may last months (Schmidt, Richey, Buckner, & Timpano, 2009). Not surprisingly from research reviewed above, cognitive bias modification has to date had more support in modifying anxiety than depression (for a recent meta-analysis, see Hallion & Ruscio, 2011).

There is preliminary evidence to suggest that attention modification training is as effective in changing healthy older adults' visual attention to emotional information as in younger adults, and that such training may have associated effects on older individuals' mood. Training older and younger participants to attend to either positive or negative information via a modified dot-probe task, Isaacowitz and Choi (2011) found that older adults' trained to attend to positive information tended to show reduced visual attention to negative images post-training, as well as stable mood, while older adults' trained to attend to negative images experienced more negative mood over time. Surprisingly, younger adults' later visual attention for negative information was reduced with negative, and not positive, training, and attentional training of either type did not appear to have an effect on younger adults' moods (Isaacowitz & Choi, 2011). These results suggest not only that older adults' mood-congruent attention may be as malleable as younger adults, but also that altering older adults' attentional processing for emotional information may have even more pronounced effects on mood than in younger individuals. While further research is needed, particularly in clinical populations, preliminary results point to the possibility that direct attentional training of the positivity effect may benefit older adults experiencing negative mood.

An explicit focus in therapy on guiding older adults to recall positive autobiographical memories would also be predicted to be effective by the literature on mood congruence and depression. In support of this, older adults with high levels of depressive symptoms who received life review therapy involving 4 weeks of prompted retrieval of specific positive autobiographical memories, reported reduced depressive symptoms, including hopelessness, as well as improved life satisfaction following intervention as compared to a control group (Serrano, Latorre, Gatz, & Montanes, 2004). This study, and the findings described previously on mood–emotion linkages in older and younger adults, would suggest that "training" emotional memory with older clients may require more effort but also have better and more lasting results once the effects of mood-congruent processing are reversed and the positivity effect is reasserted.

In conclusion, while there has been considerable research on the prevalence, nature, and treatment outcomes of mental disorders in later life, there has been relatively little work applying lifespan developmental psychology or mood–cognition linkage theory and research to understanding the processes underlying these disorders or to guiding adaptations of psychological interventions for older adults. The research summarized here on the mood-congruence phenomena in younger and older adults can be taken as a start, providing insight into when older adults normally better emotional regulation strategies are overwhelmed by negative mood, what cognitive mechanisms might operate to sustain this negative mood, and, finally, what empirically based adaptations in psychological assessment and therapy might benefit depressed and anxious older adults.

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CHAPTER

16

Psychological Vitality in the Oldest Old

Jacqui Smith[1,2] *and Lindsay H. Ryan*[1]

[1]**Institute for Social Research, University of Michigan, Ann Arbor, MI, USA**

[2]**Department of Psychology, University of Michigan, Ann Arbor, MI, USA**

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INTRODUCTION

Depending on country, culture, birth cohort, and idiosyncratic factors, the post-retirement period in the twenty-first century could extend over 20–40 years of an individual's life. Life expectancy after age 65 has increased and more people are surviving to the ninth and tenth decades (Vaupel, 2010). Population demographers categorize those women and men who survive

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beyond the average life expectancy for their age cohort as the *oldest old* (He & Muenchrath, 2011). The chronological age used to identify entry into this age category varies but it generally ranges between 80 and 85. Unlike any other age strata, the oldest-old population is characterized by a unique excess of women over men, relatively high levels of comorbidity, dementia, institutionalization, and excess consumption of medical services.

Although research typically focuses on the less desirable outcomes associated with living a long life, not all of the oldest old have dementia nor are they disabled or fully dependent on others for assistance in the basic activities of daily life. Christensen, McGue, Peterson, Jeune, and Vaupel (2008), for example, reported that 30–40% of Danish nonagenarians born in 1905 were independent from age 92 to 100. A focus shift to instead characterize the subgroups of the oldest old that do not meet clinical thresholds (e.g., for dementia) would inform us about heterogeneity of functioning in the oldest old and the potential for long-lived individuals to maintain autonomy, be socially engaged, enjoy life, and adapt to health challenges.

Scope of the Chapter

This chapter was motivated by the challenge to shift focus. We review research published in the decade from 2004 to 2014 in order to evaluate contemporary evidence and scenarios about psychological functioning and well-being in the oldest old. Given the absence of defined evaluative cutoffs for psychological functioning (e.g., analogous to definitions of dementia and disability), we use the term *psychological vitality* to describe functionally desirable profiles in psychological domains as they are observed in the oldest old and at the end of life. Earlier reviews (Baltes & Smith, 2003) used the term *psychological mortality* to describe the inverse status, namely a loss of functional vitality. They characterized advanced old age as a life period that tests the limits of adaptive capacity.

We adopted the concept of psychological vitality rather than using more well-established concepts such as optimal, active, robust, and successful aging, because researchers agree that the established concepts are complex and may need to be expanded to be appropriate for the oldest old. For example, McLaughlin, Connell, Heeringa, Li, and Roberts (2010) estimated that only 2.2% of participants over age 85 in the Health and Retirement Study (HRS 1998–2004) met the Rowe and Kahn (1997) criteria for successful aging (i.e., low probability of disease and disease-related disability, high cognitive and physical functional capacity, and active engagement with life). There is consensus, however, that concepts such as successful aging encompass components and processes that contribute to adaptive capacity and resilience in very old age.

This chapter begins with a brief description of the characteristics and life histories of the oldest old observed in contemporary research and a discussion of research challenges associated with this population. We then consider cross-sectional and longitudinal reports about five domains of psychological vitality after age 80: non-pathological cognition, personality, self-related functioning, social connections, and subjective well-being. After reviewing this material, we conclude with a brief discussion of current knowledge gaps about the *psychological vitality* in the oldest old and directions for future research.

WHO ARE THE CONTEMPORARY OLDEST OLD?

The oldest-old men and women observed in 2014 (aged 85+) were born in the years from 1898 to 1929. This age group comprised 1.8% of the US population in 2010 (Older Americans, 2012). The average life expectancy after age 85 for men was 5.9 years and for women 7 years.

Thirty-two percent were married, 12% were in poverty, 14% were in long-term care facilities, and 67% of those living in the community required assistance with multiple instrumental activities of daily life.

The oldest old in 2014 also share a set of period- and cohort-specific characteristics. On average they have a lower level of education compared with subsequent cohorts and they were exposed to formative historical events in their first 30 years of life (e.g., WWI, the Spanish Flu epidemic, the 1930s Depression, WWII, access to penicillin). These birth cohorts have also been exposed to macro-level medical, technological, and societal changes that have had major effects on their lives throughout midlife and into old age. Of course, within these cohorts of the contemporary oldest old there are large individual and subgroup differences in life and health histories and variation in the onset age for chronic illness and disability.

The majority of large panel studies of the oldest old that include several indicators of non-pathological psychological functioning are located outside of the United States. Although the Health and Retirement Study (HRS), which encompasses the AHEAD cohort born prior to 1923, collected measures of memory, dementia, and depression from its inception in 1992–1993, it is only since 2006 that coverage of psychological functioning has been extended and added to the longitudinal protocol. Studies elsewhere that include the oldest old vary in scope, panel size, and duration. Some (e.g., the Berlin Aging Study (BASE), Australian Longitudinal Study of Ageing (ALSA), and German Socio-Economic Panel (SOEP)) include multiple domains whereas others assess only a few (e.g., Origins of Variance in the Oldest-Old (OCTO), Lothian 1921 cohort). Furthermore, there are studies that focus specifically on subgroups of the oldest old (e.g., centenarians).

RESEARCH ISSUES

There are a multitude of complexities to consider when studying the oldest old. A primary concern is the generalizability of research findings due to sampling and mortality selection processes. Not all adults aged 85+ are willing and/or able to engage in research. In this population, issues related to vision, hearing, physical functioning, cognitive decline, frailty, and distance-to-death all play a role in restricting participation. Given this, we argue that more attention should be paid to using actual research participation as a basic indicator of vitality in the oldest old. Being able to participate in a study is a broad indicator that the individual has sufficient ability and vitality to engage with the outside world. In addition, participation as an indicator of vitality could be scaled by the physical and psychological demands of the particular study. For example, the ability to participate in a half-hour telephone interview is less taxing than engaging in an hour-long in-home interview, which is then less taxing than traveling to a location outside of the home for an interview or completing a mail or web questionnaire without assistance.

Although many recognize the problem of selection processes in studies of the oldest old, it is more difficult to deal with this problem. Cross-sectional studies typically have little information about selective participation. One important direction for future work is to increase cross-sectional analyses of population-based samples and include adjustments for non-response bias. Comparisons of the impact of participation estimates in population-based samples of the oldest old to those that currently exist with convenience samples could inform theories and guide the design of new studies about psychological vitality in the oldest old.

Longitudinal studies have additional constraints to consider. They deal with the same issues of initial sample selectivity at baseline, but must also address selective attrition. Currently, it is common practice for longitudinal studies of all types to report attrition rates and descriptive comparisons of those who remained in the study versus those who dropped out. Typically such comparisons reveal that sample attrition is linked to death, poor health, frailty, and lower baseline cognitive and other psychological functioning, all facets integral to understanding psychological vitality.

An important theoretical consideration in designing longitudinal studies of aging is the number of measurement occasions and the time interval between those occasions to appropriately capture change. These decisions should be made with reference to theory about fluctuations and change in key variables of interest. Considering this, paired with evidence that the oldest old are an extremely heterogeneous population, future research should consider shorter intervals between waves and include bursts of assessment when following this population over time. In particular, more frequent measurement of the domains typically considered to be relatively stable before age 85 may be informative. Some studies, for example, choose to measure crystallized abilities such as vocabulary and factual knowledge less frequently than fluid cognitive abilities such as speed or memory because research has shown that knowledge and facts are relatively stable in old age compared to reliable declines in performance on fluid tasks. The rates of change in these domains, however, may be different than those in younger age groups. Depending on the domain of functioning, individual differences in variability (fluctuations) could also be markers of either adaptation or loss of vitality in the very old. In addition, because it is well-established that longitudinal studies of the oldest old experience high rates of attrition, having more frequent measurement occasions and measurement bursts will contribute more information to model functional change prior to attrition. Studies suggest that greater variability and steeper decline in functioning are important predictors of subsequent death-related and non-death attrition.

DOMAINS OF PSYCHOLOGICAL VITALITY

Psychological vitality in later life is observed within and across many domains and dimensions of functioning. Here, we review research since 2004 on cognition, personality, self-related functioning, social connections, and subjective well-being. In each domain, we ask: (i) which characteristics predict longevity; (ii) what is known about the level and heterogeneity of functioning of the oldest old on these characteristics; and (iii) does functioning in the domain change after age 80?

Cognition

Cognitive functioning is a well-known indicator of maintaining independence and survival in older adults (Ryan & Smith, 2009). Several mechanisms may underlie this association, including proposals that cognition is a resource for better health behaviors and physical functioning, better availability of resources linked with cognitive function and educational attainment (such as better health care over the life course), and underlying biological links which pair cognitive decline with terminal decline in old age. We briefly review research published since 2004 about dimensions of cognition associated with survival in the oldest old, the importance of differentiating cognitive status versus rate of decline, and heterogeneity of cognitive functioning in the oldest old.

Level Versus Change in Cognition and Survival

Research on cognition encompasses a wide array of dimensions, processes, and measures, ranging from conceptualizations of crystallized and fluid abilities, IQ, and dementia. This breadth alone challenges efforts to synthesize the associations of cognition with vitality and survival in the oldest old. One approach is to examine multiple components of cognition in a single study, such as Ghisletta, McArdle, and Lindenberger (2006) who examined links between cognitive performance and 13-year survival with a sample of 70–103–year-olds in the Berlin Aging Study. This study included three fluid measures (perceptual speed, memory, fluency) and a measure of verbal knowledge. When examining the impact of these measures in separate models on survival, results indicated that the level of cognitive function was a significant predictor of survival over and above age and gender. However, when all four cognitive domains were included in a single model, none retained significance. The authors posit that, in this longitudinal study of the oldest old, the association between cognitive performance and survival is more general and not explained by any single domain. These findings are also supported by studies which examine individual cognitive domains. Terrera, Piccinin, Johansson, Matttthews, and Hofer (2011) focused on links between memory performance and survival in a sample of the oldest old from the OCTO-Twin Longitudinal Study of Aging and found a similar pattern in that the level of memory was positively associated with likelihood of survival. Similarly, Deary, Whiteman, Starr, Whalley, & Fox (2004) found that intelligence measured at age 11 was significantly associated with survival to age 76. Unfortunately, this study did not include participants who had aged into the oldest old.

There is also evidence in recent studies of the oldest old that the rate of decline in cognitive performance is an important predictor of later survival (Alwin, McCammon, Wray, & Rodgers, 2008). One study applied latent profile analysis to examine patterns of memory, depression, and social integration over time in a sample of the oldest old (Morack, Ram, Fauth, & Gerstorf, 2013). The identified trajectory group types were largely defined by differential rates of memory decline. Compared to the individuals identified as having *preserved system integrity*, those with *compromised memory* and *failing memory* had significantly higher rates of mortality over 8 years. In addition, recent evidence suggests that, beyond the rate of decline, patterns of intraindividual variability in cognitive performance are associated with survival. In a sample of the 70+ followed over 17 years, for example, greater within-person variability in reaction time was associated with increased risk of mortality (Batterham, Bunce, Mackinnon, & Christensen, 2014).

Heterogeneity of Cognitive Functioning in the Oldest Old

As discussed earlier in this chapter, selective survival is an inherent factor in studies of the oldest segments of the population and, as such, it places important caveats on any research which aims to understand psychological vitality in aging populations. Another important issue is that, although there has been a great deal of research on cognitive aging since 2004, there is less recent work that specifically examines the oldest old. Typically, studies include samples of the 65+ or 70+, with the oldest tail of the age distribution creeping over age 80. In those studies which do include an adequate sample in the 80+ range, often the oldest old are grouped together with all older adults, thereby making it impossible to know if associations differ in the young-old and oldest-old groups. Given differential survival selection processes in the oldest old who participate in research, it is perfectly reasonable to hypothesize that associations of cognition with survival may in fact be different among the young old and oldest old. This point is supported by a study by Hülür, Infurna, Ram, and Gerstorf (2013), which found that, when anchored against distance to death, there were no cohort differences in the association of memory performance with survival. This suggests that the associations of cognition with survival in the oldest old may be qualitatively distinct from younger age ranges, considering that there is likely to be a larger proportion of the oldest-old population within their last years of life. Given survival selection effects, in addition to the potential for cohort effects related to differential life experiences, it is critical that future research on cognitive aging consider age-cohorts separately before generalizing associations across all older adults equally.

Another issue we encountered in this section relates to the measurement of cognition. While a wide variety of cognitive measures is used to characterize cognitive aging up to age 85, including multiple measures of processing speed, memory, decision making, and reasoning ability, most studies targeting the oldest old only include measures that screen potential dementia and clinically problematic functioning. These screens are known to be poor discriminators of performance within normal ranges. This bias toward using dementia-relevant measures is in part because rates of dementia and cognitive impairment are higher in the oldest old (Corrada, Brookmeyer, Paganini-Hill, Berlau, & Kawas, 2010). Several studies, for example, report that between 0% and 50% of centenarians and older do not have a diagnosis of dementia and score in the normal range on screening tests for suspected dementia (Calvert, Hollander-Rodriguez, Kaye, & Leahy 2006; Yang, Slavin, & Sachdev, 2013). In sum, it is clear that future work needs to specifically target the oldest old and to include a wide range of cognitive measures.

Personality Traits

Research on personality in old age encompasses both trait and social-cognitive perspectives. In this section, we review studies that link the Big Five traits and sub-facets to longevity and report findings about levels and change in trait stability after age 80.

Trait Predictors of Survival

Roberts, Kuncel, Shiner, Caspi, and Goldberg (2007) conducted a comprehensive review of the magnitude of effects of personality traits on mortality in 34 studies that controlled for other known predictors, such as socioeconomic status, cognitive ability, gender, and health. High conscientiousness (especially the sub-facets of self-discipline and social dependability) is consistently found to predict longevity both in studies that examine early life predictors (Deary, Batty, Pattie, & Gale, 2008; Friedman, Kern, & Reynolds, 2010; Terracciano, Löckenhoff, Zonderman, Ferrucci, & Costa, 2008) and those that examine predictors after age 65 (Weiss & Costa, 2005). Conscientiousness is associated with engaging in health-protective behaviors during adulthood as well as other protective life course factors, such as career success, and social relationships. People who survive beyond ages 65 or 70 are thus likely to be positively selected for conscientiousness. Given this, the findings of Weiss and Costa (2005) that high conscientiousness continues to be predictive of survival in very old age are noteworthy. Furthermore, the men and women in the study by Weiss and Costa (2005) were all Medicare recipients with multiple functional limitations and relatively low education.

Findings about the associations between longevity and other traits (neuroticism, extraversion, openness, and agreeableness) are less consistent. Mroczek and Spiro (2007), for example, found that neither level nor change in extraversion predicted 18-year survival among men over age 60, but level and change in neuroticism did. Whereas lower neuroticism was protective, higher neuroticism increased mortality risk by 40%. High neuroticism and low extraversion were associated with an increased risk of death in a Chicago sample aged over 65 (M=75 years at baseline; Wilson et al., 2005).

These associations were minimally reduced after adjusting for health factors, but reduced by more than 50% after controlling for levels of cognitive, social, and physical activity. Read, Vogler, Pedersen, and Johansson (2006) found that less extraverted individuals at age 83 had an increased risk of mortality over a 4-year period.

Optimism predicted all-cause and coronary heart disease-related mortality in an 8-year follow-up of 97,253 postmenopausal women aged 50–79 who participated in the Women's Health Initiative study (Tindle et al., 2009). A 10-year prospective study of Dutch men and women aged 65–85 also found that dispositional optimism was predictive of all-cause and cardiovascular mortality (Giltay, Geleijnse, Zitman, Hoekstra, & Schouten, 2004). In studies of older adults that include both men and women, there are suggestions that the predictive effects of optimism may interact with gender and age. Giltay et al. (2004), for example, found that the protective effect of optimism was somewhat higher in men than in women. The opposite gender effect was found in nonagenarians from the Danish 1905 Cohort Survey (Engberg et al., 2013). In this sample of the oldest old, optimism was protective for women, but was not significant for men.

Personality Profiles of the Oldest Old

Several studies of exceptional survivors report that centenarians are characterized by low neuroticism, high conscientiousness, and moderate levels of extraversion and agreeableness. In a nationwide study of 400 Greek centenarians (Tigani, Artemiadis, Alexopoulos, Chrousos, & Darviri, 2011), on average, men were found to be more optimistic than women. In this study, 78% of participants completed non-proxy interviews and optimism scores ranged from low to high. Participants in the study were relatively healthy: the sample represented approximately 25% of centenarians in the Greek population and excluded long-lived survivors with dementia and poor hearing.

Studies that compare the oldest old with younger groups (aged 60–80), however, typically find that extraversion, openness, and conscientiousness are lower in the oldest old. Terracciano, McCrae, Brant, and Costa (2005), for example, report age-comparative data on the NEO-PI-R for a subgroup of 190 oldest-old individuals who had participated in the Baltimore Longitudinal Study of Aging. Compared to people aged 70–79, those over 80 were, on average, 2.3 T-score points higher on neuroticism, 2.8 points lower on extraversion, 1.6 lower on openness, 0.6 lower on agreeableness, and 1.6 lower on conscientiousness. The authors caution that cohort differences may underlie these results. Consistent with these findings, Andersen et al. (2013) observed in the Long Life Study that levels of extraversion, openness. and conscientiousness for 1433 nonagenarians and centenarians (all without dementia) were, on average, 3 T-scores lower than those of their 60-year-old offspring ($n=2423$). They also report that the parent generation scored higher on neuroticism and lower on agreeableness.

Personality Change after Age 80

Studies about change in personality traits after age 80 are rare in contrast to the increasing number of such studies in younger life periods. Lucas and Donnellan (2011) examined 4-year stability and change in participants in the German SOEP. They found that compared to midlife age groups, 4-year stability was lower after ages 70 and 80, especially for conscientiousness. Indeed, the lower stability levels were similar to those found for adolescents and children. Mean levels of all of the Big Five traits declined over 4 years in participants over age 80. Mõttus, Johnson, and Deary (2012) modeled change in personality between ages 81 ($n=450$) and 87 ($n=209$) in follow-up studies of the Lothian 1921 Birth Cohort. They found relatively high 6-year stability (ranging from 0.78 to 0.89 for latent factors) and significant mean-level declines in extraversion, agreeableness, and conscientiousness. Non-participants in the 6-year follow-up (54% of the baseline sample dropped out) had reported higher neuroticism at age 81 and were physically, functionally, and cognitively less able.

Findings about the impact of health on personality change are mixed. Mõttus, Johnson, Starr, and Deary (2012) asked if change in personality was associated with cognition, physical fitness (e.g., strength), and functional limitations. They found that higher intelligence at age 79 and minimal change in physical fitness contributed to reduced decline in conscientiousness over time (i.e., greater maintenance) in the Lothian octogenarians. Individual differences in change in extraversion, agreeableness, and neuroticism, however, were not associated with these predictors. Berg and Johansson (2014), however, found that mean levels of extraversion decreased over 6 years in a study of Swedish octogenarians, and that steeper decline in extraversion was associated with impaired hearing.

Self-Related Beliefs and Self-Regulation

Self-related knowledge, beliefs, and processes are generally distinguished from personality traits and provide valuable additional insight into adaption to personal aging and changing life circumstances in very old age. Theory and research suggest that self-related functioning is less vulnerable to decline than cognition and contributes to resilience and thriving at least up to the early 80s. Since 2004, with the exception of several qualitative analyses of narrative interviews and studies of possible selves, most research on people over age 80 has focused on measures of self-perceptions of aging, valuation of life, personal control (mastery), and self-esteem. This trend is reflected in our review.

Self-Related Predictors of Survival

In contrast to the literature on personality traits, we were unable to find a review comparing multiple dimensions of self-related predictors of survival into very old age. Instead, researchers typically analyze specific self-related constructs and, although findings are adjusted for covariates such as socioeconomic status, health and cognition, adjustments for (or comparisons with) other self-related beliefs or personality traits are rare.

Several studies report that positive self-perceptions of aging and the relative maintenance of these perceptions over time predict survival to age 80 and older. Using data from BASE, Kotter-Grühn, Kleinspehn-Ammerlahn, Gerstorf, and Smith (2009) found that baseline and relative longitudinal 4-year stability of positive self-perceptions of aging predicted subsequent survival 16 years later (*M* age = 85 at baseline; range 70–103 years). Average age at death in this study was 92 years. Furthermore, the 22% of decedents in the study who survived and were able to participate in at least four in-person interviews up to 6 years after baseline reported higher satisfaction with aging and feeling younger than their actual chronological age compared to other participants at baseline. These baseline comparisons and longitudinal change findings about self-perceptions of aging are consistent with research by Sargent-Cox, Anstey, and Luszcz (2014) in a 16-year Australian panel (*M* age 77 at baseline) and by Uotinen, Rantanen, and Suutama (2005) in a 13-year Finnish prospective panel (mean age = 73 at baseline, born 1904–23).

Prospective studies of population and midlife panels over many years suggest that perceptions of control of one's life (also called mastery or self-efficacy) are predictive of survival at least into the late 70s and 80s (Infurna, Ram & Gerstorf, 2013; Turiano, Chapman, Agrigoroaei, Infurna, & Lachman, 2014). In a large panel study of over 20,000 in the United Kingdom, Surtees, Wainwright, Luben, Khaw, and Day (2006) found that a high sense of mastery was associated with lower rates of mortality from all causes, cardiovascular disease, and cancer. They examined age-group-specific associations and reported that the association was consistent in the 50–59, 60–69, and 70–80 age strata and across 2-year, 4-year, and longer follow-up periods.

Feeling useful to others, a belief associated with personal mastery, is also related to longer survival after age 70 (Gruenewald, Karlamangla, Greendale, Singer, & Seeman, 2007). Similarly, several analyses of large prospective studies find that people over age 70 who volunteer have a reduced risk of mortality (Okun, Yeung, & Brown, 2013). Furthermore, participants over age 70 in the RUSH Memory and Age Project (MAP) and Minority Aging Research Study (MARS) who reported a higher purpose in life had a substantially reduced risk of mortality over a 5-year period. Consistent with all of these studies, attrition analyses in some longitudinal studies of older adults reveal that individuals who live to age 80 and continue to participate in studies have higher self-esteem than dropouts and non-participants (Wagner, Hoppmann, Ram, & Gerstorf, 2015).

Characteristics of the Self-Related Beliefs of the Oldest-Old

After age 80, narrative self-descriptions are often characterized by reflections about the good and bad sides of a long life: they may contain a life review, expressions of surprise and thankfulness for having lived a long life, together with fears and worries about declining health and memory (Jeon, Dunkle, & Roberts, 2006). Hoppmann and Smith (2007) reported that hopes and fears about health dominated the possible selves generated by 129 women aged 85–100+ in BASE. Interestingly, they also found that women who had never had children mentioned more family-related themes than mothers, whereas the mothers addressed more friendship-related themes than the childless women.

Health also plays a central role in the self-perceptions of aging reported by the oldest old. However, on average they report feeling younger than their actual age. Kleinspehn-Ammerlahn et al. (2008) estimated that at age 85 participants felt 13.5 years younger, whereas those aged 95 felt approximately 16.5 years younger. Similar discrepancies between actual and subjective age were found by Choi, Di Nitto, and Kim (2014) in subgroups aged 80–89 and 90+ in the National Health and Aging Trends Study (NHATS). Among 267 participants from the Swedish OCTO study, almost two-thirds of the 84- to 90-year-olds reported not feeling old (Infurna, Gerstorf, Robertson, Berg, & Zarit, 2010).

Comparisons with the young old reveal that the oldest old on average report somewhat lower levels of perceived control and self-esteem (Lachman, Neupert, & Agrigoroaei, 2011). Orth, Trzesniewski, and Robins (2010), for example, estimated a difference in the level of self-esteem for a 60-year-old versus a centenarian to be −0.67 SDs. Using a sample that ranged from 65 to 85+ (baseline *M* age = 78), Krause (2007) found that the oldest participants were less likely to feel that they could control what happened in the social role that they most valued (e.g., as spouse, homemaker, or parent). Feeling able to actively engage in activities that provide a sense of competence, pleasure, and social contact contributes to a desire to live more years, a concept examined by Jopp, Rott, and Oswald (2008). They compared responses to items, such as *I have a strong will to live right now* and *I intend to make the most of my life*, given by people aged 65–79 and 80–94 from a locally representative community-dwelling panel in Germany. Only 40% of people over 80 (*N*=353) provided complete data for the analyses and while their overall scores on the measure tended to be lower than the younger group, individual differences within the oldest group were large. Poor health especially appears to challenge the capacity to remain strong-willed.

Change in Self-Related Beliefs after Age 80

Since 2004, researchers have begun to compare late-life age-related and death-related change in self-related beliefs using data from several longitudinal studies. In general, change associated with distance from death (terminal decline) appears to be greater than time-in-study and age-related change in very old age. However, the sources and extent of change associated with age- and death-related processes differ by the dimension and, regardless of the time metric used, there are typically substantial individual differences in the onset, shape, and rate of change.

Kleinspehn-Ammerlahn, Kotter-Grühn, and Smith (2008), for example, found that although satisfaction with aging declined over 6 years, the oldest old either maintained or slightly increased the gap between the age they felt and their actual chronological age over time. Change in subjective age was attenuated by chronic illness and loneliness. When Sargent-Cox, Anstey, and Luszcz (2012) examined the relationship between changes in satisfaction with aging and physical functioning over 16 years, they found that the relative maintenance of satisfaction with aging over time was protective of decline in physical functioning.

Kotter-Grühn and Smith (2011) reported that, for each additional year lived, individuals over age 85 made fewer plans for the future and were less optimistic. Similarly, Krause (2007) found that advancing age was associated with a decline in feelings of control over valued social roles and Gerstorf, Ram, Lindenberger, and Smith (2013) found significant quadratic age-related change in perceived control over desirable and less desirable outcomes. In contrast, Wagner et al. (2015) reported that self-esteem was stable up to the early 90s.

Kotter-Grühn et al. (2009) compared age- and distance-to-death models of change in satisfaction with aging and subjective age. They found that whereas the distance-to-death model was the best fit for decline in satisfaction with aging, a time-from-birth model best fitted subjective age. In other model comparison studies, average rates of decline in very old age are generally steeper over time-to-death than over age (e.g., perceived control; Gerstorf et al., 2013).

Social Connections

Social connections can be characterized in terms of frequency and quality of social contact with friends and family, social support and strain, social network size, social isolation, and loneliness. The quality of social connections is particularly important for the oldest old as individuals' social network sizes typically decline with age (Broese van Groenou, Hoogendijk, & Van Tilburg 2012; Shaw, Krause, Liang, & Bennett, 2007). While surviving to age 85 and over is an achievement, most long-term survivors are faced with inevitable losses to their networks, including spouses, siblings, friends, and sometimes even children. Over time, fewer age peers with shared knowledge of early life experiences and personal history survive. Coping with these losses and maintaining strong connections with remaining (typically younger) social network members is therefore an essential component of vitality for the oldest old.

There is ample evidence that older adults are motivated to maintain familial ties and that a great deal of their psychological and emotional well-being is derived from family (Charles & Carstensen, 2010). Not only does the maintenance of familial ties provide a sense of satisfaction and well-being to older adults, but it also can be instrumental in providing a source of informal care. Although evidence of the maintenance of family network connections in the oldest old is in line with this research, recent work has found that while earlier cohorts of the oldest old have few non-kin members in their networks, more recent cohorts show better maintenance of non-kin network members into late life (Stevens & van Tilburg, 2011; Suanet, van Tilburg, & Broese van Groenou, 2013). This is an important development, given recent evidence that the Baby Boomers are expected to have fewer traditional sources of informal care providers as they enter into late adulthood (Ryan, Smith, Antonucci, & Jackson, 2012). In a related paper, Vikström et al. (2011) investigated the potential impact of childlessness on the oldest old. Using data from the ELSA, the authors found that, contrary to expectations, childless individuals did not differ on a range of psychological well-being indicators compared to those with children. In line with Suanet, van Tilburg, and Broese van Groenou (2013), it is possible that this cohort has developed fictive kin networks to supplant "gaps" in social and instrumental support associated with being childless, supported by research showing that time spent with friends is a critical predictor of survival (Maier & Klumb, 2005). These non-traditional social networks are likely to be more common with future cohorts of the oldest old, and an important marker of psychological vitality will be the extent to which such social networks are created and maintained.

Social Connections of the Oldest Old

As is the case with much research on the oldest old, a great deal of work examining social connections is cross-sectional. This work is particularly important in that it provides essential baseline information about older adults' social networks and does not suffer the same selectivity issues inherent to longitudinal studies of the oldest old. Ailshire and Crimmins (2011) examined a nationally representative sample of older adults in HRS to determine how the oldest old (90+ in this study) compared to those in their 70s. Results found that the oldest old report more supportive relationships with family members compared to their younger counterparts. However, the oldest old were significantly more likely to feel lonely and socially isolated, possibly due to higher rates of widowhood. In another nationally representative sample of US adults, Cornwell, Laumann, and Schumm (2008) used the National Social Life, Health, and Aging Project to examine profiles of social connectedness by age. While only a portion of the participants were in their 80s, results confirmed previous findings that increasing age is associated with smaller social networks. They report that there is increased frequency of network contact beginning in the late 70s, that more frequent network contact was associated with stronger social ties, and that the probability of weekly attendance of religious services, neighborly socializing, and volunteering all increase with age. The increased community engagement with increasing age into the early 80s needs to be viewed through the lens of positive selection, given that this analysis was cross-sectional.

When considering the cross-sectional work, the overall picture is of a complex constellation of social connections among the oldest old. While objective indicators of social isolation are more likely in this population due to widowhood and other cohort losses, there are also indicators that the oldest old have generally positive social experiences and retain nonkin members in their networks. These positive social profile attributes are an important indicator of psychological vitality, that in the face of difficult social losses and feelings of loneliness, individuals are resilient and able to retain positive experiences from their remaining network members.

Social Connection Predictors of Survival

The majority of research about social connections over time is focused on later survival, so we have combined these two subsections. There are a variety of pathways and mechanisms by which social connections are associated with survival in the oldest old. As mentioned above, social connections are an important source of social and instrumental support for older adults' daily lives. Not only does the maintenance of a social connection with family, such as grandchildren and great-grandchildren, motivate activity and produce pleasure for the oldest old, but it is also instrumental in providing sources of care for frail elders. Using a sample of Danish twins aged 75 and older, Rasulo, Christensen, and Tomassini (2005) found that survival over a 6-year period was associated with having a spouse, reporting close ties with friends (for women only), and being close with the co-twin (for identical twins). This study is very useful in that it incorporated a longitudinal approach with a variety of social connection constructs, from objective measures such as frequency of contact to the quality of relationship ties.

There is a great deal of evidence linking social isolation and loneliness with increased mortality risk, which is important given the higher likelihood of being socially isolated or lonely in the oldest old (Steptoe, Shankar, Demakakos, & Wardle, 2013). Typically, social isolation is considered an objective measure of an individual's social network size and frequency of contact with the network, whereas loneliness is the self-perception of being isolated from others. One challenge in reviewing this literature is that many studies focus on a broad age range and tend to consider linear age trends rather than considering the oldest old as a qualitatively distinct group. Although it may indeed be that associations of loneliness on mortality are consistent across age groups, we argue that the extent to which age groups within the oldest old are qualitatively distinct remains an open question. It may be that while loneliness is more frequent in the oldest old, due to social network losses, the fact that these losses are normative for this group may facilitate coping and accepting the deaths of close network members. There is still much that needs to be understood about the potential meaning and context differences in comparisons of the young old and the oldest old for constructs such as loneliness.

Subjective Well-Being

Subjective well-being is one of the central indicators of psychological vitality in late life. It reflects the remarkable adaptive capacity to remain satisfied with life and to sustain a positive balance of positive versus negative affect even when challenged by illness, physical and cognitive decline, and social losses (e.g., widowhood, deaths of age peers). The literature since 2004 abounds with studies reporting that life gets better with age and that older adults are happier than midlife cohorts. However, most studies supporting these conclusions do not include the oldest old. In this section, we review research about selective survival associated with components of subjective well-being (e.g., life satisfaction, positive and negative affect) and levels and change in well-being in octogenarians, nonagenarians, and centenarians.

Subjective Well-Being and the Prediction of Survival to Age 80

There is robust evidence from long-term prospective studies that higher positive affect and satisfaction with life are associated with a reduced risk of mortality (Diener & Chan, 2011). In an extensive meta-analysis, Chida and Steptoe (2008) compared the sensitivity of 15 studies that sampled primarily participants over age 60, with a larger pool of population and lifespan studies. This revealed that higher subjective well-being had the strongest protective effect in the studies of older adults.

Findings from two studies of older twins suggest that the strong association between subjective well-being and survival continues after age 70. Sadler, Miller, Christensen, and McGue (2011) followed 3966 dizygotic and monozygotic Danish twins aged 70 and older for a median of 9 years. They found that higher life satisfaction reduced the risk of all-cause mortality and was independent of familial factors such as shared genes and common environment. Swedish octogenarians in the highest quartiles of satisfaction with present life had a twofold reduced risk of 10-year mortality compared to those in the lowest quartile (Lyyra, Törmäkangas, Read, Rantanen, & Berg, 2006). Dutta et al. (2011), however, reported that although life satisfaction was associated with survival to age 85 in the Iowa EPESE study, it did not predict survival to age 94 for men or 97 for women.

Level and Change in Subjective Well-Being after Age 80

Cross-sectional and longitudinal analyses consistently report decreases in life satisfaction after age 80. Berg, Hoffman, Hassing, McClearn, and Johansson (2009) found that differences in within-person change over 6 years were associated with time-varying factors such as loss of spouse, perceived quality of social network, and depressive symptoms. Using longitudinal data from large representative panels in Germany, England, and the United States, Gerstorf et al. (2010) determined that individual differences in late-life intraindividual changes in life satisfaction were better described using a distance-to-death rather than a distance-from-birth time metric. They identified transition points 3–5 years prior to death after which decline in life satisfaction accelerated. Models of age-related intraindividual decline in life satisfaction also were somewhat more pronounced in the oldest old than in people aged 70–84.

Although comparisons of centenarians and younger age groups (midlife and octogenarians) reveal no age differences in the percent of participants who report feeling currently as happy as in younger years (Jopp & Rott, 2006), these cross-sectional findings are not consistent with reports of longitudinal change. Gana, Saada, and Amieva (2015), for example, modeled 22-year change in a French community-based locally representative panel from Gironde and Dordogne (baseline age ranged from 75 to 92). They found a small but significant decline in the very old: fewer and fewer people report feeling happy with each year of life. Kunzmann (2008) proposed that decreases in positive affect are primarily associated with reductions in social involvement and cognitive decline. Similar to the research on life satisfaction, affective well-being is also vulnerable to terminal decline (Palgi et al., 2014; Vogel, Schilling, Wahl, Beekman, & Penninx, 2013). Schilling, Wahl, and Wiegering (2013) found that the association between increased age and decline in positive affect was stronger than that with distance-to-death. Increases in negative affect in advanced old age, on the other hand, were substantially related to impending death.

CONCLUSIONS

What conclusions can be drawn from this cursory review of psychological functioning after age 85? Is there a new body of evidence about the prevalence and possibilities for psychological vitality late in life? We summarize our impressions in four main points.

First, in the five domains we reviewed, people who reach the age of 85 and enter the oldest-old group in the population are positively selected for a single and possibly a combination of psychological factors associated with vitality. For example, they may be conscientious and have high self-esteem, or be intelligent and optimistic. Here, we use the term positively selected to refer to the demographic fact that they have outlived 80% or more of their birth cohort and participated in research. There are likely many different combinations of psychological characteristics and associated biogenetic and social pathways that have contributed to and sustained survival to the mid-80s. We currently have information about some single characteristics but know little about combinations of protective factors.

Second, despite this positive selection, it appears that even the most psychologically vital individuals after age 85 are vulnerable to the challenges of physical and cognitive decline, illness, and social losses (Charles, 2010; Shmotkin et al., 2013). Many outlive their long-term partners, siblings, same-age friends, and even their children. Physical limitations and reductions in energy and strength constrain and diminish psychological vitality. Comparisons of age-related and death-related trajectories of change observed in the very old suggest that processes that are associated with distance-to-death (terminal decline) gain in prominence. To date, we know little about the nature of these processes and the reasons for their differential impact across domains and people (Gerstorf & Ram, 2013). It is often assumed that physical and psychological decline are synchronous but the extent of this intertwine and the role of chance factors is not known. A better understanding of the complex interactions between mind and body in very old age will provide insight into intervention strategies. Current measures, however, may not be sufficiently sensitive to evaluate the range of the psychological vitality and adaptive capacity of the very old. Measures originally developed primarily to assess psychological competence, beliefs, and dispositions in early life likely underestimate the potential and vitality of the very old.

Third, we know little about the efficacy of interventions after age 85. To what extent is it possible to enhance psychological functioning in some or all of the domains we reviewed? Should some domains be prioritized? Furthermore, are there particular aspects of supportive caregiving and socio-environmental contexts that can be leveraged to enhance and sustain the psychological vitality of the oldest old?

Finally, to advance our knowledge about very old age, the field continues to need well-designed, longitudinal studies that focus on transitions from the 70s to the 80s and beyond, as well as transitions from psychological vitality to vulnerability and diminished capacity regardless of chronological age. Many studies that currently focus on specific functional transitions, such as from normal cognitive functioning to impairment and dementia, do not collect comprehensive biopsychosocial and life history protocols.

There has been, and continues to be, much "success" over the last 100 years with regard to extending the years of life beyond the seventh decade for many populations worldwide (Christensen, Doblhammer, Rau, & Vaupel, 2009). In our view, however, it remains an open question whether the psychological characteristics that likely contribute to and foster a long life can be strengthened and prolonged in the oldest old. Having more available information for current cohorts of the oldest-old would expand the set of scenarios about prospects for future cohorts to delay psychological morbidity. Should we expect an epidemic of cognitive decline and psychological dependency from 2030 onwards when the first surviving Baby Boomers move into their late 80s? Alternatively, will the majority in the expected large number of oldest-old Baby Boomers set new standards of psychological vitality in late life?

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CHAPTER

17

Cross-Cultural Psychology of Aging

Helene H. Fung and Da Jiang

Department of Psychology, Chinese University of Hong Kong, Hong Kong, China

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CROSS-CULTURAL PSYCHOLOGY OF AGING

It is public knowledge that the world's population is aging. However, what is seldom discussed is the fact that between 2010 and 2040, 66.5% of the world's older population increase will be accounted for by Asia; and within Asia, 42.0% of the increase will be accounted for by China alone (Cheng, Chi, Fung, Li, & Woo, 2015). Yet, empirical studies on aging among the Chinese are few, and the scant findings sometimes suggest that the aging of the Chinese may be different from what is suggested in the mainstream literature. Moreover, cross-cultural differences in the psychology of aging are often different from the ethnic and racial differences on aging that have been described in the literature (Jackson, Govia, & Sellers, 2011). For example, the difference in socioeconomic status that drives much of the health inequality observed in the ethnic/racial

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literature has a very minor role in the cross-cultural psychology literature. In this chapter, we first review our own theoretical and empirical work, and the work of others, on East–West differences in age-related personality, social relationships, and cognition. Next, we discuss two other approaches to studying cross-cultural aging. The first approach uses aging as a proxy of cognitive and neural changes, and then tests whether cultural differences in cognition diminish or magnify with these changes (Park, Nisbett, & Hedden, 1999). The second approach compiles cross-national data sets to test the generalizability of aging-related phenomena.

A THEORY: AGING IN CULTURE

In a theoretical paper published elsewhere (Fung, 2013), we argue that socioemotional development across adulthood may be part of the life-long socialization process: individuals in each culture learn to be better members of their culture as they grow older. Cultural differences in aging (i.e., age by culture interactions) occur when people from different cultural contexts learn different ways to become better members of their culture. By proposing this argument, we agree with the basic premise of lifespan developmental theories (Baltes & Baltes, 1990; Brandtstädter & Greve, 1994; Carstensen, 2006; Heckhausen & Schulz, 1995) that as people age, they shape their world in ways that maximize their well-being; but we add that people do so within the confines and definitions of their respective culture.

In particular, we argue that (i) individuals make sense of life (i.e., figuring out what is important to them) through internalizing the values of their cultures; (ii) these internalized cultural values become their personal goals that guide their development across adulthood; (iii) cultural differences in aging result when individuals from different cultures each pursue their own internalized cultural values with age. Below we describe these theoretical postulates in greater detail.

Individuals Make Sense of Life Through Internalizing the Values of Their Cultures

The need to make and maintain meaning is one of the basic human needs (Heine, Proulx, & Vohs, 2006). Since birth, individuals try to figure out what is important in life through sociocultural artifacts such as schooling, work, sex roles, and social relationships (Kegan, 1994). Gradually, individuals learn to resolve conflicts between societal demands and personal desires (Erikson, 1950, 1968, 1982) by means that include but are not limited to internalizing societal demands and turning them into personal goals. This process is known as "socialization" (Bronfenbrenner, 1979) or "cultural learning" (Vygotsky, 1934/1962) in the human development literature, and "acculturation" in the immigration literature (Berry, 1997).

For example, individuals in independent cultures (Markus & Kitayama, 1991) learn to value personal autonomy and uniqueness since birth, through interactions with their parents (Keller, 2003). Their parents maintain a certain level of personal distance from them (in terms of face-to-face contact, object stimulation, and mutual eye contact), and encourage them to express the self as a separate physical entity in actions, words, ideas, and feelings (Lewis & Brooks-Gunn, 1979).

In contrast, individuals in interdependent cultures (Markus & Kitayama, 1991) learn to see the self as embedded within social units through proximal parenting (Keller, 2003), i.e., their parents provide them with much body contact and stimulation. They also learn to prioritize the needs of the group over their own needs by being encouraged to follow the customs and norms embraced and prescribed by their parents and the society. Parents also directly teach children the values that they perceive as culturally important (Tam, Lee, Kim, Li, & Chao, 2012).

Later, as the individuals enter schools, those in independent cultures are encouraged to learn through exploration (Chao, 1995). But those in interdependent cultures are given more dogmatic education and training (Chao, 1995), as well as direct moral education and formal training on how to relate to other (Wu, 1996). The learned culture values influence the individuals' moral judgment (Vauclair & Fischer, 2011), priority of different needs (Triandis, 1995) and definition of life satisfaction (Oishi, Diener, Lucas, & Suh, 1999).

There are reasons to believe that these socialization processes intensify with age. Heine and colleagues (2006)'s Meaning Maintenance Model postulates that the demand to satisfy a need is increased when other needs are not satisfied (see also the literature on fluid compensation: McGregor, Zanna, Holmes, & Spencer, 2001; Steele, 1988). Almost all theories on adult development and aging agree that the second half of life is associated with some losses and declines, particularly in the physical and cognitive domains (Rowe & Kahn, 1997). These losses and declines may motivate older people to seek satisfaction by other needs. Since identifying with and internalizing cultural values help to fulfill the need for belongingness (Baumeister & Leary, 1995), to protect self-esteem (Steele, 1988) and to reduce epistemic uncertainty (Hogg, 2001), people may do so to a greater extent with age, to compensate for losses and declines in other areas.

For example, Neugarten (1968, 1977) argues that older adults perceive themselves as less able to effect change in the world. They thus place greater emphasis on meeting sociocultural demands.

Although not focusing on age-related losses and declines, a few other theories make predictions that are consistent with the argument that socialization may intensify with age. Erikson's psychosocial theory of development (1950, 1968, 1982), for example, describes each developmental stage as a conflict between personal needs and societal demands. After resolving all these conflicts, the ultimate goal in the last stage of life (i.e., old age) is integration, which can be understood as the integration of personal goals and cultural values, Along the same vein, socioemotional selectivity theory (Carstensen, 2006) argues that with age, people perceive future time left in life as increasingly limited. This sense of limited future time motivates older people to prioritize goals that aim at deriving emotional meaning from life. Making sense of life through identifying with and internalizing the values of one's culture is likely to be a good way to derive emotional meaning from life.

To test whether older adults were indeed more likely to endorse and internalize cultural values than did younger adults, we (Ho, Fung, & Tam, 2007) examined personal and cultural values among younger (aged 18–23 years) and older (aged 54–89 years) Hong Kong Chinese. Values were measured by the Schwartz Value Questionnaire (1992), which consists of 56 values grouped under ten value types: power (e.g., social power, authority), achievement (e.g., successful, capable), hedonism (e.g., pleasure, enjoying life), stimulation (e.g., daring, a varied life), self-direction (e.g., creativity, freedom), universalism (e.g., broadminded, wisdom), benevolence (e.g., helpful, honest), tradition (e.g., humble, accepting my portion of life), conformity (e.g., politeness, obedient), and security (e.g., family security, social order). To measure personal values, we asked participants to rate the importance of each value to self. To measure cultural values, we adopted the intersubjective importance approach (Wan, Chiu, Peng, & Tam, 2007) and asked participants to rate the importance of each value in reference to their culture (i.e., the Chinese culture). We calculated the correlation coefficient between the ratings of personal and cultural values for each participant, across all 56 values. We found age differences in the correlation coefficients, such that older participants showed a higher congruence between personal and cultural values than did younger participants. We also computed mean differences between personal and cultural values for each participant and then compared their age differences. Smaller discrepancies between personal and cultural values were found among older than among younger participants.

To further investigate what drove this higher congruence of personal and cultural values among older relative to younger participants, we examined age differences in personal values. Older participants reported higher endorsement of all personal value types that are more communal in nature (i.e., universalism, benevolence, tradition, conformity, security) than did younger participants. They also reported lower endorsement of four out of five personal value types that are more agentic in nature (i.e., achievement, hedonism, stimulation, self-direction) than did younger participants. These findings, taken together, suggest that with age, Hong Kong Chinese move away from more agentic values to more communal values, resulting in a closer association between personal and cultural values. In other words, we have preliminary support for the theoretical postulate that people increasingly internalize cultural values with age. Indirect evidence is also found in the literature on moral judgment. Jiang, Li, and Hamamura (in press) found that older adults made more principled moral judgment toward issues pertaining to fairness and justice than did their younger counterparts. Since moral judgment is closely associated with cultural values (Vauclair & Fischer, 2011), older adults' more principled judgment may reflect their higher endorsement of cultural values.

Internalized cultural values become personal goals that guide adult development. Cultural differences in aging result when individuals from different cultures each pursue their own internalized cultural values with age. Once people internalize their cultural values as their "personal values," their goals are set based on these values. To the extent that everyone develops across adulthood in ways that are consistent with internalized cultural values, cultures with different values should show different patterns of adult development. Indeed, in the self-enhancement literature, Sedikides, Gaertner, and Toguchi (2003) found that individuals with higher levels of independent self-construal self-enhanced on individualistic attributes (e.g., arguing for your position and against your group) whereas those with higher levels of interdependent self-construal self-enhanced on collectivistic attributes (e.g., avoiding open confrontation with your group). To the extent that self-enhancement guides the direction of self-development, or put in another way, adult development, we would expect independents to show age-related increases in individualistic attributes and interdependents to show similar increases in collectivistic attributes. We have tested this hypothesis in the following three areas: age-related personality, social relationships, and cognition.

Age Differences in Personality

For a number of years, personality development has been assumed to manifest in exactly the same way across cultures. Indeed, cross-sectional patterns of age differences in personality were found to be largely the same across cultures, ranging from Germany, Italy, Portugal, Croatia, South Korea (McCrae et al., 1999), the United Kingdom, Spain, the Czech Republic, Turkey (McCrae et al., 2000), Russia, Estonia, Japan (Costa et al., 2000) to the People's Republic of China (Yang, McCrae, & Costa, 1998). These findings have often been taken as evidence that personality development is universal. Yet, these cross-cultural findings were almost always obtained within the scope of the Five-factor model—neuroticism, extraversion, agreeableness, openness to experience, and conscientiousness (commonly known as the "Big Five"). It remains possible that age differences in other aspects of personality may differ across cultures.

Meanwhile, the literature in cultural psychology (Cheung et al., 2001) has reliably documented that when personality was measured not just by measures imported from the West but also by indigenous measures developed in China, six factors—interpersonal relatedness in additional to the Big Five—were found among several Chinese samples. Interpersonal relatedness covers items such as social reciprocity, harmony, face, and adherence to norms and tradition. When the expanded measures were then imported back to the West, the interpersonal relatedness factor was again found among several American samples (Cheung et al., 2001).

Conceptually, what distinguishes interpersonal relatedness from the Big Five is that while there is no theoretical reason to suspect that the Big Five may differ in importance across cultures, there is reliable cross-cultural evidence to suggest that interpersonal relatedness is more important among Chinese than among North Americans. For example, Chinese are found to be more interdependent than are North Americans (see Oyserman, Coon, & Kemmelmeier, 2002 for a meta-analytical review). Relationship harmony is more important than self-esteem to the psychological well-being of Chinese, whereas the reverse is true for North Americans (Kwan, Bond, & Singelis, 1997). Moreover, the lexical approach of personality argues that as people in a community talk to one another, they use vocabulary to describe different personality attributes. The personality attributes that "people in the language community have found particularly important and useful in their daily interactions" (John, 1990, p. 67) are represented by more synonyms in the language, and are eventually picked up as a factor when the language is factor analyzed. The fact that the interpersonal relatedness factor was first identified in the Chinese language suggests that it is more "important and useful" in that culture.

To test whether age differences in personality existed for interpersonal relatedness, we (Fung & Ng, 2006) examined age differences in the Big Five and interpersonal relatedness among younger (below 30 years old) and older (above 50 years old) Canadians and Chinese. Findings revealed that age differences in the Big Five did not differ across cultures. Yet, age differences in some aspects of interpersonal relatedness (i.e., social reciprocity and adherence to norms and traditions) were found only among Chinese but not Canadians. We interpret these findings as suggesting that personality may change with age according to cultural values. For Chinese, their culture emphasizes social reciprocity and adherence to norms and traditions, so they may learn to exhibit these characteristics to a greater extent with age. Canadians, in contrast, do not live in a culture that emphasizes these personality characteristics; they thus do not exhibit these characteristics to a greater extent as they grow older.

To test whether this interpretation is correct, we (Fung, Ho, Tam, & Tsai, 2011) examined age differences in social reciprocity among European Americans and Chinese Americans, aged 20–90 years. Conceptually replicating the findings of Fung and Ng (2006), age was positively associated with social reciprocity among Chinese Americans but not European Americans. Moreover, individual differences in values moderated these cultural differences. The association between age and social reciprocity was non-significant among European Americans as a group; but it became positive among European Americans who valued tradition (seeking group acceptance) more. Conversely, the association between age and social reciprocity was significantly positive among Chinese Americans as a group; but the association was weaker among Chinese Americans who valued hedonism (seeking individual pleasure) more. These findings suggest that people from each culture develop their social reciprocity, or more generally, their personality, with age according to what they value. In sum, there is at least some preliminary evidence to suggest that socioemotional aging may not be defined by a particular pattern across cultures. Even when the mechanism of aging is the same, the exact pattern of socioemotional aging across cultures may differ depending on the particular values each culture socializes its members with.

Further cross-sectional findings for the role of cultural values in personality development were obtained in a study on age differences in dispositional optimism among Americans and Chinese (You, Fung, & Isaacowitz, 2009). Prior cross-cultural research has suggested that optimism is closely associated with self-enhancing tendencies that are considered to be significantly more desirable among European Americans than among East Asians (Chang, Sanna, & Yang, 2003). The well-documented positive self-evaluation in Western cultures may not be generalized to the Asian cultures. There is a tendency to report self-criticism in Asian cultures, such as Japan (Kitayama, Markus, Matsumoto, & Norasakkunkit, 1997) and Korea. These Asian cultures believe that self-criticism is vital for individuals to support the group and maintain social harmony (Kitayama et al., 1997). These findings suggest that viewing oneself as negative or pessimistic may be somewhat adaptive in some Asian cultures. Under this context, we (You et al., 2009) examined optimism across age. We found that while Americans as a group were more optimistic than were Chinese, this cultural difference was greater with age. Older Americans were more optimistic than were younger Americans; yet, older Chinese were less optimistic than were younger Chinese. These findings, though cross-sectional, suggest that the direction of personality development may be determined by what is desirable and appropriate in each culture. Americans, living in a culture that regards optimism as desirable, become more optimistic with age. Conversely, Chinese, who live in a culture that values optimism less, become less optimistic with age.

Age Differences in Social Relationships

Other than personality, social aging also seems to show cross-cultural differences. A particular pattern of age differences in social network characteristics (SNC) has been reliably reported in the literature, including our earlier work (Fung, Carstensen, & Lang, 2001). Across cultures, increasing age was associated with fewer peripheral social partners, yet the number of emotionally close social partners remained relatively stable across age. It should be noted that most of the studies on age-related SNC cited above were conducted in the United States and Germany. We (Yeung, Fung, & Lang, 2008) predicted that East Asians with a higher level of interdependence (Oyserman et al., 2002) might be more likely to maintain interactions with social partners of greater diversity even when they grew older. In particular, East Asians might be more likely to maintain or even increase the number of close social partners, and be less likely to reduce the number of peripheral social partners, with age.

To test these hypotheses, we (Yeung et al., 2008) examined age differences in SNC among Chinese, aged 18–91 years. More importantly, we tested whether individual differences in interdependence moderated these age differences. The stability of the number of emotionally close social partners across age, typically found in Western studies (Fung, Lai, & Ng, 2001), was replicated only among Chinese with a low level of interdependence. In contrast, those with medium or high levels of interdependence exhibited a positive association between age and the number of emotionally close social partners. Similarly, although a negative association between age and the number of peripheral social partners was observed for the entire sample, the association was significant only among those with low or medium levels of interdependence. The association was much weaker, and in fact, no longer significant, among those with a high level of interdependence. These findings revealed that age differences in the number of close and peripheral social partners depended on values such as interdependence.

Longitudinal findings provide further evidence for the moderating role of values. We (Zhang, Yeung, Fung, & Lang, 2011) examined the relationships between age, changes in the number of peripheral partners, and changes in loneliness over 2 years, among Chinese aged 18–91 years. We also tested the moderating role of individual differences in interdependence. Results showed that the well-documented negative association between age and number of peripheral partners over time was only significant for individuals with low or medium levels of interdependence, but not for those with high interdependence. Moreover, having more peripheral social partners was associated with decreased loneliness in the 2-year interval, only among older and middle-aged adults high in interdependence.

Country-level individualism also moderated age differences in trust. We (Li & Fung, 2013) examined the associations between age and generalized trust, and trust toward family members, friends, neighbors, and strangers across 38 countries, including Australia, China, and the United States, using data from the World Value Survey. The age range differed by country, but usually ranged from the late teens to the 80s or 90s. We found that age was positively related to all the five types of trust across the countries. However, countries with lower levels of individualism, as indexed by Hofstede (2001), showed weaker associations between age and trust toward friends and strangers. We interpret these findings as suggesting that people in less individualistic countries are less selective about these peripheral partners with age.

Age-Related Cognition

Even age differences in basic cognitive processes, such as attention and memory, show differences across cultures. In recent years, an age-related phenomenon called the "positivity effect" (Carstensen & Mikels, 2005) has been identified. This effect involves preferential cognitive processing of positively valenced, relative to negatively valenced or neutral, stimuli with age. Isaacowitz and colleagues, for example, found the positivity effect in American samples using eyetracking techniques (Issacowitz, Wadlinger, Goren, & Wilson, 2006a,b).

However, information from the external environment, whether positive or negative, may carry important social cues. In particular, negatively valenced information, such as angry facial expressions, may be at least as useful as, if not more useful than, positively valenced information, such as happy facial expressions, in maintaining social harmony (Kitayama & Karasawa, 1995). As a result, Asian cultures that value interpersonal relationships and interdependence (Markus & Kitayama, 1991) may not show a bias for positive information. For example, in describing the construct "happiness," Americans only describe the positive features, whereas Japanese describe both positive and negative (e.g., social disruption) features (Uchida, 2007). In another study, Markus, Uchida, Omregie, Townsend, and Kitayama (2006) found that while American athletes explained Olympic performance primarily in terms of positive attributes, Japanese athletes did so in terms of both positive and negative (e.g., their family have made a lot of sacrifice) attributes.

In addition, while optimism or even positive illusion were found to be beneficial to well-being in the mainstream (i.e., Western) psychological literature (see Carver & Scheier, 2002, for a review), we (Cheng, Fung, & Chan, 2009) found that older Chinese who foresaw more negative future selves had higher well-being 12 months later. Likewise, despite the well-established finding in the mainstream literature that negative social exchanges had adverse effects (Rook, 1984), we (Fung, Yeung, Li, & Lang, 2009) found among Chinese, aged 18–91 years, that more negative exchanges were positively associated with increases in emotional closeness over a 2-year period.

Given the above, we predicted that to the extent that people in East Asian cultures found negative information as useful as positive information, they might either not show the positivity effect or show it to a lesser extent with age. To test this prediction, Fung et al. (2008) compared attention among younger and older Chinese, using eyetracking techniques in exactly the same way, with the exact same stimuli, as Issacowitz et al. (2006a,b). In contrast to the aforementioned positivity effect reliably found among Americans, older Chinese actually looked away from positive stimuli (in this case, happy faces).

Similar cross-cultural differences were also noted in memory. In a study that compared memory for positive, negative and neutral stimuli among younger and older Chinese (Fung & Tang, 2005), a negativity bias was found among older adults. In the study, the background music of a government TV announcement on health promotion was varied such that it conveyed positive, negative or neutral valence. The only difference in recognition memory was found between the negative and neutral versions, with older adults showing better recognition memory for information presented in the negative version of the announcement than the neutral version.

To further test whether the positivity effect existed in memory among older Chinese, Fung, Isaacowitz, Lu, and Li (2010) examined age differences in free recall for positive, negative and neutral images, with the exact same stimuli and methodology as those employed in a previous study that has found the strongest positivity effect among Americans (Charles, Mather, & Carstensen, 2003, Experiment 1). Their findings revealed that older Chinese showed better memory for positive than for neutral images (i.e., the positivity enhancement effect), but they showed the same level of memory for negative images as they did for neutral images (i.e., an absence of the negativity reduction effect).

In the aforementioned studies, Chinese who were more interdependent as a group (Markus & Kitayama, 1991) did not show the age-related positivity effect to the same extent as did Americans in prior studies, who as a group were less interdependent. Fung et al. (2010) directly tested whether individual differences in interdependence moderated these age differences in memory. Older Chinese with lower levels of interdependence showed both the positivity enhancement effect and the negativity reduction effect, as their American counterparts did in earlier studies (Charles et al., 2003). However, older Chinese with higher levels of interdependence only showed the positivity enhancement effect, but not the negativity reduction effect. Younger Chinese showed a memory bias for negative images over positive and neutral images throughout the study, regardless of levels of interdependence.

Individual differences in interdependence also moderated the age-related positivity effect in attention among younger, middle-aged, and older Chinese. Fung et al. (2010) presented participants with a real-life video clip that showed positive images on one side of the screen and negative images on the other side of the screen. They found that among Chinese who were lower in interdependence, older Chinese looked at the negative images, relative to the positive images, significantly less than did their middle-aged and younger counterparts. However, no such age differences were found among Chinese who were higher in interdependence. Taken together, the above findings suggest that the age-related positivity effect is not universal. Chinese, being more interdependent as a group, are more likely to value negative stimuli as much as positive stimuli in their social environment. They are thus less likely to show preferential processing of positive stimuli over negative stimuli with age.

OTHER APPROACHES

Using Aging as a Context to Test Cultural Differences

Other than examining how adult development differs across cultures, some researchers focus on cultural differences and investigate how cultural differences may differ by age. Park et al. (1999) proposed that cross-cultural differences in basic processes, such as speed and working memory, diminished with age because of the universally decreased neurobiological function associated with aging. However, cultural differences in cognitive pragmatics, such as categorization and background processing that people acquired through the learning process, magnified with age, because these processes were influenced by culture-specific learning and practice. This argument has received some empirical support.

For example, Chee, Zheng, Goh, and Park (2010) found that cultural differences in thinking style—Americans being more likely to use analytical thinking and East Asians being more likely to use holistic thinking—could be partially explained by the fact that younger Americans had higher cortical thickness in frontal, parietal, and medial-temporal polymodal-associated brain areas than did younger East Asians. These cultural differences in thinking style disappeared among older participants, but interestingly, persisted among high-performing older participants. Park and colleagues interpreted these age differences as further support for the fact that cultural differences in thinking style were driven by neurological differences. Age-related declines in cortical thickness occurred for both Americans and East Asians, eliminating cultural differences in neurology and thus cultural differences in thinking style. However, high-performing older adults retained such cultural differences in neurology, so cultural differences in thinking style persisted. Similarly, Hedden, Park, Nisbett, and Ji (2002) found that Chinese performed better than did Americans in numeric tasks and such cultural differences became less pronounced with age. These decreased cultural differences with age were accompanied by age-related declines in visuospatial processing cross-culturally. Again, Hedden and colleagues interpreted these findings as suggesting that declined brain functions led to the attenuated cross-cultural differences in performance on numeric tasks with age, supporting the argument that cultural differences in cognition were accounted for by brain functions.

In contrast, other cultural differences in cognitive processing magnify with age. This type of cognitive processing usually requires practice across adulthood. For instance, Gutchess et al. (2006) found that Westerners used categorization more than East Asians did, and such differences became more pronounced with age. In this study, categorization was measured by a ratio of clustering, that is, the extent to which the participants successfully recalled relevant words together. Gutchess and colleagues interpreted the finding as reflecting that categorization was a cognitive skill that required practice. To the extent that a skill is in use, an older person theoretically has practiced the skill for a longer period of time than does a younger person. Westerners who use the skill more improve it with practice whereas East Asians who use the skill less do not enjoy such benefits. As a result, cultural differences in categorization magnify with age. A similar explanation was also used to account for the finding that younger Chinese performed better in tasks on naming common objects—providing more specific depiction and greater variance in depiction—than did younger Americans, and such cultural differences were more pronounced between older Chinese and older Americans (Yoon, Feinberg, & Gutchess, 2006).

In addition, the differential rates of age-related cognitive declines among people in different cultures can also magnify some cultural differences. Goh et al. (2006) tested the neurobasis of object-focused versus background-focused differences between Western and East Asian cultures. They found that although the functioning of the object-processing brain regions decreased with age in both Western and East Asian cultures, such functioning of East Asians declined to a greater extent with age. This led to a larger cross-cultural difference in object processing between older Westerners and East Asians (Goh et al., 2006).

In summary, researchers from this approach dissert culture by age interactions by examining whether particular cultural differences diminish or magnify with age. They then investigate whether the factors that change with age, for example, specific brain functioning, may account for the decrease or increase in cultural differences.

Cross-Cultural Aging as Tests of Generalizability

Last but not least, the most common way of studying the cross-cultural psychology of aging is to construe culture as a context—as much as gender, socioeconomic status, and rural versus urban are contexts—to test the generalizability of aging-related phenomena. For example, Fredrickson and Carstensen (1990) found among US citizens that older adults preferred familiar social partners to novel social partners, whereas younger adults did not show this preference. This finding was offered as a potential explanation for why the shrinkage of social network size with age did not affect the well-being of older adults. Using the same paradigm, Fung, Carstensen, and Lutz (1999) replicated these age differences in social preferences among Hong Kong Chinese, and Fung et al. (2001) further replicated these age differences among Taiwanese Chinese and Mainland Chinese. These replications suggest that the observed age-related pattern is reliable, and is unlikely to be under the influence of other variables that differ between the cultures, such as social structure or living arrangements. Some may even conclude from these findings that the age differences in social preferences are universal.

Others go one step further and link individual-level age differences to country-level sociocultural variables. For instance, Löckenhoff et al. (2009) examined perceptions of aging across 26 cultures. They found cross-cultural similarities in many aspects of perceptions of aging, such as perceived declines in societal views of aging and perceived increases in wisdom. However, when cross-cultural differences were found, they attempted to account for the differences by examining their associations with country-level variables. For instance, the proportion of older adults, aged 65 years or older in the population was associated with more negative perceptions of societal views on aging. These attempts to link individual-level variables across age with country-level variables offer important opportunities for us to study age-related changes in the context of environmental affordances.

In order to compare across cultures, it is necessary to compile cross-national data sets. Several such data sets exist in the cross-cultural psychology, including but not limited to the World Values Survey (World Values Survey Association, 2009), the World Health Organization Quality of Life network (Molzahn, Kalfoss, Makaroff, & Skevington, 2011) and the Adolescent Personality Profiles of Cultures Project (De Fruyt, De Bolle, McCrae, Terracciano, & Costa, 2009; Löckenhoff, Terracciano, Patriciu, Eaton, & Costa, 2009). Moreover, there have been few, but important, attempts to develop parallel data sets across countries. For example, the national survey of Midlife Development in the United States (MIDUS), which aimed at investigating the age-related changes in health status and psychological well-being from mid-life onward, was originally conducted among Americans. In order to make cross-cultural comparisons, a parallel study was carried out in Japan (MIDJA). Using data from MIDUS and MIDJA, several interesting findings have been observed. For instance, Karasawa et al. (2011) compared age differences in psychological well-being among middle-aged and older Japanese and Americans. They found that older Japanese perceived a greater level of personal growth than did their middle-aged counterparts, whereas a reversed pattern was found in American samples.

In addition, many countries have their own national survey on aging, including but not limited to Australia (Cubit & Meyer, 2011), Canada (Sheets & Gallagher, 2013), China (Zhang, Guo, & Zheng, 2012) and Japan (Muramatsu & Akiyama, 2011). All of these surveys measured age, health status, socioeconomic status and psychological status, providing opportunities for comparisons across these cultures. Regretfully, other measures were not parallel. Nevertheless, they are efforts in the right direction. As the importance of cross-country surveys becomes better known, hopefully more efforts will be made in future to develop parallel surveys in aging across cultures.

Although even less well known, there have been attempts to combine behavioral data with genetic data to examine the differences in expression of genes (known as epigenetics) across different environmental contexts. Such gene–environment interaction may reveal the contextual factors that can facilitate or inhibit the behavioral expression of a particular genetic predisposition. These studies have started to gain popularity in cross-cultural psychology. For instance, Cheon, Livingston, Hong, and Chiao (in press) studied the moderating role of 5-HTTLPR in the relationship between perceived outgroup threat and intergroup bias. Although this specific study only included college students, it is a promising future direction for the field of cross-cultural aging. Despite philosophical debates on whether genes differ by ethnicity and/or culture, it is plausible, at least theoretically, to argue that cultures, as prototypical examples of environmental contexts, may interact with age to determine the expression of genes. In fact, in biological aging, there have already been studies on how aging may be associated with highly defined epigenetic changes in the human epidermis (Raddatz et al., 2013). It probably will not be long before we start to examine how age-related epigenetic changes may be moderated by culture-specific environmental contexts.

SUMMARY, CAVEATS, AND CONCLUSION

In this chapter, we first reviewed empirical findings suggesting that socioemotional aging, at least in the areas of personality, social relationships, and cognition, may not manifest in exactly the same way across cultures. Moreover, when cultural differences in aging occur, they are usually consistent with known cultural differences in values. These findings inspire us to argue that socioemotional development across adulthood may be part of a lifelong process: individuals in each culture learn to be more culturally appropriate as they grow older. Cultural differences in aging (i.e., age by culture interactions) occur when people from different cultural contexts learn different ways to become culturally appropriate. Next, we reviewed two other approaches of studying cross-cultural aging. The first approach examines cultural differences across age and pays particular attention to whether such cultural differences diminish or magnify with age. The second approach tests the generalizability of aging phenomena across cultures and examines their associations with genetic predisposition or country-level variables.

We acknowledge that due to the limited number of studies on the intersection between aging and culture, much empirical evidence we have cited is based on cross-sectional studies, conducted in only a couple of cultures. Longitudinal studies on a wider range of cultures are needed. From the life course perspective (see Alwin, 2012, for a review), both place (in this case, culture) and time (in this case, age as well as cohort) contribute to human development. The cross-sectional findings should be interpreted with caution as age differences can reflect cohort effects and/or developmental changes. Nevertheless, since cohort effects tend to vary with culture, reviewing whether the patterns of age differences are the same or different across cultures can help to partially isolate developmental changes from culture-related cohort effects.

Moreover, despite the preliminary nature of the evidence reviewed above, it suggests a promising direction for future research: aging does differ across cultures, particularly in terms of personality, social relationships, and social cognition. These cultural differences can be predicted. It may be fruitful to look for cultural differences in aging (i.e., culture by age interactions) in areas where known cultural differences in values (i.e., culture main effects) exist. In addition, drawing parallels between cultural differences and age differences in areas such as cognition may allow us to better understand the mechanisms underlying both. It will also be promising to compile cross-national data sets to examine the associations between age-related individual differences and macro-level differences across cultures. Last but not least, studying cultures as environmental contexts that may moderate the expression of genes with age is likely to be a hot topic for future research.

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CHAPTER

18

Work, Retirement and Aging

Mo Wang[1] and Junqi Shi[2]

[1]Department of Management, Warrington College of Business Administration, University of Florida, Gainesville, FL, USA [2]Department of Management, Lingnan (University) College, Sun Yat-sen University, Guangzhou, China

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In this chapter, we discuss how the aging process is intertwined with two important aspects of life experiences: work and retirement. Following Hulin (2002), we define work as paid employment activities. It is well-recognized that work provides many things and meanings to our life, including income, security and autonomy, identity and self-esteem, relationships outside of the family, opportunities to develop skills and creativity, and a structure to everyday life (Hulin, 2002). Further, following Shultz and Wang (2011), we define retirement as an individual's exit from the workforce, which accompanies decreased psychological commitment to and behavioral withdrawal from work. This definition is consistent with the argument made by life stage developmental theories that retirement is a life stage that not only corresponds to decreased levels of physical activities and productivities, but also involves lowered stress and less responsibility to others in day-to-day life (Levinson & Levinson, 1996; Super, 1990). As such, one's aging process often coincides with the transition from work to retirement.

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Demographic projections have shown that by 2050, more than 20% of the total US population will be age 65 or older, up from 13% in 2010, which is likely to lead to a sizable increase in the number of people who will transit from work to retirement in the next four decades (Vincent & Velkoff, 2010). This demographic change pattern is also demonstrated and projected by data from other countries and regions (e.g., the European Union, Japan, China, and India; Tyers & Shi, 2007), reflecting the fact that the population as a whole is getting older due to several factors, such as the aging of the large Baby Boom Generation, lower birth rates, and longer life expectancies (Wheaton & Crimmins, 2013). Therefore, workforce aging and retirement have become important research topics in psychology, gerontology, sociology, economics, and business management (Wang & Shi, 2014; Wang & Shultz, 2010).

This chapter is organized in the following ways. We first discuss how individuals' aging experiences may be shaped by the work context. In particular, we focus on examining the relationship between work and cognitive aging, the employee–organization relationship (EOR) for aging workers, aging in the context of human resource management (HRM), and aging and work family issues. We then discuss the issues associated with individuals' transition from work to retirement. Specifically, we review the temporal process model of retirement (Shultz & Wang, 2011; Wang & Shi, 2014) to depict the process through which workers transit from work to retirement. We also review research on major retirement outcomes, including financial well-being, physical well-being, and psychological well-being. We conclude this chapter by pointing to some general future research directions.

AGING IN THE WORK CONTEXT

Work may be one of the most important social contexts for individuals who enter their adulthood and remain so until they fully exit from the workforce (Hulin, 2002; Wang, Olson, & Shultz, 2013). Research has consistently shown that work and organizations play important roles in shaping people's cognitive functioning (Schooler, Mulatu, & Oates, 2004), knowledge and skills (Goldstein & Ford, 2002), values and motivations (Ostroff, Kinicki, & Muhammad, 2012), emotional experiences (Wang, Liao, Zhan, & Shi, 2011; Wang, Liu, Liao, Gong, Kammeyer-Mueller, & Shi, 2013), and social relationships (Ferrin, Dirks, & Shah, 2006). Therefore, in this section, we examine how work context may shape individuals' aging experience in four aspects. First, we focus on how work itself may shape cognitive functioning during the aging process. In particular, we review evidence related to the use-it-or-lose-it hypothesis (Denney, 1984; Salthouse, 2006) that links work activities to individuals' cognitive development. Second, we examine how EOR may evolve for older workers and may influence their retirement-related decisions. Third, we examine how organization's HRM practices may influence aging individuals' experience at work. Given that HRM practices often lead to financial and motivational consequences for employees and are likely to trigger the sense making process of employees, it is important to understand the impact of HRM practices on older workers (Wang et al., 2013). Finally, older workers may also experience unique challenges and opportunities in managing the interface between their work and family roles (Allen & Shockley, 2012). As such, we examine how these challenges and opportunities may shape workers' aging experience.

Work and Cognitive Aging

As Bowen, Noack, and Staudinger (2011) pointed out, when studying the effect of work on cognitive development, much research has focused on the association between the degree of cognitive stimulation at work and concurrent or later patterns of cognitive functioning. The main guiding theoretical perspective for this research topic is the use-it-or-lose-it hypothesis (Denney, 1984). This hypothesis argues that changes in cognitive functioning, especially aging-related reduction in cognitive capacities, are in part due to the disuse of certain skills and abilities and the lack of cognitive challenges throughout one's adulthood and old age. This is because exposure to complex cognitive challenges can stimulate beneficial changes in the brain (e.g., the generation of new dendritic branches and more synapses; van Praag, Kempermann, & Gage, 2000), which may create more cognitive repertoire and enhance the brain's ability to compensate for age-related reduction in cognition.

Longitudinal research has largely supported the use-it-or-lose-it hypothesis in the work context. For example, Schooler et al. (2004) demonstrated that the self-directedness of work (measured as a combination of job complexity, routinization, and the closeness of supervision) affected workers' intellectual functioning 20 years later in a stronger degree than intellectual functioning affected self-directedness, after controlling for the effects of age, gender, race, and education. Further, using data from a large sample of World War II veterans, Potter, Helms, and Plassman (2007) found that intellectual demands and human interaction at work were positively associated with cognitive functioning, after controlling for early adulthood intelligence, age, and education. They also found that individuals with lower levels of initial intelligence in young adulthood benefitted more from intellectually demanding work than those with higher levels of initial intelligence. These findings are consistent with findings from the longitudinal Maastricht Aging Study (Bosma et al., 2003), which showed that older people with mentally demanding jobs had lower risks of developing cognitive impairment 3 years later, after controlling for the baseline intellectual abilities as well as a number of individual differences (e.g., age, gender, education, family history of dementia, etc.). Finally, a population-based study of Swedish twins (Andel et al., 2005) found that the work complexity of an individual's predominant life-time occupation was negatively associated with the incidence of dementia and Alzheimer's disease.

Another set of evidence for the use-it-or-lose-it hypothesis in the work context comes from research that investigates retirement's effect on older adults' cognitive functioning. For example, Schaie (2005) found that workers with more complex and less routine jobs suffered a greater cognitive decline following retirement than those with less complex, more routine jobs. Similarly, Finkel, Andel, Gatz, and Pedersen (2009) found that following retirement, individuals previously holding jobs with high complexity of work exhibited faster rate of decline in their spatial ability than those previously holding jobs with low complexity of work. Finally, Rohwedder and Willis (2010) found that retirement, defined by "not working for pay," was associated with decreased memory as measured by word recall. Given that retirement has conventionally been viewed as indicating lack of work activities (cf. Wang & Shi, 2014; Wang & Shultz, 2010), these patterns seem to suggest that complex working tasks and challenging day-to-day work activities may help protect one's cognitive functioning from aging-related reduction, supporting the use-it-or-lose-it hypothesis.

EOR for Aging Workers

Although the focus of previous research on EOR has varied, a common theme that emerges is that EOR has been conceptualized as a resource exchange state between the organization and the employee (Shore, Coyle-Shapiro, & Tetrick, 2012). Specifically, when the organization hires an employee, a sequence of beneficial exchanges initiates between the organization and the employee (Wang et al., 2013; Wang &

Zhan, 2012). The typical benefits employees receive from their organizations may include economic/material benefits, informational benefits, time benefits, and socioemotional benefits. The typical benefits organizations may receive from their employees include productivity, organizational citizenship behaviors, and loyalty (Cropanzano & Mitchell, 2005; Tsui, Pearce, Porter, & Tripoli, 1997). These beneficial exchanges evolve to create feelings of mutual obligation between the exchange partners and lead them to develop trust that beneficial treatment will continue to be reciprocated by the exchange partner (Cropanzano & Mitchell, 2005). In addition, these beneficial exchanges are governed by the norm of reciprocity, which refers to the norm that the bestowing of a benefit creates an obligation to reciprocate in social exchange (Gouldner, 1960). Therefore, employees generally feel obligated to respond equitably to treatments from their organizations and expect reciprocation to their contributions to the organization.

Although it appears that each employee's perception of EOR is largely determined by the organizational treatment that he or she receives, it is important to recognize that depending on the unique things that are valued by different employees (e.g., younger vs. older employees), the same organizational treatment may lead to different perceptions of EOR for different employees (Wang et al., 2013). Therefore, older workers' retirement-related decisions may be a unique type of reciprocation triggered by their perceptions of EOR. For example, although poor perception of EOR may lead to workers' withdrawal intention from the organization, such withdrawal intention may translate into job search and turnover decisions for younger workers, but retirement decisions for older workers. In other words, poor EOR could trigger older workers to engage in the gradual process of exiting the workforce (Shultz & Wang, 2011; Wang & Shultz, 2010). In particular, once older workers perceive their organizations to be less supportive, less willing to provide discretionary benefits to them, and even discriminating against older workers, they will be more likely to withdraw from the organizations in the form of retirement as reciprocating to organizations' withdrawing resources from them (Wang et al., 2013).

Further, it is important to recognize that older workers who perceive high levels of EOR may expect better treatment from organizations when they approach retirement age. For example, older workers tend to compare their working status with their expected post-retirement life in planning their retirement decisions (Wang & Shultz, 2010). On the one hand, they value their work role identity; on the other hand, they expect less demands and more personal time during retirement. As such, older workers with higher levels of EOR may be more likely to expect a better supportive system from their organizations, such as flexible work schedule and respect for older workers. Therefore, positive EOR may encourage older workers to continue working in their organizations by satisfying the older workers' expectation of reduced work commitment without losing their work role identity (Wang et al., 2013). Similarly, Zappala, Depolo, Fraccaroli, Guglielmi, and Sarchielli (2008) have also shown that older workers tended to retire late if the management team in their company displayed special attention to maintain the employability of older workers and the supervisors took into account their age, health, and capacity when assigning tasks and conducting evaluations.

It is necessary to point out that the relationship between EOR and retirement intention and decision is not exclusively negative. The impact of EOR on retirement intention/decision may vary due to the different strategic goals adopted by organizations. In particular, positive EOR may lead to an increased rather than decreased tendency to retire if organizations strategically encourage employees' retirement

(Wang & Zhan, 2012). With a higher level of EOR, older workers may also tend to expect a satisfying retirement package and healthcare package from their organizations. Therefore, a pleasant retirement process may occur for older workers retiring from organizations with which they have positive EOR. Below, we continue our discussion on workers' aging experience by focusing on HRM as a relevant aspect of the work context.

Aging in the Context of HRM

Researchers have argued that a firm's HR practices need to not only match the strategy and environment constraints, but also meet the needs of different groups of employees (Lepak & Snell, 2002; Tsui et al., 1997). For example, younger workers will have different needs compared to older workers. Therefore, differentiated systems of HR practices are needed to address both the needs of various constituents within the organization and the contingencies posed by the organization's strategy and environment (Wang et al., 2013).

Given these distinctions, a different attitude toward older workers could be expected by virtue of the organization's strategy and supporting culture of HRM. For example, according to Porter's (1985) categorization of business strategies, under an innovation/differentiation strategy (i.e., basing the business growth on high levels of employee creativity, long-term focus, greater willingness to take risks, and high tolerance for ambiguity and unpredictability), the organization may wish to design HR practices that will retain the knowledgeable employees to the organization for longer periods of time and take advantage of their willingness to take risks. Under a cost leadership strategy (i.e., basing the business growth on managing predictable and repetitive behaviors of employees), the organization's culture of stability and low risk-taking might best be supported by HR practices that minimize risk of turnover for mid-aged workers while encouraging an earlier retirement date for older workers to limit the cost. Therefore, when matching HR practices to any of these business strategies, it is important for an organization to understand its anticipated human capital (e.g., skills and knowledge) need relative to future corporate objectives and anticipatory changes in the business environment (Sackett & Laczo, 2003, Chapter 2). After such workforce planning goals are clarified, various HR practices can be adopted to support the future growing anticipations of the company. The HR practices that are most relevant to older workers include employee benefits, knowledge transfer strategy, motivation and performance management, and retention and recruitment (Wang et al., 2013).

Employee Benefits

Organizations typically offer benefits to their employees for three purposes: (i) to meet their goals for corporate social responsibility, (ii) to attract and retain workers, and (iii) to increase productivity and foster positive work-related attitudes among employees. As such, practices on employee benefits are important ways for an organization to carry out its HR strategy. From the standpoint of older workers, the two most important categories of employee benefits are likely to be health care benefit and retirement benefit (Wang et al., 2013). With physical aging, health care is an important factor to consider for older workers, especially given the recent rapid increase in health care cost. However, employers are often not required by law to provide health insurance coverage for their employees or their retirees. Therefore, the decision by an employer to offer health care benefits and the manner in which they are offered are based on a number of firm strategic goal-related factors. At the most basic level, employers provide benefits to align older workers' behaviors and attitudes with organizational strategy before they retire and to a certain degree offset the financial burden that is due to the health care cost incurred by the employees, and sometimes their families (especially for those single-earner families with kids). Employers may also provide health care benefits to their employees after they retire to offer some security and continuance, which is also beneficial for maintaining the tie between the retirees and the company. It is important to point out that regardless of the employer intention to provide health care benefits, older workers typically benefit from this HR practice in terms of both the health care quality and financial subsidy (Wang et al., 2013).

However, these goals for providing health care benefits do not always coincide with one another. For example, an organization may want to foster long-term relationships with their older employees by demonstrating legitimate concerns for their long-term welfare even after retirement. Retiree health benefits would seem to be one mechanism to accomplish this strategic goal. However, these types of benefits are costly and the research suggests that older employees are as much as 21% more likely to retire if they have access to retiree health benefits (Robinson & Clark, 2010). The same is true for the case of early retirement. For example, Strumpf (2009) showed that a retiree health insurance offer may increase the probability of early retirement by over one-third for both men and women. Thus, rather than encouraging longer tenure, this type of health benefit practice might actually encourage older workers to retire if its costs can be justified for that purpose.

Another type of employee benefit that is important to older workers is retirement benefit. The main way in which organizations help workers with their retirement preparation is through the provision of retirement-related financial benefits, in the form of funding defined benefit (DB) plans or defined contribution (DC) plans (Wang et al., 2013). The DB plans specify a particular benefit payout level once the employee retires. Under the typical payout rules, the largest payouts occur for those who have remained with a single employer for a long period of time and have their highest earnings with that employer. Therefore, for organizations offering DB plans, it is most likely to translate into high retention rates among mid-aged workers, while pushing workers to consider retirement when they are eligible for social security payment. The latter is particularly likely to be the case if the sum of the social security income and the income from the DB plans is close to or equal to the salary income coming from full-time working.

In DC plans the amount of payout upon retirement is not specified but an amount of investment contribution from the organization is. The payout at retirement is based on how well the investment account has performed. DC plans are portable; employees may transfer their account into other retirement accounts when they leave an organization. For older workers who enrolled in the DC plans, they will be less mindful about their retirement benefits when they consider alternative jobs. However, due to the market risk, older workers may have to postpone their retirement in adverse economic situations because of their loss in the retirement investment in the DC plans. This may also be an important factor to drive older workers to continue working, as it is difficult to be sure whether there will be sufficient market stability in their retirement years so that their investment in the DC plans can provide them with a sustainable stream of income.

Knowledge Transfer Strategy

With older workers approaching retirement age, one important issue faced by organizations is the potential loss of accumulated knowledge (Wang & Shultz, 2010). In order to retain the accumulated knowledge of its retiring employees, organizations need to implement a knowledge transfer strategy to identify and transfer valuable knowledge so that it can be used by others to achieve organizational objectives (Slagter, 2007). Key elements of the knowledge transfer process aimed at older workers include facilitating an organizational culture that supports knowledge transfer and developing and deploying specific tools needed to achieve knowledge transfer. This culture may be manifested by: (i) valuing employees nearing retirement for what they know, (ii) creating mutual respect and trust among the parties to the process, and (iii) an emphasis on learning and development (Slagter, 2007). HRM practices such as reward and recognition programs can facilitate the development of such a culture. In most cases, these cultural elements are effective in facilitating older workers to transfer their knowledge to a younger generation of workers (Stevens, 2010).

Establishing an effective knowledge transfer strategy has important implications for enhancing older workers' experience in organizations. Specifically, such strategy encourages and values knowledge-seeking on the part of the younger workers and knowledge-sharing on the part of older workers who are in their mid and late careers. In addition, the supportive knowledge transfer culture can also facilitate the fulfillment of the generative motivation for older workers and make them feel valued by the organization and their younger colleagues. In turn, older workers may be willing to remain in the organization longer and find their work to be more meaningful and significant, or once retired, more willing to return to their organization to serve in a mentoring role (Madvig & Shultz, 2008).

Motivation and Performance Management

A firm's motivation and performance management strategy may also impact older workers' aging experience at work. While there is little empirical evidence to suggest motivation and performance necessarily decline with age, there is growing evidence that there is something unique about motivating older workers (Kanfer & Ackerman, 2004; Ng & Feldman, 2010; Zhan, Wang, & Yao, 2013). Techniques that work on younger workers may not be effective on older workers nearing retirement. For example, Warr (1997, 2001) argued that older workers' job preferences are more likely to include things like security (physical, job, financial) and opportunities to utilize their skills rather than high job demands, job variety, and feedback. Thus, as workers age, organizations may find that they are not motivated by the same things as in the past. This suggests that the reward structure may need to be realigned with older workers' needs and desires. For example, Claes and Heymans (2008) conducted focus group sessions with HR managers and identified three sources of motivation that might be particularly important for older workers. First, HR managers indicated that older workers attached more importance to having contact with their superiors, a relationship with the business owner, and having opportunities to take on responsibility and consequently were more motivated when these conditions were met. Second, HR managers suggested that older workers were more motivated when they were given clear goals that were challenging and time-related. Third, HR managers observed that older workers were highly motivated by the opportunities to mentor others, pass along their knowledge, and recognition for their efforts.

Given that few empirical studies have been conducted in evaluating effective HR practices that are designed to manage older workers' work motivation, it is still unclear how workers' aging experience may be shaped in this arena. Nevertheless, to match motivation practices with the organization's strategy, it is important to understand the source of low motivation among older workers (Wang et al., 2013). Further, whether the organization wishes to encourage older workers to retire or wishes to extend older workers' value in the workplace is important. As with other HR practices discussed earlier, a company concerned about cost containment may wish to encourage retirement of older, more expensive workers. These organizations could adopt more age-based policies and practices that establish an implied retirement age and climate. In particular, they may offer early retirement, create benefits for retired employees, or designate an age for phased retirement eligibility. On the other hand, an organization that focuses on quality of service, product, or processes may wish to extend the work life of older, knowledgeable workers for as long as possible. HR policies and practices that accommodate older workers' changing physical and cognitive challenges (e.g., job redesign, ergonomic changes, job reassignment, and career development) should increase work motivation for older workers. Accommodating older workers' changing preferences for leisure and work may also encourage them to stay in the workplace longer, albeit with reduced hours but perhaps with sustained motivation.

Finally, it is important to recognize that organizations are often not active in managing older workers' motivation and performance due to age-related stereotypes (Posthuma & Campion, 2009). Organizational leaders may hold negative biases about older workers because they see them as either: (i) not having the necessary skills and most current technical knowledge, or (ii) not willing/able to learn new skills that are required to complete their work and perform at the same level as their younger counterparts (Cappelli & Novelli, 2010). These biases against older workers are often linked to a lack of understanding of the talents that older workers bring to their work roles coupled with management/human resource practices that reinforce these biases (i.e., giving training opportunities predominantly to younger workers so that we invest in our future, older people will retire sooner and we will not receive a payback on the training investment). While it may be true that some older workers do not want to work the same number of hours, and they may not have the same goals and aspirations as they did earlier in their careers, there are also many younger workers who do not want to work longer hours and do not aspire to higher-level positions either.

Retention and Recruitment

Retention refers to the set of HR practices aimed at retaining workers in the organization. Different workers may have the intention to leave the organizations for different reasons. Identifying these reasons and providing solutions that could address the worker's concerns are important challenges to an organization's HR system in terms of its flexibility and its adherence to the organization's business strategy. For example, an older worker may decide to leave the organization due to elder care needs. In that case, accommodating the employee with flexible work schedules may successfully address the problem without significantly losing the productivity (Matz-Costa & Pitt-Catsouphes, 2010). On the other hand, an employee who is approaching retirement may be retained to work on a part-time basis. This may involve the use of phased retirement (i.e., the continuing employment of current employees at a reduced workload until full retirement) and contingent work arrangements (i.e., rehiring retired workers as independent contractors or as "temporary" workers through staffing effort; Shultz, 2003). In addition, one recent study found that HR practices such as training and development targeting older workers was positively related to perceptions of organizational support, which was, in turn, related to intention to remain with one's employer (Armstrong-Stassen & Ursel, 2009).

When considering finding the talent from the external labor force that is accessible to an organization, the key HR practice is recruitment. Recruitment is the process of attracting potential employees to apply for open positions in an organization. In one national study of 578 organizations, approximately 62% had taken steps to recruit an age-diverse workforce (Pitts-Catsouphes, Matz-Costa, & Besen, 2009). Several typical HR practices used to recruit older workers and retirees include: (i) flexible work options, (ii) training and development opportunities, (iii) new, challenging, and meaningful work assignments, (iv) improved compensation, (v) unbiased feedback and performance evaluation, and (vi) giving recognition and respect (Armstrong-Stassen, 2008a, 2008b). Further, in order to be effective in recruitment these types of practices have to be communicated in a manner that signals to retirees that the organization values their contributions (Rau & Adams, 2005; Wang et al., 2013).

It is important to recognize that both retention and recruitment practices targeted at older workers can be challenging to implement for organizational reasons as well as legal and regulatory reasons. Many of the suggestions for both retention and recruiting rely on the notion of creating part-time work (reduced responsibility, fewer hours per day, fewer days per week, seasonal employment) and creating contingent work arrangements. While these are attractive to older workers, part-time work is not the most optimal configuration for all jobs (Wang et al., 2013). In addition, organizations might have legitimate concerns about the job performance of some of its employees. In this case, certain retirements, like other types of turnover, may be very functional.

Aging and Work–Family Issues

Workers do not live in a social vacuum. In addition to their work roles, they also have important family roles in life. Previous research has shown that having to manage multiple roles associated with work and family domains has both positive and negative implications (Allen & Shockley, 2012). Work–family conflict (WFC) occurs when the pressures associated with work versus family roles are incompatible. Conflict can arise in two different directions, from work to family (work interference with family [WIF]) and from family to work (family interference with work [FIW]) (Greenhaus & Allen 2011). Compared to FIW, WIF is more common among employees. Research has shown that expectations linked with work and family roles can lead to employee physical and psychological strain in two ways (Allen & Shockley, 2012). First, the demands of multiple roles can lead to an overall increase in workload. Second, suppositions surrounding either of these roles can arouse pressures that command the time of an individual and disrupt the expectations associated with the performance of the other role.

On the other hand, balancing between demands from work and family can have positive implications. The role enhancement perspective suggests that fulfilling role demands from one domain can lead to positive outcomes in the other, which is characterized by work–family enhancement (WFE) (Greenhaus & Allen, 2011). Specifically, work enhancement of family (WEF) occurs when benefits are derived from work and applied to the family domain. For example, employees may apply new communication skills learned from work to facilitate their communications at home. In addition, family enhancement of work (FEW) describes the instances where benefits from the family are applied to work. For example, providing care to an important elder and knowing that they are in good hands, could help an individual focus more on their work.

Because of their position in the lifespan, older workers may experience unique challenges and opportunities associated with managing their work and family roles. In terms of challenges, first, older workers are likely to have the responsibility of caring for aging parents, commonly referred to as eldercare. Eldercare represents a unique challenge for older workers because research suggests that caring for aging parents can be more stressful than caring for children. Eldercare may not be anticipated, and unlike childcare responsibilities, eldercare tends to become more onerous over time and ultimately ends in the death of the care receiver (Kossek, Colquitt, & Noe, 2001). Home- or family-based care makes one less able to separate from the care recipients' deterioration and emotional or health problems, which may add to the caregivers' distress. This is especially true when the care receiver is approaching death. The caregiver may experience increased depression and WFC, and lower well-being. Ultimately, their performance for work and family roles may suffer. For example, primary caregivers for an aging parent are more likely to take unpaid leaves from work, reduce their work hours, and rearrange their work schedules (Kossek et al., 2001). In addition, those who spend more time caring for their aging parents tend to have more work interruptions such as telephone calls related to their care responsibilities. As such, they are likely to experience higher levels of FIW (Gottlieb, Kelloway, & Fraboni, 1994).

A second challenge faced by older workers is the requirement to simultaneously manage eldercare and childcare responsibilities with work role demands. These individuals are referred to as sandwiched caregivers, who care for both adults and children at the same time. Providing care for parents and children at the same time may represent a qualitatively different experience compared to providing care to either group alone. Research suggests that the breadth (i.e., the number of caregiving roles one holds) of caregiving, rather than the depth (i.e., the intensity of the caregiving requirements), is what increases distress (Gerstel & Gallagher, 1993). The result of multiple caregiving roles can be a competition for the caregiver's time, energy, and resources, which can lead to distress for the caregiver. Increased responsibilities from multiple caregiving roles among older adults have been shown to lead to decreased physical and mental health over time (Haug, Ford, Stange, Noelker, & Gaines, 1999).

In terms of opportunities, older workers may develop positive, meaningful relationships with their care recipients, which may lead to FEW through transfer of positive affect and other resources (Greenhaus & Allen, 2011). Older female employees' positive work experiences have also been shown to offset the negative stress associated with simultaneous caregiving, demonstrated WEF. Thus, having high-quality role experiences at work and family may represent a unique opportunity for older workers to balance the rewards and stress associated with managing multiple role demands (Martire & Stephens, 2003). In addition, holding multiple roles across different domains (e.g., as employees, spouses, parents, etc.) helps older workers validate their self and gain esteem through enacting meaning, guidance, direction, and purpose through their roles (Greenfield & Marks, 2004). This suggests that older workers may uniquely benefit from successful management of work and family roles, and experience higher levels of WFE.

A number of organizational practices have been designed to assist employees to manage work–family issues, some of which may be particularly beneficial for older workers. First, flexible work arrangements regarding schedule and location, such as flexitime, a compressed work-week, and telecommuting, have been implemented to reduce time-based WFC. These arrangements are highly effective, being cited by employed parents as the most important family-friendly benefits offered by organizations (Baltes, Briggs, Huff, Wright, & Neuman, 1999). These flexible arrangements have also been shown to be positively related to productivity, job satisfaction, and work schedule satisfaction, and negatively related to absenteeism (Allen & Shockley, 2012).

Second, organizations may provide dependent care to help meet employees' caregiving needs. Dependent care may take in the form of on-site day care, on-site care for sick children, off-site day care, an in-home nurse for care of dependents, or special care services such as elder care. Traditionally, such benefits have focused on providing care for young children. Increasingly, organizations have started to provide support for caring for older parents (Mesmer-Magnus & Viswesvaran, 2006). Adequate dependent care was strongly linked to reports of lower WFC. As older employees have increased caregiving responsibilities for their aging parents, provision of dependent care by the organization may be particularly beneficial for older workers.

THE TRANSITION FROM WORK TO RETIREMENT: THE TEMPORAL PROCESS AND OUTCOMES

Having discussed how work context may shape individuals' aging experiences, we now shift our attention to how individuals may transit out of the workforce and enter retirement. In particular, we review the temporal process model of retirement (Shultz & Wang, 2011; Wang & Shi, 2014) to provide a heuristic description of the process through which workers transit from work to retirement. In addition, we review major outcomes associated with retirement, including financial well-being, physical well-being, and psychological well-being in retirement.

The Temporal Process Model of Retirement

The temporal process model of retirement suggests that the process for one to transit from work to retirement usually consists of three broad and sequential phases: retirement planning, retirement decision making, and retirement transition and adjustment (Shultz & Wang, 2011; Wang & Shi, 2014). Specifically, the process starts with a distal preretirement preparation and planning phase (i.e., retirement planning) where individuals begin to envision what their retirement might entail and begin discussing those plans with friends, family members, and colleagues. Through this process, retirement planning helps to generate more accurate expectations for retirement life as well as mobilizing and organizing resources to serve the needs in the coming retirement (Taylor & Schaffer, 2013). In particular, Taylor-Carter, Cook, and Weinberg (1997) categorize retirement planning into financial and cognitive planning. The goal of financial planning is to find a balance between revenue income and revenue expenditure that allows the individual to maintain a desired lifestyle in retirement. Given that there often are social security and employer-provided pension funds for retirees to some degree, the focus of financial planning for retirement is on private savings (Hershey, Jacobs-Lawson, & Austin, 2013). Regarding cognitive planning for retirement, according to Adams and Rau (2011), the goal is to address four key questions: What will I do? How will I afford it? Where will I live? Who will I share it with? Answering these questions requires the individual to gather large amounts of information about the current situation (e.g., amount of current funds or current state of health) as well as to use cognitive skills to make predictions about possible futures (e.g., community involvement or working state of a spouse; Leung & Earl, 2012; Wang, 2007). Previous research has demonstrated that retirement planning in both financial and cognitive ways is crucial for structure, social interaction, and maintaining a standard of living into retirement (Taylor & Schaffer, 2013).

Next, as retirement gets closer, one enters the retirement decision-making phase. During this phase, one has to weigh the values of work and leisure over time against individual circumstances to make the retirement decision (Shultz & Wang, 2011; Wang & Shi, 2014). Some researchers have attempted to specify the retirement decision-making phase into smaller stages. One line of this research focuses on the ways that capture the thought-change process concerning retirement decision making. In particular, Feldman and Beehr (2011) categorize the retirement decision-making phase into three stages: imagining the possibility, assessing when it is time to let go of the job, and putting concrete plans into action at present. These three stages characterize a cognitive process that first brainstorms possible futures, then considers the past experiences at work, and finally uses the compiled information to take steps toward retirement in the present (Feldman & Beehr, 2011). Another line of research decomposes the phase of the retirement decision making in terms of the decision elements. Specifically, Jex and Grosch (2013) separate the content of the retirement decision into three key elements: the decision to audit and gather resources needed for retirement, the decision to actually retire, and the decision to choose the form that retirement will take. For example, people can engage in intense retirement planning without actually deciding when to retire. There also exists a distinction between the retirement forms of complete withdrawal from the workforce and continuing to work in another capacity (e.g., working for reduced hours or reduced physical load; Jex & Grosch, 2013).

Sometimes the individual may also be faced with the decision of whether to retire early. Early retirement has been defined as exiting the workforce before an individual is eligible for receiving social security benefit and/or pension (Damman, Henkens, & Kalmijn, 2011; Feldman, 1994). As such, in the United States, early retirement is usually operationalized as retiring before age 62 (i.e., the earliest one can start receiving social security benefit). Recently, Feldman (2013) argued that one's status of early retirement is at least partly subjective as well. In other words, whether a person retires early also depends on whether the retirement happens at an age that is younger than one's expected retirement age (Potocnik, Tordera, & Peiro, 2010; Wang, 2007). This subjective component for defining early retirement has become more and more prominent, given that continuous technology advancement and health care improvement have allowed people to work longer, even after they take early retirement incentives (Kim & Feldman, 2000). This subjective definition also emphasizes the role of perceived person–environment (P–E) fit in making early retirement decisions, as people who perceive poor P–E fit with their work are more likely to exit the workforce early (Feldman, 2013; Herrbach, Mignonac, Vandenberghe, & Negrini, 2009).

Finally, as individuals make the transition from full-time worker to retiree, they enter the phase of retirement transition and adjustment. The most prominent component of this adjustment process involves daily activity changes. Retirees have many options for how to spend their time after entering retirement, including leisure activities, volunteer work, and various forms of paid work (Adams & Rau, 2011). Among them, leisure activities are characterized by enjoyment, novelty, relaxation, companionship, aesthetic appreciation and intimacy, including talking to or visiting friends and family, involvement in clubs and organizations, religious activity, physical activity such as exercise and sports, and hobby activity such as gardening, arts, and crafts (Nimrod, Janke, & Kleiber, 2009). Volunteer work can involve housework and caring for one's family members as well as formally volunteering outside the home in business and civic organizations (Dosman, Fast, Chapman, & Keating, 2006).

After entering retirement, one may continue with some paid work. This type of work activity is referred to as bridge employment, which is defined as the pattern of labor force participation exhibited by older workers as they leave their career jobs and move toward complete labor force withdrawal (Feldman, 1994; Shultz, 2003; Wang, Adams, Beehr, & Shultz, 2009). Recent studies have documented the high prevalence of engagement in bridge employment among retirees in the United States. For example, Brown, Aumann, Pitt-Catsouphes, Galinsky, and Bond (2010) showed that over 20% of workers age 50 and older who reported themselves as being retired were also working for pay at the same time, which suggests a much higher prevalence rate for retirees to take at least one bridge job before completely exiting the labor force. They also found that 75% of workers aged 50 and older expect to have a paid job during retirement. Similarly, Giandrea, Cahill, and Quinn (2009) using the Health and Retirement Study (HRS) data from 1998 through 2006 found that among those aged 51–56 in 1998, 64% moved to a bridge job prior to exiting the labor force completely. This labor force transition pattern is corroborated by Wang and Chan's (2011) finding from analyzing the HRS data with mixed latent Markov modeling technique. Cahill, Giandrea, and Quinn (2013) have noted that many financial factors could motivate an individual to seek further work after retirement, such as an increasing age to qualify for social security benefits, a decline of traditional DB plans in favor of DC plans (like 401ks), and improved labor market earnings. Individuals may also try to mitigate and adapt to the lifestyle change in retirement by continuing workforce participation (Wang & Shultz, 2010).

Bridge employment can take many different forms. When the work hours in bridge employment are reduced compared to the preretirement job, the bridge job operates in the form of phased retirement, which has been shown to help retirees to ease into their retirement (Wang et al., 2009). From the organizational perspective, one can continue working for one's preretirement employer or for a different employer either full-time or part-time when entering retirement (Jones & McIntosh, 2010; Zhan et al., 2013). From the career perspective, bridge employment can also take two forms: career bridge employment, in which the individual works in the same industry or field as the individual's career job, and bridge employment in a different field (Feldman, 1994; Shultz, 2003; Wang, Zhan, Liu, & Shultz, 2008). Previous research suggests that a psychological attachment to the career and incentives given by companies to keep their skilled labor force make it likely for an individual to keep working in the form of career bridge employment, whereas a need to change working conditions contributes to bridge employment in a different field (Wang et al., 2008). Nevertheless, both forms of bridge employment can also be the result of lack of retirement planning (Wang et al., 2008).

Using the temporal process model to describe and understand the transition from work to retirement allows researchers to investigate retirement as it unfolds over time from one phase to another (Wang & Shi, 2014). The general unfolding sequence established by this model helps researchers to further examine the interdependence among these retirement phases (e.g., how these stages influence one another and how they together influence the long-term adjustment outcomes of retirement; Shultz & Wang, 2011). However, it is important to note that this temporal process is not homogeneous across individuals. Within the broad phases are smaller and shorter segments that individuals go through as they approach retirement, transition through the retirement decision–making process, and begin life as a self-designated retiree. In addition, this process is unlikely to go smoothly for all retirees. Some older individuals enter retirement experiencing ambivalence, anxiety, fear, depression, and a deep feeling of loss. As research summarized by Brown, Fukunaga, Umemoto, and Wicker (1996) and O'Rand (2003) shows, disabled individuals, individuals from traditionally disadvantaged race and ethnic groups, those from lower social classes, undocumented immigrants, the economically needy, individuals who have never worked, and the chronically unemployed will approach the retirement planning, decision-making, and transition and adjustment processes with vastly different experiences and perspectives. Thus, this temporal process model of retirement reinforces the need to examine the unique psychological dynamics that each individual faces as they transition through their own retirement process (Wang & Shi, 2014).

Outcomes of Retirement

In this section, we review major outcomes associated with retirement. These outcomes include financial well-being, physical well-being, and psychological well-being in retirement, which are often studied as indicators of adjustment to retirement life (Wang & Shi, 2014). However, it is important to recognize that retirement as a single life event is rarely the cause of these outcomes. Rather, as suggested by the resource-based dynamic model for retirement adjustment (Wang, Henkens, & van Solinge, 2011), it is the resource-related factors or changes associated with the retirement process that are driving these outcomes. As such, following Wang and Shi (2014), our discussion here also emphasizes various factors embedded in the retirement process that may influence these outcomes.

Financial well-being. A retiree's financial well-being can be defined as the extent to which the person feels satisfied with his/her financial status and is able to maintain effective financial functioning (e.g., receive stable income that will fully cover his/her expenses; Wang, 2012). Among various individual attributes that influence financial well-being in retirement, financial literacy is the one that receives the most attention. Dozens of investigations have been carried out on financial literacy during the past two decades, which have revealed that the extent and veracity of one's domain-specific knowledge in finance is related to financial well-being after retirement (for a review, see Lusardi, 2011). Another important individual attribute that influences financial well-being in retirement is how clear a person is regarding his/her financial goals after retirement. The clarity of one's financial goals has been shown to predict perceived financial preparedness for and financial well-being in retirement (Noone, Stephens, & Alpass, 2010; Stawski, Hershey, & Jacobs-Lawson, 2007).

Not surprisingly, engagement in pre-retirement financial planning has been repeatedly documented to lead to better financial well-being in retirement. Specifically, financial planning is associated with increased saving for retirement, improved budgeting, and established long-term investment plans (Hershey, Henkens, & Van Dalen, 2007). Further, people who received additional financial incentives to retire (e.g., taking early retirement incentives or redundancy packages) are often more likely to be financially better off when entering retirement (Quick & Moen, 1998). In contrast, unemployment right before retirement may pose a risk to retirees' financial well-being because it is often harder for older adults to find jobs that offer the amount of salary that is comparable to what they had before they were laid off (Pinquart & Schindler, 2007). Therefore, they may have to dip into their savings before entering retirement, which creates financial pressure later in retirement.

The number of dependents and costs related to dependent care often jeopardize people's financial well-being in retirement. The more dependents the retiree has and the more cost incurred due to the dependent(s), the more likely financial well-being in retirement will suffer (Marshall, Clarke, & Ballantyne, 2001). Further, for retirees who are in poor financial situations, working after retirement often provides additional income for their retirement, thus easing their financial difficulty (Quinn, 2010). However, it is also known that retirees often seek bridge employment opportunities because of financial hardship (Cahill et al., 2013). Therefore, the causal relationship between bridge employment and financial well-being is unclear.

Physical well-being. Following the contemporary wellness perspective adopted by the public health literature, a retiree's physical well-being can be defined as the extent to which there is absence of physical diseases (e.g., heart disease and cancer) and functional limitations (e.g., the lack of capability to handle daily life and engage in social activities; Jex Wang, & Zarubin, 2007; Zhan, Wang, Liu, & Shultz, 2009). It is not surprising that retirees' pre-retirement health status is most predictive of their physical well-being in retirement (Zhan et al., 2009). This is consistent with the notion that genetic and allostatic factors (i.e., the accumulated cost for our body to adapt to the changing social and physical environments in which we live) are the dominant causes for major diseases (Wang & Shultz, 2010). Further, healthy behaviors and habits, such as exercise, healthy diet, absence of drug and alcohol dependence, and hygiene are important for maintaining physical well-being in retirement as well (Wang, 2012).

Job-related physical demands have been documented as a factor related to physical well-being in retirement. People who retire from highly demanding physical jobs are more likely to experience worse cardiovascular health when they enter retirement, although over time it may improve (Wang, 2012). People's health insurances in retirement are also related to their physical well-being. Retirees typically enjoy better physical well-being when their health insurances offer more extensive service coverage and incur lower out-of-pocket costs (Stanton, 2006). In addition, retirees with better-quality and consistency of health care are also more likely to have better physical well-being in retirement (Singh, 2006).

Among post-retirement activities, research has unequivocally shown that retirees who engaged in bridge employment and voluntary work had fewer major diseases and functional limitations than retirees who chose full retirement (Cahill et al., 2013; Dave, Rashad, & Spasojevic, 2008). In fact, it has been found that engaging in bridge employment showed no differential effects on individuals' physical well-being as compared to continuing work without official retirement (Zhan et al, 2009). This suggests that it is the level of physical and/or cognitive activities in working behaviors that help to maintain retirees' physical health.

Psychosocial well-being. A retiree's psychological well-being can be defined as the extent to which the person is generally content with his/her psychological states and enjoys effective psychological functioning (Wang, 2012). Using the nationally representative longitudinal data from the US HRS and growth mixture modeling technique, Wang (2007) was able to demonstrate that over an 8-year period of retirement transition and adjustment process, about 70% of retirees experienced minimum psychological well-being changes; about 25% of retirees experienced negative changes in psychological well-being during the initial transition stage, but showed improvements afterwards; and about 5% of retirees experienced positive changes in psychological well-being. These findings were further corroborated by Pinquart and Schindler (2007), who used a nationally representative sample of German retirees from the German Socioeconomic Panel Study. Specifically, Pinquart and Schindler (2007) found that during retirement transition and adjustment, about 75% of German retirees experienced trivial changes in life satisfaction; about 9% of German retirees experienced significant decrease in their life satisfaction during the initial transition stage, but continued on a stable or increasing life satisfaction thereafter; and about 15% of German retirees experienced significant increase in their life satisfaction. Although the proportion estimates for subpopulations were not entirely the same across American and German retirees, both studies support the multiple-pathway nature of retirement transition and adjustment, suggesting that retirees' psychological well-being does not follow a uniform transition and adjustment pattern.

Retirees' work role identity has been shown to be negatively related to retirees' psychological well-being (Quick & Moen, 1998; Reitzes & Mutran, 2004). In particular, retirees who strongly identify themselves to their work roles are often more likely to experience decreases in psychological well-being when entering retirement. Further, people who retire from jobs that involve high levels of work stress, psychological and physical demands, job challenges, and job dissatisfaction are more likely to enter retirement with low levels of psychological well-being (Quick & Moen, 1998; van Solinge & Henkens, 2008; Wang, 2007). Finally, people who experienced unemployment right before retirement are also more likely to enter retirement with low levels of psychological well-being (Marshall et al., 2001; Pinquart & Schindler, 2007).

Among retirement transition-related factors, the voluntariness of the retirement (Reitzes & Mutran, 2004; van Solinge & Henkens, 2007) and retirement planning (Petkoska & Earl, 2009; Reitzes & Mutran, 2004; Wang, 2007) have been shown to be positively related to retirees' psychological well-being. People who retire earlier than expected or planned are more likely to experience decreased psychological well-being entering retirement (Quick & Moen, 1998; Wang, 2007). Further, people who retire for health reasons are more likely to experience decreased psychological well-being, whereas those who retire to become engaged in leisure or other non-work-related activities and those who receive financial incentives or redundancy payouts are more likely to experience better psychological well-being in retirement (Quick & Moen, 1998).

Among post-retirement activities, bridge employment (Kim & Feldman, 2000; Wang, 2007; Zhan et al., 2009), volunteer work (Dorfman & Douglas, 2005; Kim & Feldman, 2000), and leisure activities (Dorfman & Douglas, 2005) are all beneficial to retirees' psychological well-being. Further, when retirees work for generative reasons (i.e., working for teaching and sharing knowledge with the younger generation), they are more likely to experience improved psychological well-being (Dendinger, Adams, & Jacobson, 2005). Finally, retirees' anxiety associated with maintaining their social status and contacts via social activities was negatively related to retirement satisfaction (van Solinge & Henkens, 2007, 2008).

Finally, it is important to recognize that retirees' financial, physical, and psychological well-being have an important influence on their longevity and mortality (Tsai, Wendt, Doonelly, de Jong, & Ahmed, 2005). They also influence retirees' work-related behaviors. For example, Wang et al. (2008) found that: (i) retirees who had better physical health and experienced less psychological stress were more likely to engage in career bridge employment than full retirement; (ii) retirees who had better physical health and financial conditions were more likely to engage in bridge employment in a different field than full retirement; and (iii) retirees who had better financial conditions and experienced less psychological stress were more likely to engage in career bridge employment than bridge employment in a different field.

CONCLUSIONS AND FUTURE DIRECTIONS

In this chapter, we have reviewed how people's aging experiences are intertwined with their experiences at work and in retirement. It is clear that different aspects of work, such as the work tasks and the organization's practices, can have a profound impact on aging workers. Moreover, maintaining a positive relationship with the employer and successfully balancing the work and family demands are also essential to ensure one's productivity and work motivation in older ages. Further, with the aging of

America and many other countries, perhaps the largest proportion of our society will soon be classified as retired. This is one of the fundamental driving forces for studying retirement as an institutional and society-wide phenomenon. Accordingly, we have reviewed the transition process from work to retirement, as well as important retirement outcomes in this chapter.

Moving forward, we offer two general future research directions for readers to consider. First, the research on work, retirement, and aging phenomena is multidisciplinary in nature, involving research fields such as economics, policy studies, gerontology, sociology, psychology, public health, and management (Wang & Shultz, 2010). Although this multidisciplinary nature inspires diverse ideas and approaches for studying these phenomena, such advantages cannot be fully realized if the multiple disciplines are not communicating with each other. For example, different disciplines may use different terminologies for describing the same essential constructs. This has the danger of leading scholars in different disciplines to rediscover the same basic phenomena over and over, resulting in great concept redundancy. Further, lack of communication regarding different practices in research methods across disciplines may also create unwarranted bias toward the findings generated by a certain research methodology. For example, qualitative research methods have often been viewed as too subjective and less scientific in terms of informing cause–effect conclusions. However, if used rigorously and correctly, qualitative research methods can complement quantitative research methods and offer numerous strengths for constructing theories and hypotheses. As such, it is important for researchers from different disciplines to clearly communicate with each other on the reasons and philosophy behind their methodological choices in studying work, retirement, and aging-related phenomena. This way, knowledge generated from certain methodological traditions will not go overlooked by the field. It will also be easier to facilitate overall knowledge accumulation in the field.

Second, there is still a great need to accumulate causal knowledge in this research field. On the one hand, to solve real-world problems, work- and retirement-related interventions, practices, and policy decisions at individual, organizational, and societal levels all have to rely on causal knowledge. On the other hand, it is extremely difficult for us to isolate aging, work, and retirement processes from their contexts and study them with experimental design. For example, it is quite impossible for us to manipulate people's ages or retirement statuses and rely on random assignment to remove alternative explanations for interpreting research findings. Thus, we need to invest much more effort when it comes to designing studies in this field and conducting data analysis. In particular, the vast majority of previous studies in this field have relied on cross-sectional designs (Wang & Shultz, 2010; Wang et al., 2011). Although cross-sectional designs may be useful in establishing correlations between variables, it is difficult to make sound causal inferences based on such findings. To understand the causal processes, we will also need to understand the time sequence of the changes in variables as well as rule out alternatives. Accordingly, research in this field should use more longitudinal designs to provide more information for understanding the causal processes. For example, in order to improve the internal validity of the research, we can assess the time-lagged effect between predictors and outcomes while controlling for the baseline of the outcome variables (Hanges & Wang, 2012). We can also rule out the possibility of reversed causality by directly test it. Another advantage for using longitudinal designs is that it provides an examination of within-individual change trends in variables, which reveals how time influences variables of interest (Wang, 2007).

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CHAPTER

19

Financial Decision-Making and Capacity in Older Adults

Daniel C. Marson[1,2], *Deborah L. Kerr*[1,3], *and Donald G. McLaren*[4]

[1]Department of Neurology, University of Alabama at Birmingham, AL, USA [2]University of Alabama at Birmingham Alzheimer's Disease Center, Birmingham, AL, USA [3]Department of Psychiatry and Behavioral Neurobiology, University of Alabama at Birmingham, AL, USA [4]Department of Neurology, Massachusetts General Hospital, Boston, MA, USA and Harvard Medical School, Boston, MA, USA

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INTRODUCTION: WHAT IS FINANCIAL CAPACITY? LEGAL, CLINICAL AND ETHICAL PERSPECTIVES

Financial capacity is a medical–legal construct that represents the ability independently to manage one's own financial affairs in a manner consistent with personal self-interest and values (Marson & Hebert, 2008; Marson, Triebel, & Knight, 2012). Financial capacity thus involves not only performance skills (e.g., counting coins/currency accurately, completing a check register accurately, paying bills) but also judgment skills that optimize financial self-interest, and values that guide personal financial choices. Financial experience and skills can vary widely among cognitively normal adults and are associated with factors such as education, occupational attainment, and socioeconomic status (American Bar Association & American Psychological Association [ABA/APA] Assessment of Capacity in Older Adults Project Working Group, 2008; Marson et al., 2012).

From a legal standpoint, financial capacity represents the financial skills necessary for handling a person's financial affairs and estate, and is the basis for determinations of conservatorship of the estate (or guardianship of the estate, depending on the state legal jurisdiction). Broadly construed, financial capacity also conceptually encompasses more specific legal capacities such as contractual capacity, donative capacity, and testamentary capacity. Thus, financial capacity is an important area of property rights in the civil legal system (ABA/APA Assessment of Capacity in Older Adults Project Working Group, 2008; Marson & Hebert, 2008), and one that psychologists and other clinicians are increasingly called upon to evaluate in forensic settings (Marson, 2002; Marson et al., 2012; Widera, Steenpass, Marson, & Sudore, 2011).

Historically, the legal standard for financial capacity in conservatorship statutes was generally (and vaguely) cast as the capacity to manage "in a reasonable manner all of one's financial affairs" (ABA/APA Assessment of Capacity in Older Adults Project Working Group, 2008). A more modern and specific standard is set forth in Section 410(2) of the Uniform Guardianship and Protective Proceedings Act (UGPPA), which states that a court may appoint a conservator if the court determines that "the individual is unable to manage property and business affairs because of an impairment in the ability to receive and evaluate information or make decisions, even with the use of appropriate technological assistance; and the individual has property that will be wasted or dissipated unless management is provided, or funds are needed for the support of the individual or of others entitled to the individual's support" (UGPPA, 1997; see also ABA/APA Assessment of Capacity in Older Adults Project Working Group, 2008; Marson, 2001; Marson, Hebert, & Solomon, 2011; Marson et al., 2000). This is a two-pronged legal definition for conservatorship that requires not only impairment of financial skills, but also property and/or individuals at risk due to this impairment.

From a clinical standpoint, financial capacity is a cognitively complex instrumental activity of daily life (IADL) that is vulnerable to neurological, psychiatric, and medical conditions that affect cognition such as dementia, stroke, traumatic brain injury (TBI), and schizophrenia (Marson et al., 2012). In particular, clinical issues of financial capacity arise frequently in the context of older adults with cognitive decline and dementia. Family members of such older adults often raise concerns about an elderly person's new problems managing household finances, making poor financial decisions, or being financially exploited. Clinicians are increasingly being asked by families, physicians, clinicians, attorneys, and judges to evaluate and offer clinical opinions regarding the financial capacity of older adults (ABA/APA Assessment of Capacity in Older Adults Project Working Group, 2008; Marson & Hebert, 2008; Widera et al., 2011). These decisions can be highly charged given the psychological importance of managing one's own funds. Along with driving and mobility, financial capacity is a core aspect of individual autonomy in our society (Marson, 2001; Marson et al., 2000, 2011, 2012).

In contrast, despite its importance, bioethicists have given relatively little attention to financial capacity and the issues that it raises for younger and older adults, their families, and for clinicians and other professionals (Marson, 2013). This is somewhat surprising, insofar as considerable energy in bioethics has been devoted in recent years to issues of treatment consent capacity and research consent capacity in older individuals with dementia, schizophrenia, and other severe neuropsychiatric disorders (Appelbaum & Grisso, 1995; Dunn & Jeste, 2003; National Bioethics Advisory Commission, 1998; Roberts, Warner, Anderson, Smithpeter, & Rogers, 2004; Roberts et al., 2003; Stroup & Appelbaum, 2003). However, the bioethics and clinical literature has been largely silent concerning financial capacity (Marson, Savage, & Phillips, 2006). As trenchantly noted by Frank and Degan, "the literature of law and psychiatry is unaccountably mute on the subject of patients' competence to handle money" (Frank & Degan, 1997; Marson et al., 2006).

This silence signals a key knowledge gap for bioethics, insofar as financial capacity, like other decisional capacities, implicates core issues of personal autonomy in adults (Moye, 1996). Financial capacity is critical to, and possibly the single best litmus for, a person's ability to function independently in the community (Melton, Petrila, Poythress, & Slobogin, 1987). When financial capacity issues go unresolved, patients are at risk for significant financial losses that can jeopardize their living situation, estate planning, long-term care, and ultimately personal autonomy (Faulk, 2011). Loss of financial capacity also makes patients vulnerable to exploitation and abuse by others (Rosenzweig, 2011), and thus can present challenging situations for clinicians who may be morally and legally responsible to report such abuse (Widera et al., 2011). This is particularly true in cases where caregivers and family members are suspected of financially exploiting the older person. Thus loss of financial capacity presents ethical, as well as clinical and legal, issues for psychologists and other health care professionals treating adults with cognitive decline and psychiatric illness (Marson, 2013).

In this chapter, we examine issues related to financial decision-making and capacity of older adults in our aging society. Specifically, we discuss the crucial phenomenon of cognitive aging and diminished financial capacity, the impact on financial capacity of cognitive disorders of aging such as Alzheimer's disease (AD), and the early warning signs of diminished financial capacity in older adults. We then present a clinical model of financial capacity that has proven useful as a means of articulating the financial capacity construct. Using the clinical model as a guide, we briefly describe different approaches to assessing financial capacity and then examine empirical research on financial capacity in older adults, with a particular focus on patients with cognitive disorders: mild cognitive impairment (MCI) and AD. This chapter concludes with sections addressing exciting new neuroimaging investigations of financial decision-making and capacity, the importance of psychiatric and other non-cognitive contributions to financial capacity in the elderly, and directions for future research in financial capacity.

THE FINANCIAL CAPACITY PROBLEM: COGNITIVE AGING AND DISORDERS OF AGING

Although financial capacity is an IADL essential for all community-dwelling adults, it is a topic with particularly important implications and urgency for older adults: there is a tremendous and underappreciated "financial capacity problem" posed by our rapidly growing older adult population. Older adults represent that portion of the US population most vulnerable to impairment and loss of financial skills and capacity, as a result of the effects not only of AD, Parkinson's disease, and related dementias, but also of normal cognitive aging (Marson & Sabatino, 2012).

Normal cognitive aging has been defined by Salthouse and colleagues as "…the decrease in performance on various measures of cognitive functioning associated with increasing age in the adult portion of the lifespan" (Salthouse, 1991). Multiple cognitive abilities are affected in normal aging, with different trajectories of decline over time, including auditory and visual perception, divided attention, working memory and processing speed, episodic memory, executive and planning skills, numeracy and arithmetic skills, and "fluid intelligence" (Glisky, 2007; Salthouse, 1991). These normative cognitive declines in aging impact a range of financial skills, including attention to and recollection of investment details, appraisal of risk, comprehension of investment alternatives, and overall financial decision-making capacity (Laibson, 2011). Laibson and colleagues have suggested that age 53 is the time point in the human lifespan at which financial decision-making acumen reaches its apogee, with gradual diminution of financial abilities and increasing financial errors occurring from that point onward (Agarwal, Driscoll, Gabaix, & Laibson, 2009).

In addition to normal cognitive aging, older adults as an age group are also highly vulnerable to neurodegenerative diseases like AD and other cognitive disorders of aging, which can devastate financial decision-making and capacity (Marson et al., 2000, 2009). As discussed in more detail below, an increasing number of studies have documented substantial impairments of financial skills in patients with AD (Marson et al., 2000) and with Parkinson's disease dementia (Martin et al., 2013), as well as early but already salient financial impairments in prodromal cognitive states (e.g., MCI) associated with these dementias (Griffith et al., 2003; Martin et al., 2013; Triebel et al., 2009). Thus older adults are uniquely vulnerable over time to diminished or impaired financial capacity, due to cognitive declines associated with both normal cognitive aging and with cognitive disorders of aging.

The onset of this cognitive decline also comes at a point in the lifespan in which older adults have accumulated substantial personal wealth and hold a disproportionate amount of wealth relative to other age groups (Marson & Sabatino, 2012). In the United States, older adults ages 65 and older currently comprise only 13% of the population (Amercian Psychological Association, 2011) and 21.4% of family households (Laibson, 2011; Pilson, 2011), but hold 34% of the nation's wealth (Laibson, 2011; Pilson, 2011). This combination of wealth, cognitive decline, and diminished financial capacity represents a tremendous and growing economic and public policy challenge to our society. Given that overall household wealth in the United States in 2009 was estimated at $53.1 trillion, the amount of wealth currently held in older adult households amounts to a staggering $18.1 trillion (Laibson, 2011). This may be referred to as the "$18.1 trillion dollar problem"—the fact that the disproportionate wealth of the older adult age group is at increasing risk due to this age group's unique situation of declining cognitive abilities and associated vulnerability to diminished financial capacity and to financial exploitation.

With the continued aging of our society, and the "silver tsunami," as coined by Dr. Alireza Atri, of Alzheimer's and related dementias mounting over the next few decades (estimated at over 14 million persons in the United States by 2050), both this percentage of households and overall older adult wealth will only increase, and issues of financial capacity in elders will become ever more prevalent and urgent.

CLINICAL WARNING SIGNS OF DIMINISHED FINANCIAL CAPACITY

Impairment and loss of financial capacity has important economic and psychological consequences for older adults and their families. Impaired individuals are at risk for making decisions that jeopardize assets needed for their own long-term care, or that are intended for testamentary distribution to family members (Marson et al., 2000; Triebel & Marson, 2012). People with diminished financial capacity are also at risk for financial exploitation (Marson et al., 2000; Nerenberg, 1996; Widera et al., 2011), including consumer fraud and other financial scams (Marson et al., 2000; "Woman Out $5,300 in Two Cons", 1996). Accordingly, early detection of impaired financial skills and prompt intervention are essential for protecting the economic resources and emotional wellbeing of impaired individuals and their families (Marson et al., 2000). Warning signs of declining financial capacity may be subtle at first, and family members may be slow or unwilling to recognize them. And, because of the loss of self-awareness and insight associated with AD, many individuals with late MCI or early AD do not recognize these financial declines in themselves (Okonkwo et al., 2008; Triebel & Marson, 2012; Wadley, Harrell, & Marson, 2003).

In addressing specific clinical warning signs, it is important to consider a person's prior level of financial functioning and experience. A "warning sign" of financial decline inherently implies a change from a prior level of performance. Individual financial experiences can vary widely because of educational, socioeconomic, occupational, and other factors. For example, take an elderly lady who in the past was very skilled, meticulous, and detail-oriented regarding her finances, but who now forgets to pay bills on time and who increasingly must rely on others to make financial decisions for her. There has been a clear departure from the elderly lady's premorbid level of financial functioning or baseline. Contrast this situation to that of an elderly man who throughout his life has never been skilled with money and in fact has had a lifelong pattern of mismanaging his finances. The latter individual's current financial problems are simply the newest iteration of his ongoing problem of managing money, and thus do not represent a "warning sign" of change in his financial capacity (Triebel & Marson, 2012).

Our group has identified six clinical warning signs of diminished financial capacity, based on our aggregated clinical and research experience with cognitively impaired older adults (Triebel & Marson, 2012). As discussed above, to be true warning signs, the following behaviors should reflect clear declines from an individual's prior baseline level of financial functioning:

- *Memory lapses*: Increasing memory lapses resulting in errors and failure to fulfill financial obligations (failing to pay bills, paying the same one several times)
- *Disorganization*: Increasing disorganization and misplacement of financial and other documents at home, with associated failures such as missing tax and other deadlines
- *Declines in checkbook management skills*: Changes in a person's ability to use a checkbook and check register to carry out everyday transactions
- *Arithmetic mistakes*: Noticeable declines in everyday math skills, such as those employed when making change to pay for things at the store, or when computing an appropriate tip in a restaurant
- *Conceptual confusion*: Increasing confusion and loss of general knowledge regarding basic financial terms and concepts such as mortgage, will, or annuity
- *Impaired judgment*: Loss of judgment about financial investments and use of money, often manifested as a new and abiding interest in get-rich-quick schemes, as well as unfounded anxiety about the nature and extent of one's personal wealth.

Once financial warning signs are detected, families must act promptly and have "the conversation" with the older individual, in order to protect the vulnerable elderly person's financial assets and prevent possible future financial catastrophe (Siegel-Bernard, 2010). At the same time, this conversation and the steps taken by family members need to be carefully considered and implemented in light of the individual and family dynamics involved (Triebel & Marson, 2012).

CHALLENGES IN MODELING FINANCIAL CAPACITY

Since Lawton's seminal 1969 paper on IADLs (Lawton & Brody, 1969), it is striking how little conceptual and definitional work has been conducted in the area of financial capacity. Early work in the area of IADLs offered only very elementary and unsatisfactory schema such as "financial management skills," without providing needed conceptual structure or detail. This theoretical vacuum has to some degree persisted to the present day, as surprisingly few clinical definitions or models of financial capacity exist. In part this vacuum relates to the fact that financial capacity is a complex, multidimensional construct (Marson et al., 2012). It comprises a broad range of conceptual, pragmatic, and judgment abilities, used on an ongoing, daily basis across a range of everyday settings, that are critical to the independent functioning of adults in our society (Marson, 2001; Marson et al., 2000, 2011). Studies have suggested that financial capacity is an "advanced" or instrumental activity of daily living (IADL) (Marson et al., 2000; Wolinsky & Johnson, 1991). Advanced ADLs are mediated by higher cognitive functions and can be distinguished from "household" ADLs (e.g., meal preparation, shopping, housekeeping) and "basic" ADLs (e.g., bathing, dressing, walking) (Wolinsky & Johnson, 1991). Financial capacity itself entails a broad set of abilities, ranging from very basic skills of identifying and counting coins/currency, to conducting cash transactions, to higher-level abilities of managing a checkbook and a bank statement, to complex activities of making investment decisions and asset purchases. In addition, as might be expected, financial abilities can vary enormously across individuals, depending on a person's socioeconomic status, occupational attainment, and overall financial experience (Marson, 2001; Marson et al., 2000).

Financial capacity can be understood to have both a performance aspect and a judgment aspect (Marson et al., 2012). To possess financial capacity, a person must be able to perform a variety of tasks and skills in order to meet his or her needs within his/her life context. Such tasks and skills include understanding basic financial concepts, possessing basic monetary skills, carrying out cash transactions in a grocery store, and paying bills. However, in addition to such performance skills, an individual must also be able to exercise judgment and decision-making to promote his or her own financial well-being. Thus, in addition to performance skills, the individual must be able to carry out financial activities in ways that promote and protect his or her self-interest (Marson, 2001; Marson et al., 2000, 2011).

For all these reasons, financial capacity has been a complex construct to define and model clinically. No widely accepted clinical definition for financial capacity exists. Our group has proposed the following definition: "the capacity to manage money and financial assets in ways that meet a person's needs and which are consistent with his or her values and self-interest" (Marson et al., 2011; Widera et al., 2011). This working definition incorporates performance and judgment aspects characteristic of financial capacity (see above), as well as consideration of a person's longstanding financial values. It also implicitly incorporates the concept of financial decision-making and judgment as a component of overall financial capacity.

CLINICAL MODEL OF FINANCIAL CAPACITY

We present below a clinically based conceptual model of financial capacity in older adults (Marson, 2001; Marson et al., 2000; Martin et al., 2008). This model has been the basis for instrument development and for ongoing empirical studies of financial capacity in MCI, AD, and other clinical populations such as TBI (Dreer, DeVivo, Novack, & Marson, 2012; Marson, 2001; Marson et al., 2000, 2011; Martin et al., 2013), which are discussed in a subsequent section of this chapter.

Because financial capacity represents a broad continuum of activities and specific skills, it may be best conceptualized as a series of domains of activity, with each having specific clinical relevance (Griffith et al., 2003; Marson, 2001; Marson et al., 2000). Examples of these domains include: basic monetary skills, carrying out cash transactions, managing a checkbook, managing a bank statement, exercising financial judgment and avoiding scams, and making investment decisions. This domain-based approach is clinically oriented and is consistent with the presumed multidimensionality of financial capacity and its variability across individuals. It is also consistent with the legal principle of limited financial competency adopted within most state legal jurisdictions, which recognizes that an individual may be competent to carry out some financial activities and not others (Grisso, 1986; Marson, 2001; Marson et al., 2000, 2011).

In addition to domains of activity, this model identifies specific financial abilities, or tasks (Marson, 2001; Marson et al., 2000). Tasks reflect discrete financial skills that when combined together comprise domain-level capacities. For example, the domain of "financial conceptual knowledge" might draw upon specific abilities, such as understanding simple concepts (e.g., a loan or savings) and pragmatically applying such concepts in everyday life (e.g., selecting interest rates, identifying a medical deductible, or making simple tax computations). The domain of financial judgment might consist of tasks related to detection/awareness of financial fraud, or of creating a balanced household budget. Therefore, tasks represent abilities that when combined together constitute broader, clinically relevant domains of financial activity. In our model we have defined tasks as being simple or complex, depending on the level of cognitive resources they appear to require (Marson, 2001; Marson et al., 2000, 2011).

The model also considers financial capacity at the global level (Griffith et al., 2003; Marson, 2001). Capacity, or competency as referenced in the legal sphere, is ultimately an overall categorical judgment or classification made by a clinician or legal professional. Thus, the clinical model has three levels (Griffith et al., 2003): (i) general domains of financial activity, which are each clinically relevant to the independent functioning of community-dwelling older adults; (ii) specific financial abilities or tasks, each of which is relevant to a particular domain of financial activity; (iii) overall financial capacity, which reflects a global estimate of capacity based on overall domain- and task-level performance. A recent revised version of the model, presented in Table 19.1, is composed of nine domains, 18 tasks, and two global levels (Griffith et al., 2003; Marson, 2001; Marson et al., 2000, 2011; Martin et al., 2008). This model has been the basis for financial capacity instrument development, including the Financial Capacity Instrument (FCI), which is discussed later in this chapter.

APPROACHES TO ASSESSING FINANCIAL CAPACITY

Regardless of the assessment approach, the goal of a financial capacity assessment is to evaluate a patient's current financial functioning in reference both to the patient's current environmental demands and his/her premorbid financial experience and abilities. At least three different measurement approaches exist for clinically assessing financial capacity (Marson et al., 2011). These approaches are: (i) patient and informant-based ratings and reports of financial skills, (ii) direct assessment of financial skills using performance-based instruments, and (iii) clinical interview approaches that involve clinician interviewing to obtain information about a patient's financial skills and functioning. A patient and informant-based report of everyday financial functioning in community settings can be gathered through written questionnaire or rating forms. Performance-based instruments provide a direct and quantitative assessment of specific financial skills that are norm referenced and usually more finely grained than rating forms. Clinical interviews combine the strengths of both informant rating/report and direct performance approaches, by drawing upon the interviewing skills of a clinician who can also choose to use various direct assessment techniques to examine financial skills. In the sections below, we provide an overview of the three assessment approaches and highlight examples of instruments developed for each approach. However, before doing so, we first address the key conceptual issue of assessing premorbid financial capacity.

Assessing Premorbid Financial Capacity

As noted above, the financial experience and skills of individuals vary widely, based on educational, occupational, socioeconomic status, and other factors. Thus, when conducting a financial capacity evaluation, one of the clinician's first objectives is to estimate a patient's premorbid financial experience and ability levels. Using this information, the clinician can form an impression of premorbid function against which current financial activities and performance levels can be measured and compared. In addition, information on premorbid financial function can inform the areas of evaluation and test measures used. For example, if a patient has never used a checkbook/register to pay bills, but instead has used only money orders or cash, it would be inappropriate to assess his/her checkbook management abilities and conclude that impaired performance

TABLE 19.1 Clinical Conceptual Model of Financial Capacity: 9 Domains, 18 Tasks, 2 Global Scores

Domain/Task	Description	Difficulty
DOMAIN 1	***BASIC MONETARY SKILLS***	
Task 1a Naming coins/currency	Identify specific coins and currency	Simple
Task 1b Coin/currency relationships	Indicate relative monetary values of coins/currency	Simple
Task 1c Counting coins/currency	Accurately count groups of coins and currency	Simple
DOMAIN 2	***FINANCIAL CONCEPTUAL KNOWLEDGE***	
Task 2a Define financial concepts	Define a variety of financial concepts	Complex
Task 2b Apply financial concepts	Practical application/computation using concepts	Complex
DOMAIN 3	***CASH TRANSACTIONS***	
Task 3a 1 item grocery purchase	Enter into simulated 1 item transaction; verify change	Simple
Task 3b 3 item grocery purchase	Enter into simulated 3 item transaction; verify change	Complex
Task 3c Change/vending machine	Obtain change for vending machine use; verify change	Complex
Task 3d Tipping	Understand tipping convention; calculate/identify tips	Complex
DOMAIN 4	***CHECKBOOK MANAGEMENT***	
Task 4a Understand checkbook	Identify and explain parts of check and check register	Simple
Task 4b Use checkbook/register	Enter into simulated transaction; pay by check	Complex
DOMAIN 5	***BANK STATEMENT MANAGEMENT***	
Task 5a Understand bank statement	Identify and explain parts of a bank statement	Complex
Task 5b Use bank statement	Identify specific transactions on bank statement	Complex
DOMAIN 6	***FINANCIAL JUDGMENT***	
Task 6a Detect mail fraud risk	Detect and explain risks in mail fraud solicitation	Simple
Task 6c Detect telephone fraud risk	Detect and explain risks in telephone fraud solicitation	Simple
DOMAIN 7	***BILL PAYMENT***	
Task 7a Understand bills	Explain meaning and purpose of bills	Simple
Task 7b Prioritize bills	Identify bills that need immediate attention	Simple
Task 7c Prepare bills for mailing	Prepare simulated bills, checks, envelopes for mailing	Complex
DOMAIN 8	***KNOWLEDGE OF ASSETS/ESTATE***	
	Indicate/verify asset ownership, estate arrangements	Simple
DOMAIN 9	***INVESTMENT DECISION MAKING***	
	Understand investment options/returns; make decisions	Complex
Global 1 Domains 1–7	Overall performance across domains 1–7 and tasks	
Global 2 Domains 1–7 + 9	Overall performance across domains 1–7 + 9 and tasks	

Adapted from and reprinted with permission from Griffith et al. (2003), permission from the American Academy of Neurology.

necessarily is the product of a mental disorder or illness. Instead, the examiner should inquire as to whether the individual has previously used a checkbook, and if not, what other forms of payment have been used, such as money orders or cash—and tailor the evaluation tasks accordingly. The ultimate goal for the clinician is to form a clear picture of the patient's premorbid level of financial functioning in order to select appropriate assessment measures and to draw meaningful conclusions regarding the patient's overall current financial capacity in relation to his/her living circumstances and associated environmental demands.

Self and Informant-Based Assessment

The self and informant report approach to financial assessment involves gathering data about a person's real-life financial functioning through self-report, collateral report, or both. Ideally, the informant can provide information about a person's prior optimal levels of financial skill, how financial functioning may have changed over time, as well as about current financial activities and skills. The primary advantages of self and informant report are the potential ecological validity of the information received and the relative ease of administration and minimal cost of obtaining such functional information. In current clinical practice and research settings, most information regarding financial functioning is derived from patient and collateral report, whether obtained during a standard clinical interview or through a questionnaire/report form.

Detailed questionnaires of financial functioning are not widely available. Most functional inventories assess a broad spectrum of basic and advanced activities of daily living, and include only a very limited review of financial abilities. One of the earliest functional report forms was the Lawton & Brody Instrumental Activities of Daily Living Scale (Lawton & Brody, 1969), which included one finance item asking about the respondent's independence in financial matters such as paying bills, making purchases, or handling money. The Blessed Dementia Scale, another early survey of functional and behavior change, included just one question related to finances, "Inability to cope with small sums of money" (Blessed, Tomlinson, & Roth, 1968). The Functional Assessment Questionnaire (FAQ), a more recent clinician-administered measure, includes two financial items among its ten functional questions: "writing checks, paying bills, balancing checkbook" and "assembling tax records, business affairs, or papers" (Pfeffer, Kurosaki, Harrah, Chance, & Filos, 1982). In general, although surveys of instrumental activities of daily living frequently reference overall financial functioning, they rarely include more than one or two specific financial items. In addition, a self-report or informant questionnaire is usually not standardized or norm referenced, and thus results cannot be generalized easily across patients and settings. Finally, the questionnaire approach is further limited by patient anosognosia (a neurologically based deficit in a patient's awareness of having a neurodegenerative disorder and of its effects on their cognition and everyday functioning) and informant report biases affecting the accuracy of financial information received (Wadley et al., 2003). For example, our group found that both patients with AD and their family caregivers had difficulty making reliable estimations of patients' financial abilities. Patients with AD overestimated their financial abilities due to their increasing anosognosia, while family member estimates were more accurate but showed problems with judgment reliability over short time periods, possibly due to the stresses of caregiving (Wadley et al., 2003).

Performance-Based Assessment

Performance-based instruments directly assess functional abilities in a clinical or laboratory setting. These instruments ask individuals to perform a series of conceptual and pragmatic tasks similar or equivalent to those performed in home and community settings. Performance-based measures are standardized, quantifiable, repeatable, and norm referenced, and thus results can be generalized across patients and settings. Performance-based assessment of financial abilities may be included as part of a global functional status assessment, or financial skills may be explored alone or in greater detail with specific financial capacity instruments.

A distinct advantage of an objective performance measure is the freedom from subjective reporter bias. Performance-based instruments can provide information that is more objective and frequently more reliable than third-party observations or examinees' self-reports. Thus, a person's performance on specific financial tasks can illuminate possible concerns with the reliability of patient and informant reports, and be highly relevant to diagnostic formulations and treatment recommendations. In addition, the findings from these measures are often much more precise and granular than patient and collateral reports. For example, change over time can be evaluated with much more precision using repeated performance-based measures, and magnetic resonance imaging (MRI)-based brain metrics have recently been successfully analyzed in relation to performance-based measures of financial capacity (Griffith et al., 2010; Kerr, Bartel, McLaren, & Marson, 2014; Stoeckel et al., 2013).

There are also weaknesses to performance-based measurement of financial capacity. One issue is the requirement for a specialized measure and materials, and a trained administrator, which together make performance instruments more challenging, expensive, and time-consuming to administer. A second and key issue is ecological validity, as tasks are completed in clinical or laboratory settings and not real-world home and community settings (ABA/APA Assessment of Capacity in Older Adults Project Working Group, 2008). In general, performance-based instruments provide good evidence of adequate reliability, but there is less empirical evidence regarding the predictive validity of each scale in terms of real-world functioning (Moore, Palmer, Patterson, & Jeste, 2007). Measures conducted in a laboratory or clinical office setting cannot take into account either the contextual cues or distractions within the home environment that may assist or interfere with a person's abilities to perform everyday financial tasks. Successful performance on direct performance measure may demonstrate ability under controlled and potentially optimal conditions, but may not always accurately predict actual everyday functioning. Ultimately, it is the ability of patients to engage in self-initiated instrumental activities in home and community environments that is critical for their independence.

One example of a performance-based measure dedicated to assessment of financial capacity is the FCI (Marson et al., 2000). The FCI is a standardized psychometric measure designed specifically to assess everyday financial activities and abilities in older adults with MCI and dementia. The FCI is based on the aforementioned conceptual model that views financial capacity at three levels (Table 19.1): specific financial abilities (tasks), broader financial activities (domains) important to independent functioning, and overall financial capacity (global score) (Marson, 2001; Marson et al., 2000). The current version of the FCI (FCI-9) (Triebel et al., 2009) directly assesses financial abilities across the 18 tasks, nine domains, and two global scores of the model (Table 19.1). The FCI tasks range from testing basic skills such as naming and counting coins/currency, and making one-item grocery purchases, to more complex skills such as managing a checkbook and register, managing a bank statement, and preparing bills for mailing. The first global score measures overall performance across the first seven FCI domains: basic monetary skills, financial conceptual knowledge, cash transactions, checkbook management, bank statement management, financial judgment, and bill payment. Two additional optional domains of the FCI are knowledge of personal assets/estate arrangements, and investment decision-making. The second global score measures overall performance across domains 1–7 and domain 9 (Table 19.1).

Trained technicians administer and score the FCI, and administration time is about 50 min for cognitively normal older adults and 60+ min for patients with MCI and dementia. Scoring of task, domain, and global performance is performed according to a standardized scoring system which is norm referenced based on performance of cognitively normal older adults. The FCI has demonstrated good internal, test–retest, and inter-rater reliabilities, as well as good content and construct validity (Marson, 2001; Marson et al., 2000). The FCI has been used in a range of research studies involving older adults with MCI and AD (Griffith et al., 2003; Marson, 2001; Marson et al., 2000; Martin et al., 2008; Sherod et al., 2009; Triebel et al., 2009), Parkinson's disease (Martin et al., 2013), and more recently patients with TBI (Dreer et al., 2012; Martin et al., 2012).

Clinical Interview Assessment of Financial Capacity

As noted above, financial capacity may also be directly assessed by a clinician using a specialized clinical interview. In addition to clinical interview questions, such an interview can include the semi-structured examination of specific performance skills. However, it remains distinct from formal performance-based instruments that require standardized administration, a trained psychometrician, and more intensive materials and stimuli. Clinical interview approaches also differ in that they do not generally yield quantitative scores, but rather categorical impairment ratings reflecting the clinician's judgments regarding a patient's various skill levels (e.g., capable/intact, marginally capable/marginally impaired or incapable/impaired). Such categorical outcomes have clinical utility, as they logically connect to issues of capacity and capacity outcome, and can be more readily understood and applied by other clinicians and professionals than informant ratings or quantitative performance scores. Our group has developed a conceptually based clinical interview assessment measure called the Semi-Structured Clinical Interview for Financial Capacity (SCIFC), which has been used in MCI and AD patient research (Marson et al., 2009).

EMPIRICAL STUDIES OF FINANCIAL CAPACITY

In this section, we discuss existing empirical research studies on financial capacity in older adults. As noted until recently there were few, if any, studies in this area. As reflected below, most of the work to date has been conducted in older adults with MCI and AD (Griffith et al., 2003; Marson, 2001; Marson et al., 2000; Martin et al., 2008; Sherod et al., 2009; Triebel et al., 2009), with a few additional studies conducted in populations with Parkinson's disease (Martin et al., 2013), TBI (Dreer et al., 2012; Martin et al., 2012), and severe mental illness (Barrett et al., 2009; Patterson, Goldman, McKibbin, Hughs, & Jeste, 2001).

Financial Capacity in Patients with Mild and Moderate AD

Over the last decade or so, a number of studies using the FCI have investigated financial capacity in patients with AD (Marson, 2001; Marson et al., 2000). The original FCI (FCI-6) assessed six domains and 14 tasks (Marson et al., 2000) (the global level was introduced in later versions of the FCI). In an initial study

(Marson et al., 2000), mild AD patients on the FCI-6 performed equivalently to control subjects on the basic monetary skills domain, but significantly below cognitively normal older adults on the other five domains. Moderate AD patients performed significantly below controls and mild AD patients on all domains. On the FCI-6 tasks, mild AD patients performed equivalently to cognitively normal older adults on simple tasks such as naming coins/currency, counting coins/currency, understanding parts of a checkbook, and detecting the risk of mail fraud. Mild AD patients performed significantly below older controls on more complex tasks such as defining and applying financial concepts, obtaining change for vending machine use, using a checkbook, understanding and using a bank statement, and making an investment decision. Moderate AD patients performed significantly below cognitively normal older adults and mild AD patients on all tasks (Marson, 2001; Marson et al., 2000, 2011).

Using a cut-score method derived from performance of cognitively normal older adults (Marson, 2001; Marson et al., 2000), the quantitative performance of the AD patients was translated into categorical outcomes (capable, marginally capable, incapable) on each domain. In the context of a prototype instrument and small control sample, our group advised that these outcomes should be interpreted cautiously. However, mild AD patients demonstrated an interesting pattern of categorical impairment across the domains. Less than 30% of mild AD patients achieved "capable" outcomes on complex domains of checkbook management and bank statement management, and less than 15% were found capable on the domain of financial judgment. Moderate AD patients, in turn, demonstrated very high rates of "incapable" outcomes on all FCI domains (range 90–100%). The relationship of the AD patients' dementia level to their capacity outcomes was statistically robust for all domains (Marson et al., 2000, 2011).

To our knowledge, this was the first empirical study of financial capacity in patients with AD, and possibly the first empirical study specific to financial skills in any clinical population (Marson, 2001). The findings suggest that significant impairment of financial capacity occurs in AD, even in the mild dementia stage. Mild AD patients appear to experience significant deficits in complex financial abilities (tasks) and some level of impairment in almost all financial activities (domains). Moderate AD patients appear to experience loss of both simple and complex financial abilities and show severe impairment across all financial activities. Based on these initial findings, Marson proposed two preliminary clinical guidelines for the assessment of financial capacity in patients with mild and moderate AD (Marson et al., 2000) (p. 883):

1. *Mild AD patients are at significant risk for impairment in most financial activities, in particular complex activities like checkbook and bank statement management. Areas of preserved autonomous financial activity should be carefully evaluated and monitored.*
2. *Moderate AD patients are at great risk for loss of all financial activities. Although each AD patient must be considered individually, it is likely that most moderate AD patients will be unable to manage their financial affairs.*

Longitudinal Change in Financial Capacity in Patients with Mild AD

A longitudinal study by Martin et al. (2008) using the FCI-9 showed that financial capacity declines rapidly in patients with mild AD over a 1-year period. Financial capacity was assessed at baseline and 1-year follow-up in cognitively normal older adults and individuals with AD. Baseline results from this study replicated prior cross-sectional findings (Griffith et al., 2003;

Marson et al., 2000) and indicated that patients with mild AD exhibit widespread financial deficits relative to same-aged cognitively intact peers. At 1-year follow-up, mild AD patients exhibited marked declines in overall financial capacity and on the majority of FCI domains. In contrast, the cognitively normal older adults exhibited intact and stable FCI performance over the course of the study. Overall, the mild AD group exhibited a 10% decline in FCI score over 1 year from their original baseline performance relative to controls (Marson et al., 2011; Martin et al., 2008).

Financial Capacity in Patients with MCI

Financial capacity has also been investigated in patients with MCI. As noted above, MCI represents an intermediate and often transitional phase between normal cognitive aging and dementia (Petersen et al., 2001). In addition to focal cognitive impairment not normal for age, patients with MCI can show clear impairment in instrumental activities of daily living over time (Daly et al., 2000; Griffith et al., 2003; Marson et al., 2011; Petersen et al., 2001; Ritchie, Artero, & Touchon, 2001), although this functional impairment does not reach a level warranting a dementia diagnosis. In an initial study, financial capacity was assessed using the expanded FCI-9 in cognitively normal older adults, amnestic MCI (aMCI) patients, and mild AD patients (Griffith et al., 2003). We found that at the task level, cognitively normal older adults performed significantly better than the aMCI group on tasks of applying financial concepts, understanding and using a bank statement, understanding bills, and preparing bills for mailing. There were no tasks on which the aMCI group performed better than cognitively normal older adults. The aMCI group, in turn, demonstrated significantly higher scores than the mild AD group on tasks of understanding and applying financial concepts, using a vending machine, understanding and using a checkbook, understanding and using a bank statement, prioritizing bills, and preparing bills for mailing. As expected, cognitively normal older adults performed significantly better than the mild AD group on most financial abilities, with the exception of simple tasks of basic monetary skills, cash transactions, and telephone fraud (Griffith et al., 2003; Marson et al., 2011).

At the broader domain level, cognitively normal older adults also performed significantly better than the aMCI group on the domains of financial concepts, checkbook management, bank statement management, financial judgment, and bill payment. There were no domains on which the aMCI group performed better than cognitively normal older adults. In turn, the aMCI group performed significantly better than mild AD patients on all domains except financial judgment and knowledge of assets and estate arrangements. Cognitively normal older adults performed significantly better than mild AD subjects on all domains except knowledge of assets and estate. For global financial capacity (sum of FCI domains 1–7), cognitively normal older adults performed significantly better than both aMCI and AD participants, and aMCI participants performed significantly better than AD participants (Griffith et al., 2003).

This study represents one of the first published reports of performance-based evidence for functional decline and capacity loss in patients with aMCI. Using a direct assessment approach, patients with aMCI demonstrated significant, albeit mild, deficits on some (but not all) financial abilities compared to age, education, gender, and racially matched healthy controls. Compared to cognitively normal older adults, aMCI patients showed a negative differential of 1.74 SD units in overall financial capacity, while mild AD patients showed a negative differential of 4.52 SD units. These results indicate that initial declines in financial capacity are already present in the MCI phase prior to the development of a frank dementia (Griffith et al., 2003; Marson et al., 2011).

Financial capacity has also been shown to decline in a subset of aMCI patients who converted to AD over a 1-year period (Triebel et al., 2009). Using the FCI-9, this longitudinal study investigated FCI change in relation to MCI patients' conversion from aMCI to dementia. Performance on the FCI domains and global scores was compared within and between groups of cognitively healthy controls, MCI patients who converted to Alzheimer-type dementia (aMCI converters), and MCI patients who did not convert to dementia (aMCI non-converters). These analyses revealed significant group differences on FCI variables and also group-by-time interactions.

As shown in Table 19.2, controls at baseline performed better than MCI converters and non-converters on almost all FCI domains and on both FCI total scores, replicating prior cross-sectional findings in patients with aMCI (Griffith et al., 2003), and indicating that impairment of financial capacity in aMCI was already present prior to baseline assessment (Triebel et al., 2009). At 1-year follow-up, aMCI converters showed decline relative to controls and aMCI non-converters for checkbook management and for both FCI total scores. A strong trend emerged for bank statement management. aMCI converters showed declines in procedural skills associated with checkbook management and bank statement management, such as calculating the correct balance in a checkbook register, highly consistent with the arithmetic errors previously noted as a clinical "warning sign" of financial decline (Triebel & Marson, 2012). Interestingly, declines did not occur in the conceptual understanding of a checkbook or a bank statement. This study indicated that declining financial skills are detectable in patients with aMCI in the year prior to conversion to AD (Triebel et al., 2009).

Neuropsychological Predictors of Financial Capacity

Neuropsychological studies afford the opportunity to identify cognitive abilities that are associated with and likely driving changes in financial capacity in different neurocognitive disorders. Given the limited research on financial capacity as a construct, and limited number of available assessment instruments, there have been correspondingly few neuropsychological studies to date of financial capacity (Marson et al., 2011). A study by our group using the FCI examined cognitive predictors of financial capacity in a sample of cognitively normal older adults, patients with aMCI, and patients with mild AD (Sherod et al., 2009). The study goal was to develop and compare multivariate cognitive models of financial capacity across the continuum from normal aging to dementia. Robust cognitive models of financial capacity emerged for each of the three groups. Written arithmetic skill (WRAT-3 Arithmetic) was the primary predictor of financial capacity across all three models, accounting for 27% of variance in the older control model, 46% in the mild AD model, and 55% in the aMCI model (Sherod et al., 2009). Visuomotor tracking/executive function (Trails A/B) was a secondary cognitive predictor of financial capacity across the two patient models. Short-term verbal memory and visuomotor tracking/executive function were secondary predictors for the normal aging group. This study demonstrated that very similar neurocognitive predictor models of financial capacity exist across the dementia spectrum of normal cognitive aging, MCI, and mild AD (Sherod et al., 2009). In particular, the findings strongly implicated written arithmetic skills as a critical cognitive function subserving financial skills and capacity in normal cognitive aging, as well as in prodromal and clinical AD (Sherod et al., 2009; Mackin & Arean, 2009).

TABLE 19.2 One Year Change in FCI Domain and Global Domain Variables Across Older Control, MCI Non-Converter, and MCI Converter Groups

		Older controls		MCI non-converters		MCI converters			
		Time 1	Time 2	Time 1	Time 2	Time 1	Time 2		
	Range	*n*=76	*n*=76	*n*=62	*n*=62	*n*=25	*n*=25	Baseline[a]	Interaction[b]
D1. Basic monetary skills	0–34	32.1(2.7)	32.7(2.3)	30.6(3.8)	30.3(3.9)	29.2(4.7)	28.4(5.6)	<0.001[c]	0.064
D2. Financial concepts	0–32	29.3(2.5)	29.9(2.1)	27.9(4.0)	27.5(4.5)	24.9(5.7)	24.7(5.6)	<0.001[d]	0.174
D3. Cash transactions	0–24	21.7(2.0)	21.7(2.2)	20.5(3.0)	19.9(3.3)	18.7(4.7)	17.6(4.7)	<0.001[d]	0.134
D4. Checkbook management	0–50	48.2(2.7)	48.2(2.6)	46.9(3.6)	47.0(3.8)	44.6(6.1)	40.8(7.9)	<0.001[c]	0.001[e]
D5. Bank statement management	0–39	35.4(3.1)	34.7(3.3)	31.9(5.4)	31.6(6.0)	28.0(6.8)	24.9(9.5)	<0.001[d]	0.021
D6. Financial judgment	0–16	13.9(2.4)	14.7(1.6)	13.9(2.9)	14.1(2.9)	12.5(2.8)	12.4(3.6)	0.002[e]	0.190
D7. Bill payment	0–46	44.4(2.4)	43.9(4.0)	40.2(6.2)	41.3(6.1)	35.8(9.0)	33.5(10.6)	<0.001[d]	0.124
D9. Investment decision making	0–17	14.3(2.4)	14.5(2.4)	12.9(3.1)	12.2(3.3)	11.6(4.4)	10.5(4.4)	<0.001[c]	0.056
FCI Global (D1–7)	0–241	225.0(9.9)	225.9(1.9)	212.0(20.9)	211.5(22.2)	193.7(29.6)	182.3(39.0)	<0.001[d]	0.002[e]
FCI Global (D1 − 7 + 9)	0–258	239.3(10.9)	240.4(13.0)	224.9(22.8)	223.7(24.2)	205.3(32.4)	192.8(42.3)	<0.001[d]	0.001[e]

Adapted from and reprinted with permission from Triebel et al. (2009), the American Academy of Neurology.
Note: MANCOVA (age entered as covariate) was the statistic employed.
[a]*p value of baseline group comparison on FCI variables between controls, MCI non-converters, and MCI converters.*
[b]*p value of time × diagnostic group interaction over 1 year on FCI variables between control, MCI non-converter, and MCI converter groups.*
[c]*Controls > MCI non-converters, MCI converters.*
[d]*Controls > MCI non-converters > MCI converters.*
[e]*MCI converters showed greater decline compared to controls and MCI non-converters.*

NEUROIMAGING STUDIES OF FINANCIAL CAPACITY

Neuroimaging Approaches to Studying Financial Capacity

Neuroimaging research represents an exciting new form of scientific inquiry into financial capacity and aging (Knight & Marson, 2012). Although in its infancy, imaging research provides the important scientific opportunity to link together brain networks, brain activity, and brain structure with cognition and everyday function, in order to understand financial capacity in cognitively normal older adults, and also impairment and eventual loss of financial capacity in patients with neurodegenerative diseases like AD.

Positron emission tomography (PET) and MRI are two non-invasive neuroimaging modalities which can provide insight into brain micro- and macro-structure and brain networks that underlie financial capacity. PET imaging uses radiotracers to measure brain function (e.g., glucose utilization through fluorodeoxyglucose (FDG)) (Alavi et al., 1986; Raichle & Mintun, 2006) and molecular/protein localization (e.g., amyloid through AmyVid or Pittsburgh Compound B (PiB) (Rowe & Villemagne, 2013) and hyperphosphorylated tau through [18-F]-T807 (Chien et al., 2013)). Functional MRI (fMRI) is a non-invasive scan that measures changes in the blood-oxygen level-dependent (BOLD) signal when individuals are resting or performing a task (Raichle & Mintun, 2006). Structural MRI can be used to measure numerous anatomical features in brain relevant to everyday function, including cortical thickness, gray or white matter volume, white matter hyperintensities, iron deposition, and white matter microstructure.

Critical to understanding the neural basis of financial capacity is the appreciation that financial capacity is a complex multidimensional construct, which presumably draws upon numerous brain networks and cortical hubs, and associated cognitive processes, including arithmetic skills, semantic knowledge, reasoning, and judgment (Knight & Marson, 2012). Accordingly, it is important to identify specific brain networks and regions, which may underlie cognitive subcomponents within the construct, and hypothesize how compromised brain structure and function in these networks and regions can lead to cognitive and ultimately functional (financial) impairment. Current neuroimaging research examining financial capacity has focused on the brain's default-mode network (DMN), based on its role in episodic memory, arithmetic operations, financial judgments, and engagement in internal thought (Greicius, Krasnow, Reiss, & Menon, 2003; Gusnard, Akbudak, Shulman, & Raichle, 2001; Raichle et al., 2001; Raichle & Snyder, 2007), as well its preferential vulnerability to Alzheimer-type neuropathology (Buckner, Andrews-Hanna, & Schacter, 2008; Buckner et al., 2009). The DMN includes the neuroanatomical regions of the medial temporal lobe, predominantly the parahippocampal gyrus; posterior cingulate/ventral precuneus; medial prefrontal cortex; lateral temporal lobe; and inferior parietal lobule which includes the angular gyrus.

Neuroimaging Studies of Financial Capacity in aMCI and AD

Our group has recently used structural imaging and the FCI to begin to understand the neural basis of impaired financial skills in patients with aMCI and AD. In one study, MRI gray matter volume in the angular gyrus was the sole predictor of FCI score in a sample of aMCI patients, accounting for 19% of variance (Griffith et al., 2010). In addition, WRAT-3 written arithmetic score was a partial mediator of the angular gyrus–FCI score relationship. The findings were both intriguing and neurologically persuasive as the volume of angular gyrus, a neuroanatomical region that subserves numeracy and higher-order arithmetic functions in brain, was linked to financial capacity in patients with prodromal AD (Griffith et al., 2010). In a follow-up study, our group found a relationship between gray matter volumes in DMN regions (such as medial frontal lobes, angular gyrus, and precuneus) to FCI performance in mild AD patients (Stoeckel et al., 2013). In this second study, attentional abilities mediated the relationship between the medial frontal lobes and FCI performance (Stoeckel et al., 2013). To our knowledge, these two studies are the first to have used structural MRI to identify neural substrates and associated cognitive functions linked to financial capacity in patients with well-characterized neurodegenerative disease.

Neuroimaging Studies of Financial Decision Making in Cognitively Normal Older Adults

Other groups have recently used neuroimaging techniques to better understand the financial decision-making of cognitively normal older adults. For example, fMRI has been used to investigate which brain regions or networks underlie financial risk-taking and the balancing of risk and reward (Wu, Sacchet, & Knutson, 2012; Samanez-Larkin, Kuhnen, Yoo, & Knutson, 2010; Samanez-Larkin, Wagner, & Knutson, 2011). A meta-analysis revealed that the ventral striatum is activated during decisions involving large gains, whereas the anterior insula is activated when there is high variance associated with the outcome of the decision (Wu et al., 2012). A related study concluded that activation of ventral striatum is associated with a risk-seeking choice, such as a financial decision to gamble at a casino, where potential gains are viewed to outweigh potential losses. In contrast, activation of the anterior insula is associated with risk-aversive choices, such as a financial decision to purchase insurance (Kuhnen & Knutson, 2005). Consistent with these findings, increased variance in the activity of the ventral striatum was associated with riskier choices in older adults (Samanez-Larkin et al., 2010). Further research revealed that providing explicit information about the expected value of the decision could diminish riskier choices (Samanez-Larkin et al., 2011).

Studies of patients with brain lesions can also reveal neuroanatomical regions that potentially support financial capacity in older adults. Two recent studies have implicated the ventral medial prefrontal cortex as neuroanatomical areas necessary, although not sufficient, for sound financial judgments and understanding of financial concepts (Asp et al., 2012; Krajbich, Adolphs, Tranel, Denburg, & Camerer, 2009). Lesions in this area lead to increases in gullibility and a propensity for individuals to be misled by advertisements, which are forms of impaired financial judgment (Asp et al., 2012). Lesions to this area were also associated with persons having difficulty considering and comparing discordant facts, as well as lacking concern and guilt about the consequences of their decisions on others (Krajbich et al., 2009). Non-lesional whole-brain studies have also yielded insights. In a structural MRI study using voxel-based morphometry, lower gray matter volume in the striatum was associated with poor financial decisions and judgments (Ramchandran, Nayakankuppam, Berg, Tranel, & Denburg, 2011).

Summary

Neuroimaging has the potential to identify the brain networks and cortical regions that underlie financial decisions, and financial capacity as a whole, in both cognitively normal and abnormal older adults. Despite the infancy of this area, promising initial findings are emerging. First, gray matter volumes in regions of the DMN are related to performance on a measure of financial capacity (FCI) in patients with both prodromal and clinical AD, and these relationships are mediated by plausible cognitive mechanisms. Second, mesolimbic structures appear to be central to identification of the expected value of financial decisions and understanding/integrating financial concepts in cognitively normal elderly. With continuing research the field will be better able to understand the complex relationships between brain network disruption, cortical gray matter volume loss, and cognitive deficits, and how these processes impact complex downstream functional abilities such as financial capacity.

NON-COGNITIVE CONTRIBUTIONS TO FINANCIAL CAPACITY IN AGING

Up to this point, we have focused on cognitive disorders and their effects on financial capacity in aging. While arguably the preeminent predictor of financial capacity in aging, cognition by itself cannot explain all of the variance observed in the measurement of financial capacity, nor can it account for all instances of financial behavior in everyday life. Consistent with this view, our group has reported that neurocognitive predictors only account for between 25% and 65% of the variance in FCI performance across normal aging, MCI, and AD groups (Sherod et al., 2009). This finding emphasizes the importance of identifying other sources of variance contributing to older adults' financial capacity in everyday life. Both the American Bar Association and American Psychological Association have actively encouraged examinations into non-cognitive factors, such as social and cultural influences, that affect capacity in aging (Pinsker, Pachana, Wilson, Tilse, & Byrne, 2010). In this next section, we describe potential contributions of non-cognitive factors: psychological and psychiatric disorders and symptoms, physical dependency and/or medical frailty, cultural and social norms, and resilience.

Psychological and Psychiatric Contributions to Financial Capacity

It is well known that psychiatric disturbances of thought, mood, and personality can impact the capacity to perform everyday financial activities (Frank & Degan, 1997; Marson et al., 2006). Numerous psychological and psychiatric factors, whether chronic, acute, or even subclinical, can influence an individual's perception of financial control and ability to make financial decisions and carry out related tasks. For example, individuals with intact cognition but depressive symptoms can lack motivation and be apathetic towards personal financial decisions and activities, which could result in diminished financial capacity. Indeed, higher rates of impaired financial capacity have been observed in individuals with late-life depression (LLD) compared to non-depressed individuals (Mackin & Arean, 2009). This study also found that 22% of the LLD individuals had clinically impaired financial capacity and that, after controlling for age and education, attention and executive functioning accounted for only 27% of the variance in financial capacity.

A clear example of psychiatric illness impairing financial skills can be seen in schizophrenia. Although schizophrenia clearly involves cognitive impairment as a core deficit (Gold and Harvey, 1993), it also involves a range of noncognitive disturbances of thought, perception, affect, and social judgment (Dworkin, 1992) that can adversely impact financial skills and capacity. Patterson and colleagues examined financial capacity in psychiatric populations as part of a broader assessment of functional abilities using the UCSD Performance-Based Skills Assessment (UPSA) (Patterson et al., 2001). The study revealed that patients with schizophrenia or schizoaffective disorder performed significantly below controls on all five domains of the UPSA, including the financial domain. The UPSA is now an established part of many clinical trials in schizophrenia and related mental disorders. A more recent study demonstrated that the Direct Assessment of Functional Status (DAFS) scale, as compared to the MMSE, was better at classifying diminished financial capacity in severely mentally ill individuals (Barrett et al., 2009). The authors concluded that the DAFS financial skills subscale could be used by clinicians to assess financial capacity of individuals with severe mental illness. Patients with schizophrenia and severe mental illness also frequently have problems with both basic and complex financial skills, including budgeting expenses on a fixed income and selecting representative payees (Marson et al., 2006). Thus schizophrenia is paradigmatic in illustrating how severe psychiatric illness can impair financial capacity.

Research into the relationship between substance abuse and financial capacity is very limited. However, research has shown a temporal relationship between receiving entitlement benefits and drug relapse, suggesting that substance abuse is often associated with impairment in financial judgment (Shaner et al., 1995). Specifically, patients with substance abuse disorders often rapidly dissipate governmental and other financial benefits, rather than budgeting them to support themselves and family members until the next monthly disbursement (Frank & Degan, 1997; Rosen et al., 2002a, 2002b; Shaner et al., 1995; Marson et al., 2006). The inability of many substance abuse patients adequately to manage their finances has led to calls for alternative disbursement approaches such as mandatory representative payees (Grossman et al., 1997; Rosen et al., 2002a, 2002b).

Anxiety, or excessive worrying, is another psychiatric condition that can impair higher-order functional abilities such as financial capacity. Anxiety has generally been shown to be maladaptive and can lead to feelings of helplessness, a lack of focus, and a lack of attention in decision-making including financial decision-making (Pinsker et al., 2010; Barlow, 2004).

Finally, in addition to impairing financial skills, neuropsychiatric disorders can also impair an individual's awareness of his/her own cognitive and functional impairment (anosognosia). For example, one study has shown that individuals with MCI overestimated their abilities in routine financial skills (Okonkwo et al., 2008). Interestingly, severity of cognitive impairment was related to overestimation of financial abilities by patients with MCI, while depressive-like symptoms were related to underestimation of financial abilities (Okonkwo et al., 2008).

Relationship of Physical Dependence/Medical Frailty to Financial Capacity in Aging

Physical dependence, defined as physical frailty, medical frailty, and/or physical limitations from aging or medical conditions/issues, is also an important non-cognitive factor affecting financial capacity in the elderly (James, Boyle, & Bennett, 2014; Shulman & Faierman-Shulman, 2000). Physical frailty can impair a person's ability directly to carry out financial activities, by placing limitations on their ability to carry out and communicate financial decisions. An individual suffering a speech impediment from a stroke may no longer be able effectively to communicate their financial wishes, even when internal mental financial knowledge may be intact. Severe arthritis may render an individual incapable of simply writing a check or balancing a checkbook. A legion of physical ailments can effectively imprison the elderly in their homes, rendering them unable to make routine financial purchases, such as groceries, without assistance. The most common of these physical maladies include arthritis, rheumatism, heart disease, neuropathies, and osteoporosis. Arthritis, rheumatism, and heart conditions account for half of all medical issues physically limiting the activity of older adults (Quinn & Tomita, 1986).

These medical conditions can impair financial judgment and decision-making independent of frank cognitive impairment. Physical dysfunction and frailty have long been identified as factors that predispose the elderly to financial exploitation (Hall, Hall, & Chapman, 2005). A recent study looked at different risk factors for susceptibility to financial scams in a group of 639 community-dwelling older adults without dementia (James et al., 2014). In bivariate analyses, susceptibility to scams was positively correlated with frailty—as measured by grip strength, timed walk, body composition, and fatigue. In addition, the need for environmental and family support for daily living activities, including handling money, can predispose an individual to elder abuse and financial exploitation (Hall et al., 2005; Shulman & Faierman-Shulman, 2000).

Cultural and Social Contributions to Financial Capacity in Aging

An individual's exercise of financial capacity and decision-making occurs within a broader social and cultural context. Factors such as family, race, culture, gender, ethnicity, and others interact to help shape and influence an individual's financial capacity, decision-making, and vulnerability to exploitation (Sanchez, 1996). Consideration of such contextual factors in the decision-making process has been underrepresented in the capacity research arena generally and also the law. For example, the Mental Capacity Act of the United Kingdom was drafted as essentially context-blind and views decision-making of all types as solely a cognitive process (Mental Capacity Act Code of Practice, 2005).

The family provides an important context for protecting and preserving an older adult's financial capacity. A positive support network of family and friends is vital to detecting early cognitive problems and protecting an impaired older adult from his/her own declining financial decision-making, and from potential financial exploitation and abuse. In a recent study involving 639 community-dwelling older adults without dementia, social support was significantly negatively correlated with elders' susceptibility to scams (James et al., 2014). Not surprisingly, an early sign of the presence of undue influence is an uncharacteristic isolation of the individual from family, friends, community, and other stable relationships (Hall et al., 2005). In addition, recovery of older adult victims of undue influence is associated with strong support networks of trustworthy family members and social contacts.

At the same time, family members are unfortunately also the individuals most likely to financially exploit an older adult. As many as one third of all cases of financial abuse or exploitation involve a perpetrator who is a family member or close family friend, and who feels entitled to take funds because of their relationship with the older adult (Tueth, 2000). Most often the abuser is a male relative living with the victim, who takes advantage of specific areas of impairment or vulnerability, such as physical frailty or loneliness, to isolate and exploit the individual (Shulman & Faierman-Shulman, 2000). In addition to being a family member or close family acquaintance, perpetrators often have psychiatric and psychological problems, including a personality disorder and/or a history of mental illness or substance abuse (Hall et al., 2005; Homer & Gilleard, 1990; Paris, Meier, Goldstein, Weiss, & Fein, 1995; Quinn, 2002; Shulman & Faierman-Shulman, 2000; Tueth, 2000). Similar characteristics are found in female perpetrators, such as antisocial personality and longstanding histories of psychological dysfunction in relationships (Hall et al., 2005; Homer & Gilleard, 1990; Paris et al., 1995; Quinn, 2002; Shulman & Faierman-Shulman, 2000; Tueth, 2000). As noted above, these co-morbid characteristics of perpetrators are not unexpected, as financial mismanagement and poor money skills are commonly associated with psychiatric disability, and are often ranked as a target area for intervention with respect to recovery goals (Elbogen, Tiegreen, Vaughan, & Bradford, 2011). Addiction and financial mismanagement also co-occur frequently in perpetrators, possibly due to elevated delay discounting (Hamilton & Potenza, 2012).

The effect of cultural expectations on the family dynamic is important to consider. The family issues noted above in financial exploitation have been most frequently researched with respect to white middle-class individuals, with less attention to minorities. Family dynamics and cultural expectations can work together to shape financial capacity and exploitation in minority populations in ways that do not reflect the current research literature (Sanchez, 1996). Cultural expectations and exploitation can be difficult to distinguish without assessment of minority family dynamics including the nature of interactions, exchanges, and expectations (Sanchez, 1996). For example, in a study of Mexican American elderly, some familial interactions appeared exploitative through traditional screening criteria but were not perceived by participants as such. The participants instead understood these interactions as "rooted in familial and cultural expectations of exchange and support of the family and larger community" (Sanchez, 1996, p. 55).

In addition to family dynamics, factors of race and gender can also impact financial capacity in aging. A study by our group examining racial disparities in financial capacity among patients with aMCI revealed that basic academic math skills, related to educational opportunity and quality of education, accounted for a substantial proportion of the group differences in financial performance (Triebel et al., 2010). Social factors, including gender, have also been found to influence financial decision-making. A study looking at older adults without dementia showed that within households, men with relatively higher education than their spouse make more financial decisions and have higher financial literacy (Boyle et al., 2013). Additionally, despite the notion that people with dementia are often viewed as "ungendered," another study looking at the effects of gender in older adults with dementia demonstrated how women and men with dementia exhibit gendered agency (Boyle, 2013; Davis, 1991). Although women and men with dementia were both more likely to be involved in financial management when they had undertaken this role prior to dementia onset, women with dementia were agreeable to their husband's assumption of the household financial decision-making, while men with dementia were unwilling to relinquish their financial authority.

Resilience and Financial Capacity in Aging

Another non-cognitive factor contributing to financial capacity in aging is resilience—the ability to cope with and recover from stress and adversity (Eisenberg & Sulik, 2012). An individual's ability to maintain financial capacity consistent with past levels of cognitive functioning is moderated in part by their financial and social resilience. Specifically, it is an individual's capacity to perceive financial and social control, to identify controllable financial and social situations, and to exert financial and/or social control in everyday life that leads to their resilience (Chorpita & Barlow, 1998; Eisenberg & Sulik, 2012; Kumpfer, 1999; Maier, Amat, Baratta, Paul, & Watkins, 2006; Staudinger, Marsiske, & Baltes, 1995). In other words, if an older individual feels that they are in control of their finances, they are more likely to demonstrate a higher degree of financial capacity for a given level of cognitive functioning. The most direct evidence for this view comes from an analysis of the Health and

Retirement Study data, which revealed that "the ability to use knowledge and skills to manage one's financial resources effectively for lifetime financial security" was inversely related to hopelessness (e.g., "I feel it is impossible for me to reach the goals that I would like to strive for") (Murphy, 2013). While it is unclear whether hopelessness/helplessness (and consequent depression) impairs financial literacy and capacity, or impaired financial capacity causes hopelessness/helplessness and potentially depression, it appears that inescapable and/or negative financial and social situations will lead individuals to perform poorly financially or diminish their motivation to succeed, as described by the "learned helplessness theory" (Hiroto & Seligman, 1975). Not surprisingly, depressed individuals, who did not differ from non-depressed counterparts on demographic or neuropsychological measures, had lower levels of financial capacity (Mackin & Arean, 2009). In a different line of research, individuals with higher financial literacy tend to make more complex financial decisions (James, Boyle, Bennett, & Bennett, 2012), a likely illustration of the effect of perceived financial control. Another study revealed that individuals who consistently chose to avoid financial risk, even when accompanied by potential high reward outcomes (e.g., get $15 vs. 50% chance of getting $100), had lower financial literacy (Boyle, Yu, Buchman, & Bennett, 2012). In summary, feelings of financial helplessness, whether due to low financial literacy, confusion, and/or repetitive poor financial decisions, can lead to diminished resilience, which in turn can further diminish financial capacity.

FUTURE RESEARCH DIRECTIONS

In this concluding section to the chapter, we highlight four important future research directions for the emerging field of financial capacity in aging:

1. the detection of early financial declines in cognitively normal older adults;
2. the study of financial capacity in non-Alzheimer clinical aging populations;
3. the study of non-cognitive factors and financial capacity in aging;
4. understanding the evolving nature of financial capacity in our aging society.

Detecting Very Early Financial Declines in Cognitively Normal Elderly

As a result of cognitive aging, cognitively normal older adults are disproportionately vulnerable to declining financial skills and judgment, and also to undue influence by others. The widely reported case of undue influence involving Mickey Rooney is a well-publicized example (Fleck & Schmidt, 2011). Early detection of financial declines is the key to timely intervention and protection of these populations. However, very little is known about early decline of financial skills in cognitively normal older adults and the different trajectories of increasing vulnerability. Longitudinal studies of older adults using both existing and also novel metrics, such as task completion time, will provide insight into which aspects of financial capacity are most at risk during the earliest phases of cognitive aging. Models of the trajectory of these early financial declines might lead to "risk profiles" for declining financial capacity that could help families identify elders at risk well in advance of poor financial decisions or exploitation by others.

Study of Financial Capacity in Other Older Adult Clinical Populations

In this chapter we have focused on financial capacity in cognitively normal older adults and patients with MCI and AD. However, little scientific attention to date has been directed toward impairment and loss of financial capacity in other clinical aging populations, including patients with frontotemporal dementia, vascular dementia, Parkinson's disease, late-onset schizophrenia, and related disorders. A recent study using the FCI examined financial capacity in Parkinson's disease patients with both prodromal (PD-MCI) and clinical dementia (PDD), and found that impairment in financial skills is present in PD-MCI and advanced in PDD (Martin et al., 2013). Broadening the clinical scope of financial capacity research will allow us to better understand how different neuropathologies, disease processes, and symptom presentations affect financial skills in the elderly.

Study of Non-Cognitive Contributions to Financial Capacity in Aging

A third area of future research is non-cognitive contributions to financial capacity in aging, such as mental illness, physical dependence and frailty, family systems and dynamics, and resilience. Financial capacity is a fundamental IADL critical to the autonomy of older adults, but the majority of scientific work conducted to date has focused narrowly on cognitive factors, with correspondingly little attention to the role and relevance of non-cognitive factors (Pinsker et al., 2010). However, study of these non-cognitive factors may hold particular promise for intervention, as in many cases they may be treatable or otherwise modifiable, in contrast to cognitive impairments secondary to neurodegenerative disease. By studying and understanding such non-cognitive factors, the field will be in a position to develop associated interventions to better support and protect the financial capacity of older adults.

Evolution of Financial Capacity in a Technological Society

A fourth area of future research is the changing form of financial capacity itself in contemporary modern society. The construct of financial capacity is rapidly evolving in our modern technological society. In 25 years, it is possible that we may no longer use coins or paper money, and among older adults we are beginning to see a shift to online banking and increased use of credit cards, as has previously been observed in younger age groups. About 50% of American seniors are now internet users, and they comprise the fastest-growing online group (Zickuhr & Madden, 2012). The shift away from cash to a cashless society may actually increase, rather than decrease, the importance of financial capacity and its accurate assessment. Older adults may have difficulty visually scanning, and be easily confused by, complex graphical computer screen displays of their financial data, and be prone to associated errors. In addition, when older individuals make transactions with a credit card, they may be less aware of the costs and timeframes involved compared to cash transactions.

With the increasing availability and expectation of online financial activities, clinical research studies of financial capacity will accordingly need to evolve. However, to date little scientific attention has been devoted to the topic of online banking and internet-based financial activity. A recent study of community-dwelling older persons without dementia found that older adults who used the internet scored higher on a measure of global cognition, had less impairment on IADL measures, and made better health and financial decisions (James, Boyle, Yu, & Bennett, 2013). Future research should address the shift to a cashless society by examining the performance of both younger and older adults on online banking and other financial transactions.

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CHAPTER

20

Technology, Gaming, and Social Networking

Neil Charness and Walter R. Boot

Psychology Department, Florida State University, Tallahassee, FL, USA

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DEFINITION OF TECHNOLOGY AND ICT

We have experienced two revolutionary changes in the past century: marked increases in longevity coupled with accelerating rates of adoption of intelligent technology (Charness, 2004). These two changes could potentially enrich the lives of our rapidly growing aging population or restrict quality of life for those unable to harness this intelligence to serve their goals. In this chapter, we expand on some of the themes introduced in the 6th edition *Handbook of the Psychology of Aging* adaptive technology chapter (Scialfa & Fernie, 2006) as well as in Charness, Fox, and Mitchum (2011). We also try to emphasize recent studies in our overview given the rapidly expanding literature in this area. General reviews are available in Caine et al. (2006), Czaja and Lee (2008), and Wagner, Hassainen, and Head (2010). Aside from considering data and theories of technology adoption, we emphasize two historically recent phenomena: gaming and social networking technology.

We caution the reader that at this point in time there are not many solid research studies to rely on for theory building about gaming and social networking for older cohorts. The lacuna is partly because of current striking cross-sectional age differences in participation rates in such activities. It is difficult to find enough older adults to study and they are likely to be unrepresentative of their age cohort. Also, many surveys lump together very different segments of the aging population (young-old, middle-old, old-old) under the category of age 65+, so we have an undifferentiated picture of ICT use in late life. As demographers have pointed out (Meyer, 2012), even centenarians are growing faster than is the general population in the United States.

We also rely primarily on US data for highlighting technology adoption trends given its density and currency. We would expect similar trends for other developed countries, and lower adoption rates in less developed countries except perhaps for the reliance on mobile phone technology. We turn now to the thorny issue of defining technology.

The Oxford English Dictionary (http://www.oed.com/) provides seven primary definitions for technology, with the one most fitting for our interests being:

> 4a The branch of knowledge dealing with the mechanical arts and applied sciences; the study of this.
>
> 4b The application of such knowledge for practical purposes, esp. in industry, manufacturing, etc.; the sphere of activity concerned with this; the mechanical arts and applied sciences collectively.
>
> 4c The product of such application; technological knowledge or know-how; a technological process, method, or technique. Also: machinery, equipment, etc., developed from the practical application of scientific and technical knowledge; an example of this. Also in extended use.

These definitions remind us that technology is both a product and a process and that engineering is the presumptive approach. That role would be assumed by applied experimental and engineering psychology in the case of our discipline, sometimes termed gerontechnology (Bouma, Fozard, Bouwhuis, & Taipale, 2007). The primary focus in this chapter is on information and communication technologies (ICTs), those often used for social interaction (Charness & Boot, 2009). We provide a brief history of the development and diffusion of ICTs to indicate its relative recency and growing ubiquity. We overview some of the current theories of technology adoption. We discuss trends in adoption and assess research related to adoption. We conclude by offering directions for future research and application.

A CENTURY OF DEVELOPMENT AND DIFFUSION OF TECHNOLOGY

Differences in longevity between our early ancestors and ourselves (or today between people in developing vs. developed nations) are less attributable to genetics than to cultural changes, particularly technology development.

The striking rise in life expectancy at birth in the United States, from 47 years in 1900 to 78 years in 2008 (Arias, 2012) most likely reflects multiple technology advances. Medical technology reduced the risk of incurring childhood diseases and increased the chance of surviving them (vaccination programs, antibiotics). Agricultural technology provided an abundant/inexpensive food supply (e.g., modern tractors). Civil engineering technology provided clean water and effective sewage disposal in growing urban environments.

At least initially, new technology is costly and widespread adoption is difficult to achieve in poor societies. The rapid rate of diffusion of technology products now compared to a century ago (e.g., wired phone vs. mobile phone adoption rates) undoubtedly reflects wealth increases. Enormous gains in economic productivity due to better work technology and a more highly educated labor force (both in terms of job-specific training and in terms of general fluid intelligence gains: Fox & Mitchum, 2013) are likely the main factors that resulted in exponential increases in real income comparing those working today versus in 1900 (Charness, 2008). Educational technology coupled with increasing public participation in advanced education undoubtedly lies behind some of these human capital increases.

Many of the technology tools that have developed in the twentieth century and beyond are fundamentally different than those of prior generations of technology in that they include microchips capable of being programmed, making them multipurpose devices rather than dedicated single-function tools. The invention of the digital computer chip (e.g., Intel's 4004 chip in 1971, http://www.intel.com/content/www/us/en/history/museum-story-of-intel-4004.html), enabled miniaturization of intelligent technology.

Home Computing and Gaming

The ability to manufacture computers for consumer use encouraged added functionality, namely entertainment, and specifically gaming. Early 1980s computers for the home emphasized gaming capabilities, with work capabilities representing almost a secondary feature. It seems likely that diffusion of such technology in the population (see the later section on technology diffusion) was associated with familiarity in office environments leading to adoption at home. Whether the current trend to later retirement ages and partial retirement will change the flow pattern for seniors who have traditionally been isolated from work environments remains to be seen. Also, technology transfer does not always proceed from work to home; smartphone adoption has moved in the opposite direction. The earlier diffusion pattern meant that retired older adults (> age 65) would be left out of the computer revolution. The first "digital divide" report by the US National Telecommunications and Information Administration in 1995, while focused on rural/urban differences in technology adoption (telephone, computer) duly noted "… rural seniors rate lowest in computer penetration" (http://www.ntia.doc.gov/ntiahome/fallingthru.html). Given that education and income were then (and still are, see Figure 20.4) among the strongest predictors of ICT adoption, it is not surprising to see seniors lagging behind their younger working counterparts in many areas. This brief history points to the recency of ICT diffusion, perhaps indicating why we might expect generational differences in adoption, and to the diversity of products. We now review trends in technology adoption by age category to set the stage for discussion of theories of adoption.

TECHNOLOGY USE AND AGE

It is instructive to consider trends in technology adoption by age/cohort over time using nationally representative data. A useful source for American data is the Pew Internet and

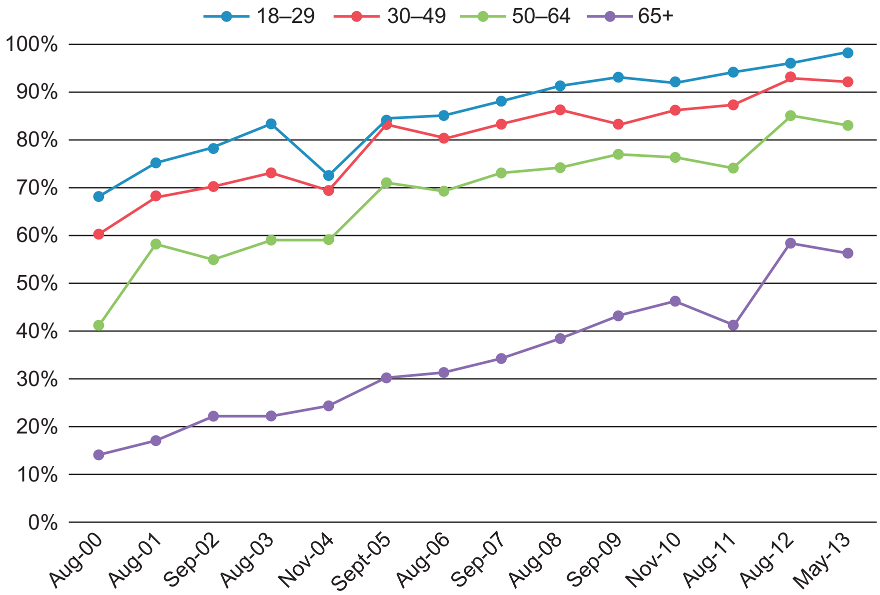

FIGURE 20.1 Percent US Internet use by age group. *Data selected at near annual intervals from the Pew Internet & American Life spreadsheet http://www.pewinternet.org/Static-Pages/Trend-Data-%28Adults%29/Usage-Over-Time.aspx supplemented by http://www.pewinternet.org/Trend-Data-%28Adults%29/Whos-Online.aspx. Accessed 30.12.13.*

American Life project (http://www.pewinternet.org/), which has been conducting representative sample surveys since 2000. Below in Figure 20.1 Internet use is plotted.

Notable is the persistent lag in Internet use by those age 65+ compared to other age/cohort groups. The 65+ cohort in 2013 only reached levels of use exhibited 13 years earlier by those age 30–49 and still lagged behind Internet use registered by those age 18–29 in the year 2000. Even in 2013 about 44% of those age 65+ did not use the Internet. A survey of offline US adults (Madden, 2013) showed that the primary reasons for non-use were lack of interest (21%), not having a computer (13%) and too difficult/frustrating (10%). When asked whether they would be able to start using the Internet in the future, only 13% of those age 65+ indicated that they would know enough to go online, and 66% indicated they would need help.

Although it appears that those age 65+ have shown enormous growth in Internet use, particularly from 2011 to 2012, it is worth noting that these are cross-sectional panels, not longitudinal data. Much of the growth may be due to earlier cohorts shifting over time into new age categories, carrying along their original Internet use habits. As an example, the 50–64 age cohort in 2001 was at about 60% Internet use and 12 years later, when most had moved into the age 65+ cohort, use in the 65+ cohort was also near 60%. There is undoubtedly time-associated growth but it is unclear how much of that is confounded with age category shifts. Nonetheless, as the Baby Boom cohorts (e.g., born 1946–1964) begin to dominate the age 65+ category, it is safe to assume that most of them will have Internet access. How they will access the Internet (devices) and what activities they will pursue on the Internet will be a function of general factors in technology adoption.

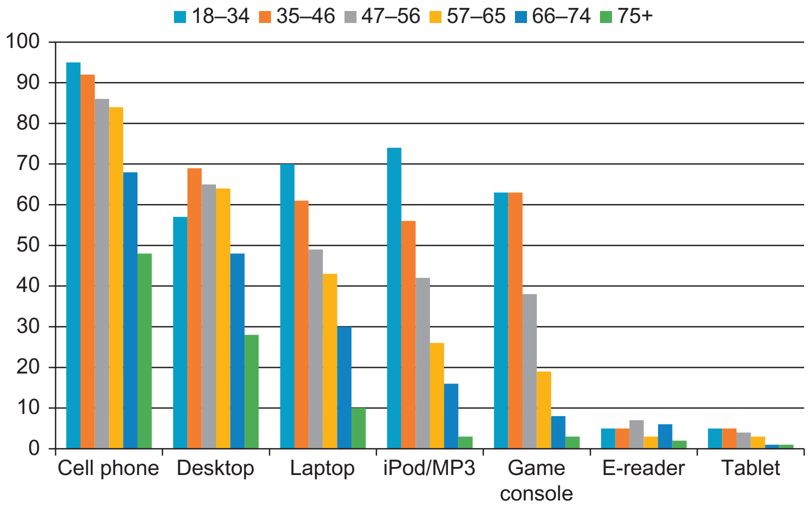

FIGURE 20.2 US percent device ownership in 2010. *Data from Zickuhr (2011), http://www.pewinternet.org/~/media//Files/Reports/2011/PIP_Generations_and_Gadgets.pdf. Accessed 31.12.13.*

Surveys have shown similar trends for adoption in other countries. In Europe, the percent of people who use the Internet at least once a week is 93% for 16–24-year-olds, 78% for those age 25–54, and 42% for those age 55–74 years (Seybert, 2012).

There are similar findings for other ICT devices. A cross-sectional example of US use in 2010 is plotted below, showing rapid fall-off with age/cohort for all but relatively new products such as e-readers and tablets. That is, there is a consistent age/cohort-based technology lag (reminiscent of societal structural lag that sociologists such as Riley, 1998, have discussed) (Figure 20.2).

It is worth noting that older adult cohorts sometimes lead younger ones, though for older forms of technology. As an example, a Gallup Poll (http://www.gallup.com/poll/166745/americans-tech-tastes-change-times.aspx?) in the United States in December 2013 showed that VCR ownership was higher in the age 65+ category than the 18–29-year-old category (74% old vs. 41% young) and the same was true for basic cell phone ownership (61% old vs. 24% young) but the reverse was true for smartphone ownership (88% young vs. 25% old). We turn next to theories of technology adoption to assess potential reasons for these age differences.

THEORIES AND MODELS OF TECHNOLOGY ADOPTION

Over the past few decades a variety of models have been proposed to explain the diffusion of technology and technology acceptance by individuals. These models are briefly reviewed to frame the subsequent discussion of the adoption of digital games, social networking sites (SNSs), and other ICTs by older adults. In general these models aim to capture the attitudinal and contextual factors that work to facilitate or impede the adoption of new technology.

Rogers Diffusion of Innovation (Rogers, 1995)

Rogers (1995) described the five-stage process a non-user of technology progresses through to become a technology adopter or non-adopter, starting with the process of obtaining basic knowledge related to the existence of a technology and what it does (knowledge stage). Importantly, during the persuasion stage the individual forms a positive or negative impression of the technology, driven in part by factors such as the perceived advantage of using the technology and the perceived difficulty of using the technology. At this stage the ability to try a new piece of technology can have an important influence, as well as the opportunity to observe others using the technology. This is followed by a decision stage in which the pros and cons of the technology are weighted and a decision is made, at which point the technology is either rejected or incorporated into the individual's life (implementation stage). Following implementation, an individual reevaluates the outcome of deciding to use a piece of technology and decides to maintain or discontinue use (confirmation stage), resulting in either adoption or rejection of the technology. In sum, Rogers highlights that the decision to adopt a technological innovation is a complex one, involving many attitudinal, social, and environmental factors.

Technology Acceptance Model

Technology Acceptance Model (TAM; Davis, 1989) has been one of the most influential models of technology acceptance, with two primary factors influencing an individual's intention to use new technology: perceived ease of use and perceived usefulness. An older adult who perceives digital games as too difficult to play or a waste of time will be unlikely to want to adopt this technology, while an older adult who perceives digital games as providing needed mental stimulation and as easy to learn will be more likely to want to learn how to use digital games. While TAM has been criticized on a number of grounds, it serves as a useful general framework and is consistent with a number of investigations into the factors that influence older adults' intention to use new technology (Braun, 2013).

Unified Theory of Acceptance and Use of Technology

Unified Theory of Acceptance and Use of Technology (UTAUT; Venkatesh et al., 2003), a more complex offshoot of TAM, includes similar factors of perceived ease of use (effort expectancy) and perceived usefulness (performance expectancy), but also explicitly recognizes that broader contextual factors may facilitate or inhibit technology adoption. These factors include facilitating conditions such as the perception that technical support would be available if needed, and social influences, such as the perception that other individuals expect them to adopt new technology. According to this model, an older adult is more likely to sign up for a Facebook account if he or she felt social pressure to do so, and if he or she felt that family and friends would be available to help.

Other Factors in Technology Acceptance and Use

Contextual factors can be varied. Charness (2003) suggested that a useful framework would include factors such as access, motivation, ability, design, and training. Caine et al. (2006) surveyed 50 years of research on acceptance of high technology and provided a heuristic tool for factors that designers of technology should keep in mind in addition to perceived usefulness and ease of use. The factors they stressed included perceptions about compatibility, complexity, fun and enjoyment, self-image, newness, privacy, relative advantage, and risk of harm. Barnard, Bradley, Hodgson, and Lloyd (2013) argue that different models are needed to account for variables affecting perceptions about ease of learning and those influencing technology acceptance/rejection. Ease of learning factors include self-efficacy, perceived difficulty, and attitudes toward learning. System and user acceptance of technology factors include system characteristics affecting usability (transparency, affordance, feedback, error recovery, and training support) as well as user experience factors involving transfer of prior knowledge. We next apply these frameworks to try to understand factors in adoption of gaming and social networking.

OLDER ADULT GAME USE AND GAME PREFERENCES

Gamer Demographics

According to the Entertainment Software Association, video game sales in the United States reached approximately 15 billion dollars in 2012, exceeding domestic movie ticket sales for the same year by 4 billion dollars. These figures highlight digital games as a dominant form of entertainment and a pervasive form of modern technology. In addition to increased sales we are also witnessing a trend for the diversification of the gamer population. Contrary to the stereotype of the teenage male gamer, the average gamer is 30 years old and is almost as likely to be female as a male. However, data suggest that video game use is still relatively rare among older adult cohorts (according to a 2008 Pew survey, only 23% of adults 65+ reported playing digital games compared to 53% of all individuals 18 or older; Lenhart, 2008).

A push by the gaming industry to reach "casual" gaming audiences may account for an increased interest by older adults to explore digital games (in addition to an increase in female gamers). Casual games do not require the gamer to invest large amounts of time to learn, are often modeled after familiar non-digital games, and can be played in short sessions. Although older adult gamers are relatively rare, it is also true that they are among the most active gamers with over a third reporting playing almost every day or more. With respect to gaming platform, console game use (e.g., Playstation 4, Xbox One) is especially

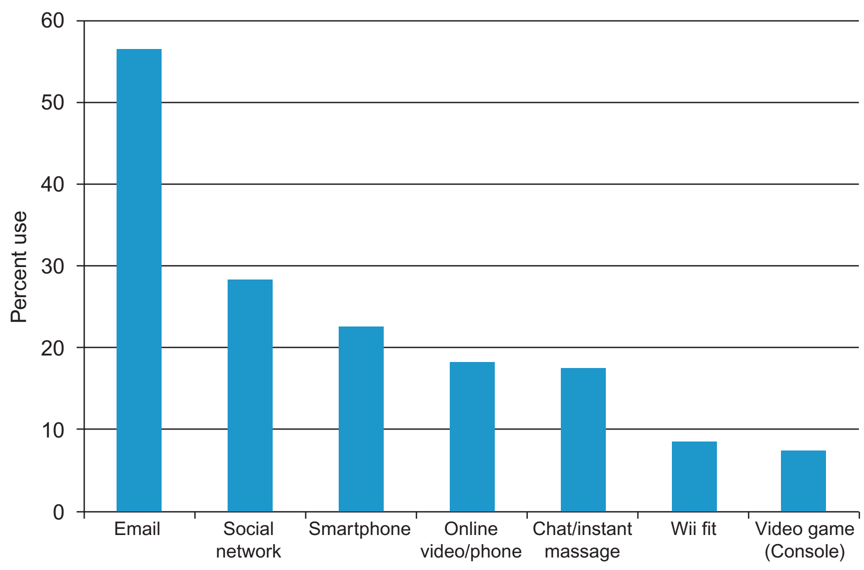

FIGURE 20.3 Communication and game use of a representative sample ($N = 1740$) of retired individuals (age 50+) from the Health and Retirement Study 2012 data set.

rare among older adults (Figure 20.3; also, the aforementioned Gallup Poll in 2013 showed 18–29-year-old ownership at 64% and age 65+ at 10%), with the majority of older gamers relying on computers to play. In addition to gaming platform, it is also clear that the types of games older cohorts enjoy playing are different from some of the most popular game genres enjoyed by younger players.

Game Preferences of Older Adults

Action/shooter games and sports games tend to be the most popular console video games, and strategy and roleplaying games tend to be most popular non-console games as indicated by the top selling games of 2012. In 2013, the violent action game Grand Theft Auto V became one of the best-selling games of all time, with sales reaching over a billion dollars faster than any other entertainment property. However, several survey and focus group studies suggest that the types of games that older gamers play, or would like to play, are different from the games that are most popular among younger gamer cohorts. For example, De Schutter (2011) surveyed older adults (ages 45–85) and found that PC-based casual games were most popular among this sample, with the need for challenge being the primary motivation for game play. Games included in this category were puzzle games, computerized versions of card/board games, and games with simple dynamics and controls. De Schutter partly attributed the popularity of casual games among older adults to the ease with which these relatively simple/familiar games can be learned. Fast-paced and violent first-person shooters, one of the most popular game genres overall, tend to be unpopular with older adults (De Schutter, 2011; Nap, de Kort, IJsselsteijn, 2009; McKay & Maki, 2010). Instead, slower-paced games that emphasize intellectual challenge tend to be popular with older gamers (Pearce, 2008).

This may not be surprising given the potential mismatch between the visual, attentional, and processing speed demands of popular action, sports, and strategy games and older adults' poorer perceptual/cognitive abilities. Unfortunately, older adult game preference and gaming habits have been a relatively understudied topic. Additional research is needed to better understand older adults' motivation to engage in game play and predictors of game preference. Digital gaming represents a novel domain with which to explore and validate new and existing models of technology adoption and adherence.

Benefits of Gaming

In addition to the obvious entertainment value of games, gameplay may engender other meaningful benefits in terms of keeping older adults mentally engaged and physically active. A topic that has generated excitement (and some controversy) recently is the potential of video game play to improve a variety of perceptual and cognitive abilities (Green & Bavelier, 2008; Bavelier & Davidson, 2013; Powers et al., 2013; but see also Boot, Blakely, & Simons, 2011; Boot, Simons et al., 2013). Both cross-sectional studies comparing gamers to non-gamers, and game training studies that have trained non-gamers to play video games, suggest that video game play (especially fast-paced action game play) provides more than just entertainment: games may be good for you. While much of this work initially focused on college-aged adults there is growing interest in whether or not video game interventions can reduce aspects of age-related cognitive decline. For example, Basak, Boot, Voss, and Kramer (2008) found that training on a complex strategy game called *Rise of Nations* resulted in improved performance on laboratory tasks of memory and reasoning ability in a sample of older adults.

There has also been a focus on developing games that target specific abilities that are known to decline with age (Anguera et al., 2013), and a variety of game-based "brain fitness" programs are now commercially available for purchase and are being marketed to older adults. While direct evidence that game-based interventions can meaningfully improve cognition (i.e., result in cognitive improvements that prolong functional independence) is limited at this time, it is likely that interest in "brain fitness" games will continue to be popular. It will be especially interesting to observe longitudinal changes as younger gamers become older gamers (do game preferences change?), and to observe whether frequent gameplay in young adulthood and afterward is associated with less steep cognitive decline. In addition to cognitive abilities, there is also preliminary evidence that digital gameplay among older adults is associated with higher levels of well-being (Allaire et al., 2013). Additional research is required, however, to establish a causal relationship between gameplay and increased levels of well-being as a number of plausible non-causal relationships might explain this association.

Of particular interest with respect to current research on gaming and cognition is the general tendency of older adults to dislike the games which have been associated with the greatest benefits to cognition (fast-paced action games). This may present challenges for game-based interventions intended to improve cognition (Boot, Champion et al., 2013). McLaughlin, Gandy, Allaire, and Whitlock (2012) reviewed a number of factors that may discourage older adults from engaging in digital gameplay. Barriers to gameplay included usability issues arising from games and gaming devices not designed with the physical and cognitive abilities of older adults in mind and a belief by older adults that they cannot or should not be playing video games due to their age. However, McLaughlin et al. (2012) point out that good design and sufficient training may be able to overcome these barriers, allowing older adults to access the potential cognitive benefits of games as well as benefit from meaningful social interactions which video games can facilitate.

Less controversial is the connection between physical activity and improved physical, mental, and even cognitive health (Voss, Nagamatsu, Liu-Ambrose, & Kramer, 2011). Exergames incorporate physical motion into game play (e.g., the balance board of Nintendo Wii, Kinect motion sensor of Xbox) and represent a growing trend in the gaming industry. While research on the benefits of exergaming is still in its very early stages, preliminary evidence supports that exergame interventions with older adults are feasible, with promising cognitive and physical benefits (Bleakley et al., 2015; Larsen, Schou, Lund, & Langberg, 2013). There is also potential for these games to be used to promote motor, balance, and injury rehabilitation (Pessoa, Coutinho, Pereira, Ribeiro, & Nardi, 2014). However, as with any line of new research on an emerging technology, there are still many questions to be answered regarding the efficiency and effectiveness of exergaming interventions compared to more traditional interventions.

Since the release of Pong in 1972 (with the first home version being released in 1975), we've witnessed an extremely rapid increase in the sophistication of digital games and a rapid proliferation of this technology among the public. There is little reason to doubt that these two trends will continue. Next we turn from digital gaming technology to another rapidly expanding communication technology: SNSs.

Communication

Spurred by US military investment in computer networking (to allow communication paths to persist when parts of the communication infrastructure might be destroyed in war or natural disasters), the rise of computer-to-computer communication protocols, particularly TCP/IP and Ethernet standards helped develop early networks such as ARPANET followed by non-military networks such as Bitnet. As local and national networks merged, the Internet emerged as a world-wide network for communication. The development of protocols such as HTML for displaying information in a common format across different computer systems permitted scientists to exchange information efficiently, and quickly led to commercial development of the world-wide web.

Although e-mail messaging was the main way to communicate on Bitnet, other instant messaging protocols were in evidence early in computer networking (for communication in real time among multiple users of a single computer system), and became popularized through bulletin board systems and specialized software that could communicate across different computer platforms using a mix of closed then open standards for transmitting information. As bandwidth grew for Internet connectivity, voice (voice over IP) and video capabilities became available to computer users with broadband connections to the Internet. Streaming technologies also developed to permit broadcast of voice and video to multiple end users. Real-time communication became one of the more valuable features of the Internet.

However, just as in the case of initial consumer computer adoption, older adult cohorts lagged other population segments as users. But for communication technology, there seems to be less of a concern with motivation as a barrier. If anything, declining mobility with age makes remote communication particularly important. At present, of the many forms of communication available for those age 65+ in the United States who report using the Internet, e-mail takes priority: 87% report using e-mail, with 46% receiving or sending e-mail on a typical day (Purcell, 2011).

SOCIAL NETWORKING AS A NEWLY EMERGING COMMUNICATIONS TECHNOLOGY

We are observing a trend for diversification in the ways that individuals communicate through technology, with younger adults shifting away from more traditional communication technology such as e-mail to SNSs (e.g., Facebook, Twitter, Instagram, Pinterest, LinkedIn, and Google+). With SNSs like Facebook reporting over a billion users in 2013 it is likely that SNSs will continue to play a large role in facilitating communications and information gathering in the future. Recent data show that 73% of online adults use an SNS (Duggan & Smith, 2013). Yet, like many other forms of ICT, older adults have been relatively slow to adopt SNSs and participation in SNSs lags substantially compared to younger cohorts.

In 2013, 45% of older adult internet users (65+) participated in the Facebook SNSs compared to 84% of 18–29-year-old internet users and 71% of all internet users (Duggan & Smith, 2013). Although older adult internet users are disproportionately less likely to use SNSs compared to younger adults, social network use among this population is on the rise (compare the 43% use in 2013 to the less than 10% of reported SNSs use before 2009: Brenner & Smith, 2013). However, SNS use still represents a substantial digital divide between younger and older adults (57% of 65+ internet users do not use these sites *in addition* to the 44% of older adults who do not use the internet at all). Additionally, it is not clear whether adoption is driving the increase in older adults' use of SNSs, or whether younger cohorts of SNS users are aging into older age categories. Interestingly, the reported motivation for use differed between younger adults and older adults, with older adults being motivated by a desire to keep in touch with family, and younger adults being more motivated by a desire to interact with friends.

Benefits of SNS Use?

The opportunity for social interactions is clearly a part of successful longevity. Social engagement has been linked to greater well-being, higher cognitive functioning, and reduced risk of dementia in old age, while feelings of isolation have been associated with steeper cognitive decline (see Hertzog, Kramer, Wilson, & Lindenberger, 2008, for review). Social isolation has also been linked to poorer health outcomes, increased depression, and increased risk of mortality (Steptoe, Shankar, Demakakos, & Wardle, 2013). Given these potential benefits, SNSs may serve as promising means for older adults to engage in social interactions with friends and family members. This may be especially true for the 29% of older adults who live alone in the United States and may be at risk for social isolation as a result. Currently, there have been few rigorous systematic studies on whether social interactions occurring through SNSs might be associated with the same benefits as face-to-face social interactions. This line of research is still in its infancy, and there is a need for both correlational research to explore potential effects of using SNSs and experimental research to confirm causal relationships between SNSs and improvements on psychosocial outcome measures. Although benefits are relatively clear for communication technologies we now turn to specific barriers to ICT adoption that may explain non-use by seniors.

BARRIERS TO TECHNOLOGY ADOPTION BY SENIORS

Perceived costs and benefits dominate decision-making for technology adoption in both younger and older individuals (Davis, 1989; Morris & Venkatesh, 2000). For older adults in particular, on the cost side, financial (Carpenter & Buday, 2006) and cognitive costs (Czaja et al., 2006) have been shown to be salient predictors, as have self-efficacy beliefs (Czaja et al., 2006). Further, poor technology design that fails to account for age-related changes in perceptual and psychomotor abilities can also increase perceived costs for adoption. We also want to point to concerns about privacy/confidentiality as a barrier that may be particularly problematic for health technology adoption.

Financial Cost

Pensioners on fixed incomes may not have the economic resources to adopt a technology product, such as a tablet or smartphone, even if it is perceived as being beneficial. Mobile phones are important in part because texting, a form of instant messaging, has become very popular for communication in younger cohorts (social networking) and smartphones are also useful for gaming. Smartphones are now becoming a critical tool for accessing the Internet, particularly for racial minorities such as Blacks and Hispanics in the United States, who showed higher smartphone ownership than the majority group (64% Black, non-Hispanic, 60% Hispanic, 53% White, non-Hispanic: Smith, 2013). Other countries have shown strong age trends for accessing the Internet through mobile devices (portable computer, handheld device). Seybert (2012) found that 58% of those age 16–24, 36% of those age 25–54, and 12% of those age 55–74 accessed the Internet from a mobile device. Financial barriers to ownership may be surmounted with financing plans that enable smartphones to serve as both primary telephonic communication devices and Internet access devices.

Studies with representative samples from the population have shown that ITC product use is strongly associated with income as well as age, as seen in Figure 20.4 for smartphones.

Cognitive Cost

Cognitive cost refers to the difficulties in problem solving (e.g., troubleshooting) how to use a complex, intelligent device. Czaja et al. (2006), using a large, diverse, cross-sectional sample aged 18–91 years, showed in structural equation modeling that composite measures of cognition, such as fluid ability and crystallized

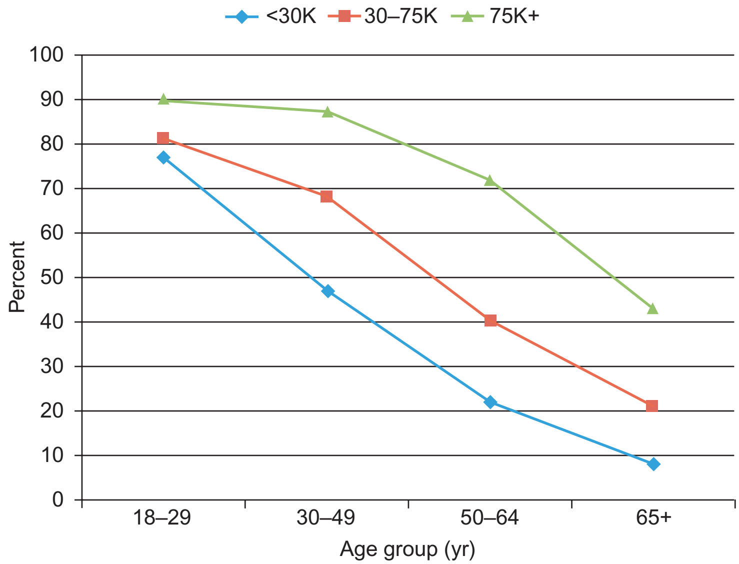

FIGURE 20.4 US smartphone ownership in 2013 by age and income. *Data from Smith (2013).*

ability, predicted technology use, breadth of computer use, and breadth of Internet use independently of other significant factors such as age, education, attitudes toward computers, and self-efficacy beliefs. Similarly, a study using a representative sample of midlife Americans (age 32–84) showed a significant relationship (beta = 0.286) between computer use and cognition (memory, speed, and executive functioning measures) controlling for age, education, gender, gender × computer use, and health status (Tun & Lachman, 2010). A recent study (Elliot, Mooney, Douthit, & Lynch, 2013) using a US nationally representative cross-sectional survey, the National Health and Aging Trends Study (NHATS), showed in a structural equation model that ICT use (combined variables measuring e-mail/text use and computer/internet use) was predicted by socioeconomic statue (SES), age, and cognitive function (clock test, immediate and delayed recall). A significant relationship between cognition measured in high school and Internet use at age 65 was also found in the Wisconsin longitudinal study (Freese, Rivas, & Hargittai, 2006). Although many a frustrated ITC device user would like to believe that problem-solving on their device leads to improved cognition, at least one clinical trial suggests that this is not the case. Slegers, van Boxtel, and Jolles (2009) assigned non-computer-using seniors interested in using a computer and the Internet to computer training or no training, then split the training group into a group given a computer system to use at home and a group with no computer provided, and also kept a no-interest control group for comparison. They found no differences in cognition across the four groups after a year of computer and Internet use. Thus, the most likely explanation is that those with poorer cognitive abilities are less willing or able to learn to use a complex device rather than that using a computer system improves general cognitive abilities. As Davis (1989) noted, perceived ease of use is a primary cost consideration for adoption; hence, the lower the actual or perceived cognitive ability, the greater the perceived cost is likely to be for technology devices.

Beliefs

Perceived cost may involve both technology-specific self-efficacy, beliefs that a product can be used successfully, and beliefs about time-to-learn cost. Czaja et al. (2006) and others (Reed, Doty, & May, 2005) have shown that older adults are less likely to exhibit high self-efficacy about technology use and that self-efficacy can be an important predictor of performance. Cognitive aging researchers have shown that older adults learn more slowly than younger adults (Salthouse, 2010). Rational models of behavior would predict that learning to use a product that is novel (e.g., novel ICT device) would be less appealing to older adults (compared to younger ones) if they realize that they are slower to learn new information. Best (2011) showed that older adults have a higher discount rate for learning investment than do younger adults. That is, they self-report being less willing to engage in additional learning to become more competent with a product (such as learning new features that take more time). However, for the discount rate for value of money, the reverse finding was obtained, with younger adults more reluctant than older adults to invest money (compared to time), suggesting that discounting is context-specific, not that older adults always show a higher discount rate.

Design Costs

Another cost within perceived ease of use is perceptual and psychomotor cost. Poorly designed miniaturized devices such as smartphones (using small screens with virtual keyboards) can tax basic cognitive, perceptual, and psychomotor activities more in older compared to younger adults (Boot, Nichols, Rogers, & Fisk, 2012; Fisk, Rogers, Charness, Czaja, & Sharit 2009) given normative age-related declines in those capabilities. Disability increases exponentially with age and impairments in vision, hearing, and psychomotor function have been shown to be negative predictors of technology use, although properly designed technology could be very helpful (Schulz, 2012). Using the NHATS sample, Gell, Rosenberg, Demiris, LaCroix, and Patel (2015) showed that even after controlling for demographic variables (age, sex race/ethnicity, education, marital status, and health variables) disability indicators were significant negative predictors of technology use (e-mail and Internet use), although pain and difficulties with breathing were associated with greater likelihood of technology use. This may be a case where a powerful motivator (uncontrolled pain and breathing difficulty) increases perceived usefulness and becomes a driver for technology adoption.

Privacy Concerns

Privacy loss can be considered a negative "facilitating condition" in a UTAUT model. In an age where technology makes it possible to monitor virtually all electronic communications (e.g., by the US National Security Agency), and where providing permission to be tracked is a condition for downloading and using many "free" smartphone applications, privacy concerns may be an important barrier to technology adoption. A 2009 survey (Hoofnagle, King, Li, & Turow, 2010) of Internet users showed few age differences across age bands for refusing to give information to a business thought to be unnecessary or too personal, or in whether there should be laws for right to know and right to delete stored information. However, older adults age 65+ were significantly more concerned about levels of privacy now compared to 5 years earlier (67% vs. 54% for 18–24 year olds). A Pew study in 2000 showed that adults age 18–29 were less likely to be "very concerned" about keeping their information private compared to those aged 50–64 (46% vs. 67%) and there was a clear age gradient in belief about online tracking with younger adults less likely to believe it to be harmful than those aged 30–49 and 50–64 (Fox, 2000).

A recent study with a representative US sample revealed that older adult Internet users show a complex pattern of concerns and behaviors with respect to privacy and security for online information (Rainie, Kiesler, Kang, & Madden, 2013). Despite the earlier finding of greater concern about privacy for their information, older adult Internet users in 2013 were less likely to take steps such as clearing and disabling cookies and browser history, or using temporary usernames and e-mail addresses than younger adults. They were less likely, however, to post material on the Internet using their real names or post with recognizable usernames than younger cohorts. Older adults were much less likely than younger adults to report having key information about themselves online such as photos, date of birth, group membership, videos, or their cell phone number. This combination of findings suggests that older users lack knowledge about how to safeguard privacy (e.g., use complex settings on browsers to block cookies, clear history) rather than lack the desire for privacy. Middle-aged adults, those aged 30–49, express the greatest eagerness to control access to personal information such as content of emails, websites browsed, etc.

In terms of actual harm suffered, by having e-mail or SNSs compromised, or being stalked or harassed, young adults report the greatest incidence, except for having had important information stolen such as a credit card, bank information, or an SNS, where those age 30–49 report the highest frequency. Lower income was also a predictor of harm suffered.

With the requirement to cede privacy to participate in some aspects of modern technological life (e.g., being tracked, providing phone and e-mail contact), people must balance costs and benefits, and there is some evidence that older adults weight benefits more highly (Melenhorst, Rogers, & Bouwhuis, 2006). The salience of benefits can be boosted by functional impairments. The more disabled, the more willing older adults may be to accept technology that lowers privacy/confidentiality (such as aspects of health status) if they believe the technology will contribute to independence and quality of life (Beach et al., 2009). This result points to the critical role that motivational factors play in adoption.

TECHNOLOGY AS A FACTOR FOR SUCCESSFUL LONGEVITY

One reason for being concerned with the cohort lags in technology adoption is that older adults may miss out on opportunities to fully participate in society and also to have technology augment or substitute for declining abilities (e.g., memory: Charness, Best, & Souders, 2012) and support quality of life (Schulz, 2012). We next outline three examples where critical information or services have become available mainly through ICT access: travel, government services, and home health care.

Travel tickets used to be booked almost exclusively through travel agents. In much of the developed world, train tickets are most easily purchased through automated kiosk systems (or via the Internet) and there may be added cost for a purchase involving a human agent. In the United States there is a surcharge levied by most airlines if a consumer books an airline ticket with a human instead of on the Internet. As shown earlier (Figure 20.1), more than 40% of older Americans do not use the Internet and so either must pay higher prices for tickets or find others to book their fares (e.g., family members or friends). Not surprisingly, a Spanish study showed that older adults were more likely to use human check-in for flights versus Internet or airport kiosk check-in (Castillo-Manzano & López-Valpuesta, 2013). This trend to encouraging consumers to substitute their labor for employee labor will likely intensify (e.g., increased deployment of automated check-out kiosks in retail stores) and older adults may suffer, particularly those with limited financial resources.

A second critical area for older workers and retired adults is interacting with government services. The push to improve efficiency, by substituting technology for human responders, makes it increasingly time-consuming to apply for and to access services through routes other than the Internet. This is occurring for everything from tax advice to unemployment benefits to health care benefits. One example is that those seeking tax advice from the Internal Revenue Service (IRS) in the United States by telephone face at least a 20-min wait for service and the IRS estimated that 39% of calls in 2013 would go unanswered: http://www.taxpayeradvocate.irs.gov/userfiles/file/2013-Annual-Report-to-Congress-Executive-Summary.pdf. Those without Internet literacy skills risk being left behind and will face increased costs to access services.

A third area where ICT is becoming critical is in health care, through telemedicine/telehealth (Charness, Demiris, & Krupinski, 2011). ICT can improve access to health care and improve outcomes as a large UK randomized clinical trial has shown (Steventon et al., 2012). Rather than relying on patients visiting clinics or hospitals, health care providers are migrating services into homes. Chronic conditions which disproportionately affect older adults (e.g., arthritis, hypertension/heart disease, diabetes, cancer) can be monitored remotely. Remote telecare devices, such as videoconferencing systems, weight scales, pulse-ox monitors, blood glucose meters, and blood pressure devices, can communicate with health care professionals to provide continuous monitoring of health conditions via home Internet connections or through cellular network connections. Such systems are reaching reasonable levels of reliability (Charness, Fox, Papadopoulos, & Crump, 2013). However, telehealth systems can make demands on user capabilities that are typically impaired by age, for instance, requiring skillful psychomotor interaction (e.g., for battery maintenance). Health applications on smartphones and tablets can also tax older adult perceptual and cognitive capabilities. To the extent that seniors are not able to take advantage of such advances in health care they may become disadvantaged in achieving successful longevity.

CONCLUSIONS

The current generations of older adults lag younger cohorts significantly in the use of recent ICT resources, particularly the use of the Internet and features such as social networking and digital gaming. One can argue, based on surveys of non-users, that such activities may evoke little interest or have little value for older adults. As the research literature reminds us, some of these activities can promote improvements in cognition (gaming) and social integration (SNS).

So, why are older individuals less likely to engage in these activities? Theories of ICT adoption stress that a potential user perceives significant benefit (relative to cost) and perceives low barriers to entry (perceived ease of use). Learning cost is certainly an age-dependent barrier and theories about lifespan changes in motivation to learn would predict diminished interest in learning to use ICT, such as selective optimization with compensation (Baltes & Baltes, 1990) and socioemotional selectivity theory (Carstensen, Isaacowitz, & Charles, 1999). Better training support for ICT learning is going to be a critical feature for promoting adoption (Czaja & Sharit, 2012). Better design of hardware and software interfaces is critical too (Fisk et al., 2009).

Current theories of ICT adoption are more frameworks than theories in the sense that they have difficulty predicting (post-dicting) technology adoption without first (retrospectively) assessing someone's motivational and cognitive state with lengthy surveys. Having shorter instruments to assess user capabilities can help (Boot, Charness et al., 2015). The literature has identified many potential mediators and moderators for generally robust predictors such as perceived usefulness and perceived ease of use, with privacy a potentially important one for ICT adoption in health care situations. One approach to address this concern is to conduct applied studies such as interventions that build multiple technology applications based on different theoretical frameworks, looking for differential impact (King, Hekler, Grieco, Winter, & Sheats, 2013).

The ultimate test of a good theory is that it makes predictions that are borne out in real-world settings. The psychology of aging provides considerable data about older adult capabilities (Verhaeghen, 2013) that can provide design guidelines for ICT (Fisk et al., 2009). As Birren and Renner (1977) pointed out in the first *Handbook of the Psychology of Aging*, chronological age is a proxy variable for other causal variables that needs to be replaced. For example, the predictive value of chronological age for tasks like information seeking on the Internet by older adults can sometimes be totally subsumed by other variables, such as cognitive abilities and knowledge (Sharit, Hernández, Czaja, & Pirolli, 2009). One goal for theories of ICT adoption should be to replace age with better predictors, as seen in UTAUT frameworks. Another is to provide quantitative theories that can predict which of two potential technology designs leads to better performance (Jastrzembski & Charness, 2007). Such knowledge should help designers of technology products (and training and support packages) to provide greater benefit to older adult users.

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CHAPTER

21

Risk Factors and Prevention Strategies for Late-Life Mood and Anxiety Disorders

Lisa C. Barry[1] *and Amy L. Byers*[2]

[1]**University of Connecticut Health Center, Center on Aging, Farmington, CT, USA** [2]**University of California, San Francisco, CA, USA and San Francisco Veterans Affairs Medical Center, San Francisco, CA, USA**

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INTRODUCTION

Mood disorders, as specified in the Diagnostic and Statistical Manual of Mental Disorders—Fourth (DSM-IV) or Fifth Edition (DSM-V), include major depressive disorder, dysthymia (i.e., persistent depression), and bipolar I and II disorder. These disorders are rare in older persons, with 3.6% of persons age 65–74 years, and approximately 2% of old-old (75–84 years) and oldest-old (≥85 years) persons, experiencing any mood disorders (DSM-IV) within a 12-month period (Byers et al., 2010). Of the mood disorders, the prevalence of either bipolar I or II among older persons is particularly low, with prevalence estimates of 0.5–1.0% (Byers et al., 2010; Kessler, Berglund et al., 2005; Unutzer, Simon, Pabiniak, Bond, & Katon, 1998). In contrast, subsyndromal depression, the presence of depressive symptoms that do not meet DSM criteria for major depression, is more common with prevalence estimates among community-living persons age 65 and older ranging from 8% to 30% (Blazer, 2003; Forlani et al., 2014). Anxiety disorders including panic disorder, agoraphobia without panic, specific phobia, social phobia, generalized anxiety disorder (GAD), and posttraumatic stress disorder (PTSD), are also frequently experienced by older persons, with a 12-month prevalence estimate of 8.9% among those age 65–74 years, 6.0% in those 75–84 years, and 8.1% in the oldest old (Byers et al., 2010). As will be further discussed, late-life mood and anxiety disorders have similar risk factors, overlapping symptom profiles, and frequently co-occur. These disorders are also often difficult to disentangle from other conditions that affect the elderly, making diagnosis and treatment challenging. However, given that persons with mental illness are living longer and that the incidence of late-onset mood and anxiety disorders is expected to increase with the rapid aging of the population, the prevalence of older persons with these disorders is expected to increase.

LATE-LIFE DEPRESSION

Epidemiology of Late-Life Depression

The first portion of this chapter will largely focus on late-life depression. Major depression is a common feature of late-life bipolar disorder. Furthermore, findings from brain magnetic resonance imaging (MRI) studies consistently indicate that white matter hyperintensity (WMH) burden, a marker of white matter disease, is high in older persons with major depressive disorder or bipolar disorder indicating similar psychopathology. Similarly, risk factors, treatment, and prevention for major depression, dysthymia, and subsyndromal depression are non-distinguishable.

Large-scale epidemiologic studies indicate that the prevalence of major depressive disorder among community-living samples of adults age 65 and older is approximately 1–5%, with the majority of studies reporting prevalence between 1% and 2% (Blazer, 2003; Hasin, Goodwin, Stinson, & Grant, 2005). Of those older adults with major depression, some evidence indicates that approximately half are experiencing their first onset of depression in late life (i.e., late-onset depression) (Brodaty et al., 2001; Bruce et al., 2002). However, because most studies of depression in later life do not distinguish early versus late onset, it is difficult to provide accurate estimates. General consensus indicates that those with early-onset depression are more likely to have a genetic predisposition to depression or a personality disorder (Brodaty et al., 2001). Yet, as will be discussed, identification of genes that may be particularly important in the development of late-life depression has focused on those associated with vascular disease. In contrast, the percentage of older persons with clinically significant depressive symptoms is high. Clinically significant depressive symptoms are depressive symptoms that do not meet the criteria for major depression yet are considered clinically important given their association with functional impairment (Blazer, 2003; Hybels, Blazer, & Pieper, 2001; Lyness, King, Cox, Yoediono, & Caine, 1999; Lyness et al., 2007). Often referred to as depressed mood, subsyndromal depression, or simply "depression," clinically significant depressive symptoms affect between 8% and 30% of older persons living in the community (Blazer, 2003; Forlani et al., 2014), with 25–49% experiencing persistent symptoms (Barry, Abou, Simen, & Gill, 2012; Mackenzie, El-Gabalawy, Chou, & Sareen, 2014; Sneed, Rindskopf, Steffens, Krishnan, & Roose, 2008). Among older persons, white males age 85 years and older have been reported as having the highest prevalence of clinically significant depressive symptoms (18.9%) (U.S. Census Bureau, 65+ in the United States; U.S. Government Printing Office, Washington, DC, 2014).

Depression in older adults is a significant public health concern because it is associated with adverse outcomes across its broad spectrum. Older adults with depression, from major depression to subsyndromal depression, are more likely to experience increased health care costs (Katon, Lin, Russo, & Unutzer, 2003), exacerbation of co-existing medical illness (Carnethon et al., 2007), onset of disability in activities of daily living (ADLs; Barry, Allore, Bruce, & Gill, 2009; Barry, Murphy, & Gill, 2011; Penninx, Leveille, Ferrucci, Van Eijk, & Guralnik, 1999), and mortality (Penninx, Geerlings, et al., 1999; Unutzer, Patrick, Marmon, Simon, & Katon, 2002). Furthermore, both risk and protective factors are similar for major depressive disorder and clinically significant depressive symptoms.

Sociodemographic Risk Factors for Depression

Sex

It is well-established that the burden of depression is disproportionately higher among older women than men (Barry, Allore, Guo, Bruce, & Gill, 2008; Beekman, Copeland, & Prince, 1999; Sonnenberg, Beekman, Deeg, & van Tilburg, 2000), with this marked gender difference remaining throughout old age and only narrowing among the oldest old (Djernes, 2006). The prevalence of depression is not only higher among older women, but women are also more likely to have more severe depressive symptoms (Shanmugasegaram, Russell, Kovacs, Stewart, & Grace, 2012). Reasons for the preponderance of depression in older women do not appear to be an artifact of greater symptom reporting among women. Rather, this sex difference has been attributed to women's greater likelihood of having been exposed to risk factors for depression including lower income and having one or more chronic illnesses (Sonnenberg et al., 2000), and women's higher likelihood of experiencing depression onset and persistence of depressive symptoms (Barry et al., 2008). One study also reported that, once depressed, women have a lower likelihood of dying as compared with men (Barry et al., 2008). Whereas older men generally have higher mortality rates than older women, irrespective of depression, the findings from this aforementioned study showed a nearly threefold difference in the odds ratios for participants who were depressed compared with those who were not depressed. Women who were depressed were 75% less likely to die as compared with men who were depressed. In contrast, among the non-depressed, women were 20% less likely to die than men.

Race

Persons age ≥65 years in the United States are predominantly white but are becoming increasingly diverse. Whereas minority populations comprised approximately 20% of older adults in 2010, projections indicate that by 2050 the composition of the older population will be 58% non-Hispanic White, 20% Hispanic, 12% Black, and 9% Asian ("Older Americans 2012: Key Indicators of Well-Being," 2012).

Despite growing numbers of minorities living to older ages, whether or not race is a risk factor for mood disorders in later life is uncertain. The majority of studies focusing on race differences in mood disorders in later life have evaluated Black–White differences in depression. However, how depression is defined across studies contributes to the uncertainty regarding the role of Black–White race in late-life depression. Whereas the 12-month prevalence of major depression has been reported to be similar among older Whites and Blacks (Byers et al., 2010), some studies report that Blacks are more likely to experience clinically significant depressive symptoms, even after controlling for factors such as socioeconomic status (SES) (Barry et al., 2014; Jang, Borenstein, Chiriboga, & Mortimer, 2005). In the United States, SES and race are inextricably related, with Blacks having markedly fewer socioeconomic resources than Whites (LaVeist, 2005). Consequently, controlling for SES is particularly important in studies evaluating race differences in health outcomes. Other studies report the opposite or have found no association (Cohen, Magai, Yaffee, & Walcott-Brown, 2005; Gallo, Cooper-Patrick, & Lesikar, 1998). Longitudinal studies evaluating race differences in trajectories of depression symptoms indicate that as compared with older Whites, older Blacks are more likely to experience an increase in depressive symptoms (Skarupski et al., 2005) and an increase in depression onset (Barry et al., 2014) over time. However, findings from the Health and Retirement Study (HRS) and its companion study, the Asset and Health Dynamics among the Oldest Old (AHEAD), indicate that the rate of change in depressive symptoms over time is lower for older Blacks and Hispanics as compared with older Whites (Xiao, Liang, Bennett, Quinones, & Wen, 2010). Because older Blacks, more so than Whites, live in areas with lower-quality healthcare, neighborhood characteristics may contribute to older Blacks' (Beard et al., 2009) higher likelihood of experiencing depression onset or an increase in depressive symptoms. Among those with depressive symptoms, the lower rate of increase over time for minorities as compared with Whites, particularly among Hispanics, may be explained by minority persons' effective use of coping strategies in old age that they learned throughout life to deal with racial discrimination (Ferraro & Farmer, 1996).

Biological and Clinical Risk Factors for Depression

The Inter-relationship Between Cardiovascular Disease, Dementia, and Depression

Older adults with depression have an increased risk of developing cardiovascular disease and dementia. In fact, evidence that vascular disease is the underlying link between depression and dementia is strong (Byers & Yaffe, 2011). This link is largely grounded in the "vascular depression hypothesis" (Alexopoulos et al., 1997; Krishnan, Hays, & Blazer, 1997), which states that cerebrovascular disease predisposes to, precipitates or perpetuates some geriatric depressive syndromes (Alexopoulos, 2003, 2005). Although it has been suggested that vascular lesions and structural changes in the brain lead to depression in late life (Camus, Kraehenbuhl, Preisig, Bula, & Waeber, 2004; De Groot et al., 2000; Thomas, Perry, Barber, Kalaria, & O'Brien, 2002), the direction of such an association is debatable, as vascular disease or vascular lesions and depression are related to an increased risk of developing the other (Thomas, Kalaria, & O'Brien, 2004).

The pathway that explains the inter-relationship between vascular disease, depression, and dementia is probably not sequential. Prior depression is related to subsequent vascular disease through multiple proposed mechanisms, including behavioral conditions (e.g., smoking, inactivity), hypothalamic–pituitary–adrenal (HPA) axis dysregulation and elevated cortisol related to the metabolic syndrome, disruption of normal endothelial function and development of hypertension, and pro-inflammatory cytokines (Butters et al., 2008). As evidence, depression has been found to increase risk of first-ever myocardial infarction and stroke (Liebetrau, Steen, & Skoog, 2008). On the other hand, evidence that vascular disease promotes development of depression is well established. For example, risk of depression is substantially increased post-MI and post-stroke (Thomas et al., 2004). In addition, MRI studies have supported robust associations between ischemic brain lesions and depression or depressive symptoms in older adults (Herrmann, Le Masurier, & Ebmeier, 2008; Steffens, Krishnan, Crump, & Burke, 2002). Longitudinal studies provide evidence that large cortical lesions and severe subcortical white matter grade are significant risk factors for developing depressive symptoms (Steffens et al., 2002); with these changes predating and predicting late-life depression (Steffens et al., 2002; Teodorczuk et al., 2007).

The "vascular–depression–dementia hypothesis," is further supported by evidence that vascular disease contributes to the clinical manifestation of dementia symptoms (Flicker, 2008, 2010). Ischemic damage, largely in the frontostriatal brain regions, may lead to significant cognitive deficits (Alexopoulos, 2006). Finally, the ischemic damage to frontostriatal brain regions may explain the executive function deficits and psychomotor slowing that are common in late-life depression (Bruce et al., 2002; Butters et al., 2008; Sheline et al., 2008). This suggests that ischemic structural changes in the brain are a common etiologic factor of both the depression and the related cognitive impairment.

Other likely biological mechanisms linking depression to dementia include alterations in glucocorticoid steroid levels and hippocampal atrophy, inflammatory changes, deficits of nerve growth factors, and increased deposition of amyloid-β plaques (Byers & Yaffe, 2011). In particular, amyloid-associated depression, defined as the presence of clinical symptoms of depression and a high plasma $A\beta_{40}$:$A\beta_{42}$ ratio, may define a subtype of depression representing a prodromal manifestation of Alzheimer disease given its strong association with memory impairment (Sun et al., 2008). Recent findings from the Health Aging and Body Composition (Health ABC) Study have also found that older persons with a high $A\beta_{40}$:$A\beta_{42}$ ratio who also have an APOE e4 allele may be at increased risk for incident depression (Metti et al., 2013).

In summary, although research supports an association between late-life depression and risk of dementia, inconsistencies across individual studies exist. Because of the timing of many of these studies in late life, they cannot distinguish whether depression or depressive symptoms are a prodromal phase of dementia or consequence of the onset of AD or are a risk factor. In fact, the variability of the duration of follow-up (e.g., 0–17 years) and unknown frequency or duration of depressive episodes may explain the heterogeneity of findings. In contrast, earlier-life depression (typically defined as depression or depressive symptoms occurring before age 60) consistently has been found to be a risk factor for (and unlikely prodrome of) dementia (Jang et al., 2005). However, more longitudinal studies over the lifespan are necessary in order to fully understand the relationship between depression and depressive symptoms and risk of developing dementia in late life.

Disability

A large body of literature has evaluated the association between disability in ADLs (e.g., bathing, walking, dressing, transferring) and depression in older persons, with general consensus that these conditions are inextricably linked. However, some research points to a stronger influence of disability on subsequent depression than that of depression on disability (Chen et al., 2012; Ormel, Rijsdijk, Sullivan, van Sonderen, & Kempen, 2002). Stress theory (Avison & Turner, 1988; Pearlin, Lieberman, Menaghan, & Mullan, 1981) asserts that new disability or the ongoing psychological and physical stress of chronic disability alters homeostasis, thereby leading to depression. In turn, depression may alter neural, hormonal, or immunological function, subsequently resulting in disability. Whereas many cross-sectional studies and studies with one follow-up period have found a relationship between disability and depression in older persons (Bruce, 2001; Harris, Cook, Victor, DeWilde, & Beighton, 2006; Ormel et al., 2002), findings from large prospective cohort studies have contributed significantly to our understanding of this relationship. The Precipitating Events Project (PEP) (Gill, Desai, Gahbauer, Holford, & Williams, 2001), an ongoing prospective cohort study of 754 nondisabled members of a large health plan who were 70 years of age or older at study initiation in 1998, includes monthly self-reported assessments of ADL disability and assessments of depressive symptoms every 18 months. Findings from PEP have shown that not only is disability a salient risk factor for depression, but also that the burden of disability influences this relationship. Barry, Soulos, Murphy, Kasl, and Gill (2013) found that PEP participants' odds of experiencing clinically significant depressive symptoms, as assessed using the 11-item Centers for Epidemiologic Studies-Depression Scale (Kohout, Berkman, Evans, & Cornoni-Huntley, 1993), increased as the severity of their disability increased, with particularly high odds of depression among those with both chronic and severe disability as compared with those with no disability (OR = 2.42; 95%CI 1.78–3.30). These researchers also found that depression in older persons is not only associated with disability onset, but it is also associated with worsening severity of disability and a lower likelihood of recovering from disability (Barry et al., 2011).

Psychosocial Risk Factors for Depression

Social Support

What is now a vast literature detailing the influence of social support on health was spurned by Cassel (1976) and Cobb (1976), epidemiologists who suggested that investigation of this relationship was critical. Whereas earlier studies had described a link between socialization and depression (Paykel, Weissman, Prusoff, & Tonks, 1971; Paykel & Weissman, 1973), it was nearly two decades after the publication of the Cassel and Cobb studies that research began to accumulate regarding the impact of social support on the mental health of older persons. Early findings from the New Haven Established Populations for Epidemiologic Study of the Elderly (EPESE) indicated that the perceptions that one has adequate emotional support and available instrumental support each were independently associated with fewer depressive symptoms in older persons (Oxman, Berkman, Kasl, Freeman, & Barrett, 1992), with emotional support characterized by the amount of "love and caring, sympathy and understanding, and/or esteem or value available from others" (Thoits, 1995) and instrumental support referring to "help, aid, or assistance with tangible needs such as getting groceries, getting to appointments, phoning, cooking, cleaning, or paying bills" (Berkman & Kawachi, 2000). To date, a large number of studies have evaluated the association between social support and depression in older persons and have expanded the research to numerous related concepts including social network, social integration/connectedness, and social participation (Schwarzbach, Luppa, Forstmeier, Konig, & Riedel-Heller, 2014). Generally, qualitative aspects of social support (e.g., perceived emotional support; quality of relationships) seem to have a greater impact on depression in late life than quantitative aspects (e.g., number of members in one's social network). Furthermore, not all social support has a positive effect on depression. The perception of social support as excessive or unhelpful, often in regard to instrumental support, has been found to be associated with increased depressive symptoms in older persons (Nagumey, Reich, & Newsom, 2004). Increased resentment as one's independence is compromised may increase the likelihood of experiencing depression, despite the intentions of the one providing the support.

Bereavement

Whereas bereavement is a normal response to death accompanied by acute grief symptoms that typically attenuate over time, it is a severe stressor that can precipitate a mental health disorder. Prior studies have found an association between bereavement and major depressive disorder, with a meta-analysis of prospective studies indicating that the risk of experiencing depression in those age 50 and older was more than threefold among the bereaved (Cole & Dendukuri, 2003). However, while this risk is high, bereavement still confers a lower risk of depression in older persons as compared with younger and middle-aged adults. In terms of spousal death, which is common in older age, the risk difference between younger and older persons is largely attributed to the greater expectedness of a spouse's death in late life as compared with early or midlife (Blazer & Hybels, 2005). Earlier studies indicate that spousal bereavement has more negative psychological effects on men. Following the death of a spouse, men are more likely to become depressed and to be depressed longer. This gender difference has been attributed to older men's unfamiliar household management roles (Umberson, Wortman, & Kessler, 1992). As traditional societal gender roles continue to diminish, it will be interesting to determine whether gender will continue to influence the association between bereavement and depression among emerging cohorts of older persons.

Whether or not bereavement leads to negative mental health outcomes in older persons may also depend, in part, on the availability of social support and the context in which it occurs. Frequency of social contact has been found to be associated with better psychological health among widowed older persons (Beckman, 1981; Silverstein & Bengtson, 1994). However, more recent data from 209 widowed persons who were participants in the Changing Lives of Older Couples (CLOC) study indicate that the amount of social contact is not associated with depressive symptoms once degree of emotional support and the agreement between the widowed person's preferred and actual levels of social contact have been taken into consideration (Ha & Ingersoll-Dayton, 2011). These latter findings indicate that the emotional meaningfulness of social relationships may matter more to older persons' psychological health than the amount of actual contact. Relatedly, negative social relationships may also be associated with psychological health among older widowed persons. For example, results from one study that focused on changes in positive and negative support from the children of widowed older persons indicated that negative support was associated with increased anxiety and a decrease in positive support was associated with increased depressive symptoms (Ha, 2010).

While bereavement may be associated with depression, whether other more severe and chronic forms of grief can be distinguished clinically from bereavement-related depression has been debated for more than two decades (Prigerson et al., 1995). In fact, there was significant debate regarding whether or not complicated grief and/or prolonged grief disorder (PGD) should be included in DSM-V (Lichtenthal, Cruess, & Prigerson, 2004; Prigerson et al., 2009; Shear et al., 2011). Given that no consensus was reached regarding their inclusion, the "bereavement exclusion" was removed from the clinical criteria of depression and adjustment disorders (Wakefield & First, 2012). However, removal of that exclusion is also controversial mainly due to a worry that grief will become "medicalized" and grieving individuals may be inappropriately prescribed antidepressant medications. Consequently, "persistent complex bereavement disorder" is included in the DSM-V in a chapter on conditions needing further study.

LATE-LIFE ANXIETY DISORDERS

Epidemiology of Late-Life Anxiety Disorders

Although most information on late-life mental health disorders has focused on mood disorders, particularly major depressive disorder, the occurrence of anxiety disorders has been found to be as high or even higher. Nationally representative 12-month prevalence estimates from the National Comorbidity Survey Replication (NCS-R) determined that nearly 12% of older adults aged 55 years and older had any anxiety disorder compared with 5% having any mood disorder (Byers et al., 2010). In younger adults (18–44 years), the 12-month prevalence of any anxiety disorder was markedly higher (20.7%) than for older adults (Gum, King-Kallimanis, & Kohn, 2009). When stratified by young-old (55–64 years), mid-old (65–74 years), old-old (75–84 years), and oldest-old (≥85 years) US respondents, the prevalence was 16.6%, 8.9%, 6.0%, and 8.1%, respectively, for any anxiety disorder (Byers et al., 2010). In comparison, for any mood disorder, it was 7.6%, 3.6%, 1.8%, and 2.4%, respectively.

Among the NCS-R adults aged 55 years and older, the most prevalent anxiety disorder was specific phobia (6.5%), followed by social phobia (3.5%), PTSD (2.1%), GAD (2.0%), panic disorder (1.3%), and agoraphobia (0.8%). Similarly, anxiety disorders were the most prevalent disorders among those aged 65 years and older in the Epidemiologic Catchment Area Survey (5.5%) with phobic disorder the most prevalent individual disorder (4.8%) (Hybels & Blazer, 2003). In contrast, the Longitudinal Aging Study Amsterdam determined high rates of GAD (7.3% vs. 2.0% in the NCS-R) (Beekman et al., 1998). This discrepancy between reported prevalence rates highlights largely methodological differences (e.g., sampling procedures and attrition rates, definition and operationalization of anxiety) and potential cultural differences between population-based studies.

Risk Factors for Late-Life Anxiety Disorders

Despite the high prevalence of anxiety disorders in late life, risk factors associated with late-life anxiety have not been well studied or conceptualized. The limited research suggests that risk factors for anxiety are similar to those for depression. This is not surprising given the strong overlap between anxiety and depression seen throughout adult life and in late life (as described below). First, shared genetic risk has been found between GAD and depression (Kendler, Gardner, Gatz, & Pedersen, 2007). Secondly, research from the NCS-R has shown that anxiety disorders throughout the lifespan are associated with female gender, higher number of comorbid chronic medical conditions, being unmarried or divorced, and having less than a high school education (Gum et al., 2009). Furthermore, research suggests that cognitive impairment and dementia may be major risk factors for anxiety in late life (Seignourel, Kunik, Snow, Wilson, & Stanley, 2008); however, the overlap of symptomatology between anxiety and dementia complicates assessing the association. In addition, older adults with vascular dementia have been found to have higher prevalence of anxiety than older adults with Alzheimer's-type dementia (Seignourel et al., 2008), which suggests that anxiety in dementia may be related to the vascular risk for depression in late life.

LATE-LIFE CO-EXISTING MOOD AND ANXIETY DISORDERS

Epidemiology of Late-Life Co-existing Mood–Anxiety Disorders

Most US studies of co-existing mood and anxiety disorders have been clinically based and found high prevalence of comorbid anxiety in patients with depression (Lenze, 2003; Lenze et al., 2000, 2001). Twenty-three percent of older subjects (aged 60 years and older) with depressive disorders had a current anxiety disorder diagnosis (Lenze et al., 2000). The most common current co-existing anxiety disorders were panic disorder (9.3%), specific phobia (8.8%), and social phobia (6.6%). Interestingly, 27.5% of older subjects with depression had symptoms that met criteria for GAD. The prevalence went up to 45% GAD symptoms for those in the inpatient psychiatric subgroup. In contrast, nationally representative estimates from population-based research in NCS-R respondents documented that the 12-month prevalence of any co-existing mood and anxiety disorder was 3% among adults aged 55 years and older (Byers et al., 2010).

Characteristics of Co-existing Mood–Anxiety Disorders

Co-existing mood and anxiety disorders in late life appear to be largely delineated by the severity of somatic symptoms related to the mood or anxiety disorder, a decline in function, or a particularly high accumulation of individual risk factors for mood or anxiety. Consequently, there is growing support for the view that because many depressed individuals meet criteria for GAD, often only during the depressive episodes, the presence of GAD in a major depressive episode should be considered a severity marker rather than as a separate diagnosis. Supporting this line of reasoning, one study found that in older adults with depressive disorders, greater severity of depressive symptoms was associated with greater likelihood of GAD symptoms including poorer social function and high levels of somatic symptoms (such as sweating, nausea, and palpitations). However, this study also found that symptoms of GAD were independently associated with greater suicidality, even after controlling for severity of depressive symptoms (Lenze et al., 2000).

RISK FACTORS FOR LATE-LIFE SUICIDE AND SUICIDAL BEHAVIOR

Older adults who are living in the community have suicide rates comparable to or higher than any other age group (Conwell, Duberstein, & Caine, 2002), accounting for approximately 15% of deaths by suicide in the United States ("Medicare Improvements for Patients and Providers Act"). Older white men are at particularly high risk. Whereas older adults are less likely than younger adults to engage in suicidal behavior which includes suicidal ideation (i.e., thoughts, plans, or wishes to die or kill oneself) or overt actions such as a suicide attempt, older adults have a much higher likelihood of dying when they make a suicide attempt. For every completed suicide among older adults, an estimated 2–4 attempts occur (McIntosh, Santos, Hubbard, & Overholser, 1994), while in younger adults the ratio of completed suicide to attempts may be as high as 200–1 (Fremouw, dePerczel, & Ellis, 1990). This difference has been attributed to older adults' higher likelihood of using methods that are likely to result in a fatality, such as firearms; 67% of suicides among older adults occur via firearms.

Depression and prior suicide attempts are well-established risk factors for suicide that are shared by all age groups (National Institute of Mental Health, 2015). As compared with younger persons, however, suicide rates in older persons are more closely associated with major depression. Depression is the most common psychiatric diagnosis in older persons who died by suicide (Conwell, Van Orden, & Caine, 2011), and both population-based studies and psychological autopsy studies among persons who have died by suicide have found that the association between suicidal ideation and depression is significantly stronger in older persons than in younger persons (Dennis et al., 2007; Gaynes et al., 2004).

Older persons also have a distinct risk profile for suicide. Research has shown that 45% of older adults who die by suicide have seen a primary care provider within a month before their suicide (Luoma, Martin, & Pearson, 2002). Comorbid chronic medical illness, particularly that which results in inpatient hospitalization or need for home care, pain, loss of independence resulting from disability in ADLs such as bathing and dressing, loss of control over choices regarding one's health, and reduced sense of purpose are risk factors for suicide in older persons (Conwell et al., 2002, 2010; Juurlink, Herrmann, Szalai, Kopp, & Redelmeier, 2004). In addition, lack of social connectedness (e.g., social isolation, low social support) is an important risk factor for suicide among older adults which, in turn, may also make them less likely to be rescued after an attempt (Conner, Conwell, & Duberstein, 2001). Emerging research areas regarding risk factors for suicide in older persons include impulsivity in the context of cognitive impairment (Dombrovski et al., 2008; Erlangsen, Zarit, & Conwell, 2008) and change in living situation, such as a move to a long-term care facility (Mezuk, Rock, Lohman, & Choi, 2014).

Suicidal behavior, like suicide, is highly associated with depression and depressive symptoms, which are considered the major risk factors for such behavior. Whereas individual anxiety disorders have not been well established as risk factors for suicide in older persons, there is some evidence indicating that anxiety disorders are associated with suicidal behavior in this population. Lenze et al. (2000) found that symptoms of GAD were associated with greater likelihood of suicidal ideation above and beyond depressive severity and other comorbid anxiety disorders in older adults with depressive disorders. In a population-based study of older primary care patients from Australia, respondents with anxiety, defined by using clinically significant cutoff scores based on the Hospital Anxiety and Depression Scale, were nine times more likely to have suicidal ideation than those without anxiety (95% confidence interval (CI): 7.3–10.5). The association was 11-fold increased odds for those with depression (95%CI: 8.7–14.3), and went up to 29-fold increased odds of suicidal ideation for those with comorbid anxiety–depression (95%CI: 23.9–36.0) (Almeida et al., 2012). Relatedly, although PTSD has been established as a risk factor for completed suicide in younger veterans (Pompili et al., 2013; Sher, Braquehaid, & Casas, 2012), little is known about the association between PTSD and suicide risk in older adults. Studies of younger veterans have shown that PTSD is highly associated with suicide and suicidal behavior (Brenner et al., 2011; Pompili et al., 2013). In addition, PTSD, agoraphobia, GAD, panic disorder, social anxiety disorder, and specific phobia have been documented in nationally representative studies of younger adults as risk factors for suicidal behavior (Thibodeau, Welch, Sareen, & Asmundson, 2013). However, research is controversial in this area, and almost nothing is known about the impact of individual anxiety disorders on suicide or suicidal behavior in late life (Sareen, 2011).

DETECTION, TREATMENT, AND MANAGEMENT

Despite the prevalence of late-life mood and anxiety disorders, and their associated negative outcomes, these conditions are amenable to treatment through both pharmacologic and psychological/behavioral methods (Alexopoulos et al., 2009; Bruce et al., 2004; Charney et al., 2003; Wolitzky-Taylor, Castriotta, Lenze, Stanley, & Craske, 2010). Antidepressant medications are the most common treatment for depression in older persons (Mottram, Wilson, & Strobl, 2006) and because many antidepressants are safe and well-tolerated in this population (Mamdani, Parikh, Austin, & Upshur, 2000; Sonnenberg, Deeg, Comijs, van Tilburg, & Beekman, 2008), they are considered a first-line treatment for a spectrum of late-life depressive disorders, including clinically significant depressive symptoms (Alexopoulos et al., 2001). Receiving therapy from a mental health professional, such as a psychiatrist, psychologist, or counselor, also has been found to be effective in treating depression in this population (Cuijpers, van Straten, & Smit, 2006; Pinquart, Duberstein, & Lyness, 2006). However, although there are effective treatments for mood disorders and anxiety, there is widespread under-treatment of these conditions in older persons across multiple settings (Barry et al., 2012; Cuijpers et al., 2006; Pinquart et al., 2006; Sonnenberg et al., 2008). This under-treatment has largely been attributable to under-diagnosis resulting from a combination of physician, patient, and system-level factors (Mitchell, Rao, & Vaze, 2010; Park & Unutzer, 2011). Physicians may misdiagnose mood disorders as dementia, may mistakenly attribute symptoms of mood or anxiety disorders as an acceptable response to illness or loss of social support in late life, or may have limited time to address mental health during a routine office visit (Tai-Seale, McGuire, Colenda, Rosen, & Cook, 2007). Older patients also may be reluctant to report psychological symptoms (Lebowitz et al., 1997; Lyness et al., 1995).

Even if late-life mood and/or anxiety disorders are recognized, estimates indicate that over 50% of older adults symptomatic for a clinical diagnosis do not use mental health services (Klap, Unroe, & Unutzer, 2003; Klap et al., 2003). Data from the NCS-R show that there is a high prevalence of non-use of mental health services for older Americans (aged 55 years and older) meeting criteria for DSM-IV mood and anxiety disorders (Byers, Arean, & Yaffe, 2012), with the highest prevalence of non-use for specific phobia (79.5%), social phobia (69.7%), and GAD (65.6%). In contrast, rates of non-use were slightly lower for younger NCS-R adults (aged 54 years and younger), with non-use approximately 60% for moderate to serious psychiatric disorders (Kessler, Demler et al., 2005). However, among older NCS-R respondents with comorbid mood–anxiety disorders rates of non-use decreased to 50%, suggesting that severity of disorder increases use of mental health services (Byers, Arean, & Yaffe, 2012). Moreover, when considering the old-old and oldest-old age groups (as documented from the National Epidemiologic Survey of Alcohol and Related Conditions (NESARC)), non-use of mental health services is extremely high with approximately 90% of those with an anxiety disorder not using services and over 70% of those with a mood disorder not using services (Mackenzie, Reynolds, Cairney, Streiner, & Sareen, 2012). Research suggests that low perceived need, moderate resources, and low motivation for mental health care help to explain why services may not be sought by older adults, despite diagnosable mood and anxiety disorders (Byers et al., 2012). Furthermore, it is only recently that parity in Medicare copayments for both physical and mental health conditions was established via the Medicare Improvements for Patients and Providers Act [H.R. 6331; 110th Congress; July 15, 2008]. Prior to this legislation, Medicare recipients were required to pay 50% for mental health services, and 20% copays for both physical and mental health services did not take effect until 2014. Research will be needed to determine the impact of this legislation on mental health services use in older persons.

The majority of older persons who are diagnosed with a mood and/or anxiety disorder are subsequently treated and managed by primary care physicians who often lack training in geriatric specialty care (Crystal, Sambamoorthi, Walkup, & Akincigil, 2003; Harman, Veazie, & Lyness, 2006). More than a decade ago, collaborative care for depression was proposed as an approach for optimizing treatment and management of depression in primary care. The collaborative care model emphasizes care management and education via a depression care manager. The Improving Mood—Promoting Access to Collaborative Treatment (IMPACT) program for late-life depression, was the first multisite randomized control trial to compare collaborative depression care with usual care in a sample comprised entirely of older persons (Unutzer et al., 2001, 2002). Results from the IMPACT trial indicated that older persons receiving collaborative care for depression had higher treatment rates, higher satisfaction with depression care, and greater improvements in depression as compared with those receiving usual care. Albeit modest, findings from the IMPACT trial have also shown a positive impact of collaborative care for depression on physical activity and quality of life. Since publication of the IMPACT trial results, many other studies have confirmed the effectiveness of collaborative care programs in decreasing depressive symptoms in older persons (Chang-Quan et al., 2009), including special populations of older persons such as low-income elders, those with concomitant chronic illnesses (Katon et al., 2010), patients with recent cardiac events (Huffman et al., 2014), and those receiving home care. Furthermore, as evidenced through results from the Prevention of Suicide in Primary Care Elderly: Collaborative Trial (PROSPECT), a randomized controlled trial comparing treatment guidelines tailored for the elderly with care management and usual care, collaborative care may be useful for reducing suicidal ideation in depressed elders. "Stepped care" is another approach to managing depression in later life. This approach, which focuses on preventing the transition from subsyndromal depression to major depressive disorder, involves using methods such as watchful waiting, physical activity, and education before use of antidepressants. Treating older persons with subsyndromal depression as a means of preventing a full-blown disorder may have significant impact. Findings from the Amsterdam Study of the Elderly indicate that treating 5.8 older persons with subsyndromal depression may prevent one of these individuals from experiencing the onset of clinical depression within 3 years (Schoevers et al., 2006). These investigators estimate that treating all older persons with subsyndromal depression could prevent 24.6% of new depression onsets during a 3-year period (Schoevers et al., 2006).

Recent advances in neuroimaging have enabled investigators to evaluate structural and functional differences in the brains of individuals with and without late-life depression, thereby determining who may be more vulnerable to developing this disorder. The use of structural imaging methods in late-life depression, described in detail in two reviews (Benjamin & Steffens, 2011; Hoptman, Gunning-Dixon, Murphy, Lim, & Alexopoulos, 2006), has been especially useful in determining white matter lesion volume—a biomarker for classifying depression into vascular versus nonvascular depression (Sneed et al., 2008).

CONCLUSION

The majority of older persons maintain high levels of subjective well-being, even when faced with significant health problems and compromised physical function. However, the number of older persons experiencing mood and/or anxiety disorders is expected to increase with the continued growth of the older adult population. Late-life mood and anxiety disorders are characterized by heterogeneity, varying widely in both severity and chronicity, and ranging from subsyndromal depression and clinically significant depressive and/or anxiety symptoms to a full-blown major depressive disorder or a co-morbid mood-anxiety disorder. Regardless of whether or not an older person's symptoms confer a clinical diagnosis, individuals who experience a late-life mood or anxiety disorder may be particularly vulnerable to both the onset and worsening of chronic illness and disability, and they are at higher risk for suicide and non-suicide-related mortality. Consequently, mood and anxiety disorders are a considerable public health problem for older persons.

There is general consensus that risk factors for late-life mood and anxiety disorders include genetic vulnerability, physical illness and disability, and psychosocial factors such as lack of social support. While these risk factors have been evaluated independently, research examining how these risk factors interact to affect the onset and/or worsening of late-life mood and anxiety disorders is sorely needed. This line of research will also help to improve our understanding of how some older persons are resilient in the face of challenges such as disability or grief, while others are more apt to experience late-life mood and anxiety disorders when confronted with the same challenges.

Effective treatments for late-life mood and anxiety disorders are available. However, there is still substantial under-treatment of these disorders in this population. With clinicians likely to see increasing numbers of older patients in the near future, improved understanding of risk factors is necessary to improve recognition of late-life mood and anxiety disorders and to help inform intervention and prevention efforts in older persons.

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CHAPTER

22

Late-Life Sleep and Sleep Disorders

Christina S. McCrae[1], *Megan E. Petrov*[2], *Natalie Dautovich*[3], *and Kenneth L. Lichstein*[3]

[1]Department of Clinical and Health Psychology, University of Florida, Gainesville, FL, USA
[2]College of Nursing and Health Innovation, Arizona State University, Phoenix, AZ, USA
[3]Department of Psychology, The University of Alabama, Tuscaloosa, AL, USA

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LATE-LIFE SLEEP AND SLEEP DISORDERS NORMAL LATE-LIFE SLEEP

In meta-analyses of cross-sectional studies, the sleep of relatively healthy older adults has been observed to be lighter (lower percentage of deep sleep stage N3 and higher percentage of light sleep stages N1 and N2) and more disrupted (longer time to fall asleep, increases in awakenings, greater difficulty in falling back to sleep) compared to younger adults (Ohayon, Carskadon, Guilleminault, & Vitiello, 2004). The profound reduction in deep sleep or stage N3 (i.e., delta [0–4 Hz] frequency EEG) is most prominent in men (Redline et al., 2004). This reduction is reflected in decreases both in the amplitude and prevalence of delta wave activity (Feinberg & Campbell, 2003). The shifts in sleep architecture tend to occur prior to 60 years of age and then reach a plateau; whereas, sleep continues to become more fragmented as older age progresses until late older adulthood (≥90 years). Older individuals also have been reported to have shorter sleep durations (Espiritu, 2008), and to be more phase advanced in the timing of their sleep such that they fall asleep earlier in the evening and wake earlier as well. However, the evidence is equivocal. The reasons for all of these age-related sleep changes are unclear. Changes in physical and psychological health as well as social rhythms may be contributory (Vitiello, Moe, & Prinz, 2002), and normal age-related changes in multiple neurobiologic substrates (e.g., growth hormone, cortisol, proinflammatory cytokines, hypocretin/orexin, serotonin, adenosine) may also play a substantial role in the quality, quantity, and timing of late-life sleep.

EPIDEMIOLOGY OF SLEEP DISORDERS IN LATE LIFE

Insomnia

Insomnia is defined as a complaint of one or more of the following: difficulty initiating sleep, maintaining sleep, waking up too early, and/or nonrestorative sleep (Bloom et al., 2009). These complaints are accompanied by daytime functioning impairments, and they occur in the context of sufficient opportunity to get the desired amount of sleep. The most commonly used classification systems used to diagnose insomnia are the Diagnostic Statistical Manual of Mental Disorders-5 (DSM-V; American Psychiatric Association [APA], 2013) and the International Classification of Sleep Disorders-2 (ICSD-2; American Academy of Sleep Medicine [AASM], 2005). Both systems define insomnia in concert with the previously described definition. The most recent edition of the DSM, the DSM-V, cross-references with the insomnia diagnoses in the ICSD-2.

TABLE 22.1 Studies Citing Prevalence of Insomnia and SDB in Older Adults

First author/ publication year	Country	Sample size	Age (years)	Method of sleep data collection	Prevalence estimate
INSOMNIA					
Bonanni/2010	Italy	1427	≥65	Reported complaint of insomnia symptoms	44.2%
Gureje/2009	Nigeria	2152	≥65	Reported complaint of insomnia symptoms	30.7%
Leger/2000	France	2456	≥65	Reported complaint of insomnia symptoms and related daytime impairment	20.4%
Lichstein/2004	United States	772	≥60	Reported complaint; sleep diaries with SOL or WASO ≥31 min, ≥3 nights per week, ≥6 months' duration; impaired daytime functioning	60–69: *M* = 9%, *W* = 17% 70–79: *M* = 23%, *W* = 26% 80–89 + : *M* = 23%, *W* = 41%
Liu/2005	China	1820	≥65	Reported complaint of insomnia symptoms and related daytime impairment	32.9% insomnia symptoms; 8.9% insomnia symptoms with daytime consequences

M, men; SOL, sleep-onset latency; W, women; WASO, wake after sleep onset.

The prevalence of insomnia in older adults varies across studies because of the different assessment methods used. Hence, the prevalence ranges from 9% to 44%, with higher rates obtained when insomnia was diagnosed without consideration of daytime impairments or the duration and frequency of the insomnia (see Table 22.1; Bonanni et al., 2010; Foley et al., 1995; Gureje, Kola, Ademola, & Olley, 2009; Leger, Guilleminault, Dreyfus, Delahaye, & Paillard, 2000; Liu & Liu, 2005). Across the lifespan, insomnia and general sleep disturbance are more prevalent among women than men, and this gender difference widens in older adulthood (Grandner et al., 2012).

Advanced Sleep Phase Disorder

Advanced Sleep Phase Disorder (ASPD) is a type of circadian rhythm sleep disorder. It is characterized by sleep and wake times that are typically more than 3h earlier compared to societal norms, and often it is accompanied by excessive sleepiness during the afternoon and evening, and early morning awakenings (Reid & Zee, 2011). The quality and duration of the sleep during this time period is usually normal (Reid & Zee, 2011). Nonetheless, ASPD, according to both the DSM-V and the ICSD-2, is characterized by complaints of difficulty staying awake in the evening and inability to maintain sleep until a preferred time in the morning. The prevalence of ASPD among older adults is undetermined; however, it is commonly considered to be more prevalent in late-life because a fifth of older adults report early morning awakenings (Foley et al., 1995).

Sleep-Disordered Breathing

Sleep-Disordered Breathing (SDB) is defined as partial (i.e., hypopnea) to complete (i.e., apnea) cessations in breathing during sleep (Bloom et al., 2009). The most prevalent type of SDB is obstructive sleep apnea (OSA), which consists of apneas and hypopneas, caused by complete (apneas) or partial (hypopneas) obstructions in the upper airway (Bloom et al., 2009), occurring five or more times per hour of sleep (i.e., the apnea–hypopnea index, AHI), with accompanying respiratory effort (AASM, 2005). The patient usually experiences excessive daytime sleepiness and unintentional sleep bouts as a consequence of interrupted sleep during the night due to these respiratory events. In the earliest large-scale study of sleep apnea in middle-aged adults, the prevalence of OSA was 2% in women and 4% in men (Young et al., 1993). However, in population-based studies of older adults the prevalence ranges from 15% to 24% when only the AHI is considered (Ancoli-Israel et al., 1991; Phillips et al., 1992).

ASSESSMENT

The essential parts of an initial sleep assessment given by a geropsychologist include a comprehensive clinical interview of the patient's sleep and daytime functioning as well as their medical, psychiatric, and substance use histories (Schutte-Rodin, Broch, Buysse, Dorsey, & Sateia, 2008). Once the initial retrospective assessment is administered, a prospective assessment is typically conducted by instructing the patient to complete 2-weeks' worth of sleep diaries. Depending on the nature of the patient's symptoms, current medical conditions, or ability to complete the diaries, objective measures of sleep such as polysomnography (PSG) or actigraphy, and medical laboratory testing may be needed. If their symptoms or current medical conditions indicate they may be high risk for sleep disorders, then objective measurement of sleep is recommended. For more detailed guidelines of the assessment of specific sleep disorders, please see the ICSD-2 (AASM, 2005).

Main Methods of Sleep Assessment

Both objective and subjective measurement approaches are important in assessing sleep in the older adult. The extent of use of either type depends on the specific sleep disorder in question.

Subjective Assessments

Sleep diaries are the best measure of subjective sleep because they are the least expensive and most time efficient (Lichstein, Durrence, Riedel, Taylor, & Bush, 2004). Recently, sleep diaries for adults were standardized to allow for direct comparison across research studies and clinical examinations (Carney et al., 2012). Sleep diaries do not alter the natural sleep environment or routines; thus, they are relatively accurate accounts of the patient's sleep from his or her own perspective. Sleep diaries also are less prone to recall bias in comparison to single-point retrospective accounts of sleep, which tend to overemphasize the poorest nights of sleep (Gorin & Stone, 2001). Sleep diaries provide prospective, albeit not in vivo, accounts of multiple sampling points that can be averaged to obtain a more representative sleep estimate than retrospective estimates. However, they are not without their disadvantages. Specifically, the three major disadvantages of sleep diaries are that they: (i) are prone to some measurement error because they are based on an individual's estimates of sleep patterns, (ii) cannot provide information on the presence and amount of sleep stages throughout the night, and (iii) do not record certain, unobserved sleep symptoms (e.g., apneic events, limb movements). Nonetheless, their accuracy relative to objective measures is similar (Lichstein et al., 2004).

Objective Assessments

PSG, the gold standard in the objective assessment of organic sleep disorders, traditionally lasts one to three nights in duration. These overnight visits can be expensive, inconvenient, and time-consuming. Older adults, who are suspected of having SDB, but have mobility issues, other safety concerns, or who are critically ill, may be good candidates for portable PSG monitoring. However, a comprehensive sleep evaluation is still required to confirm the diagnosis. In-laboratory PSG is known to create the "first night effect," which means that sleep is substantially altered by the new environment and equipment (Kales & Kales, 1984). For older adults who have considerable difficulty overcoming the "first-night effect," portable PSG monitors may also be an option.

Wrist actigraphy is another measure of objective sleep. However, compared to PSG the number of measures it offers is limited (measures sleep continuity, duration, and timing only). However, its advantages include its ability to record sleep patterns and circadian rhythms over several weeks, and it is not as costly or as cumbersome as PSG (Ancoli-Israel et al., 2003). Actigraphy should always be used concurrently with sleep diaries to allow for verification of bedtimes and wake-times. In particular, actigraphy will help distinguish sleep from sedentary activity among older adults with a sedentary lifestyle (Ancoli-Israel et al., 2003). In cases of older adults who have difficulty recalling their sleep patterns, such as persons with dementia, actigraphy is a good option, particularly when combined with additional information from a proxy respondent.

SLEEP DISORDERS

Insomnia

Development

The development of insomnia has been conceptualized as following a progression from a premorbid or predisposing state to the experience of an acute, precipitating event that induces transient sleep disruption, and then in response, the adoption of behaviors and cognitions that are often intended to compensate for poor sleep but result in the perpetuation of the sleep disruption (Spielman & Glovinsky, 1991). Examples of predisposing factors that would increase the likelihood of responding to a precipitating event with subsequent sleep disruption are impaired plasticity, hyperarousal (discussed below), personality factors, and family history. Precipitating events vary in content, duration, and quality, but the core component of the precipitating event is that it is perceived as stressful. Perpetuating factors are behaviors and cognitions that in the short term appear to be logical solutions to eliminating sleep disruption (e.g., napping, extending time in bed, consuming sedating substances to fall asleep and stimulating substances to assist with wakefulness, etc.). Over the long term these behaviors and cognitions can create greater sleep pattern variability, a non-sleep-promoting environment, and unrealistic expectations of the sleep experience. Collectively, these behaviors and cognitions can perpetuate the sleep disruption beyond the duration of the original precipitating event.

Major Theories

Hyperarousal has been conceptualized as a predisposing factor for insomnia and a characterizing feature of the insomnia experience. A review on the hyperarousal model of insomnia by Riemann et al. (2010) stated that insomnia is actually a 24-h psychobiological disorder because its etiology is associated with alterations in neurobiological substrates as well as psychosocial stress, and maladaptive behaviors and cognitions. The evidence accumulated supports this model in younger adults, but little evidence is available in older adults, and the data available suggest the model does not fit older adults as well (Dzierzewski, O'Brien, Kay, & McCrae, 2010). The reason may be that late-life insomnia is generally characterized by comorbid insomnia. Thus, several interacting biological and medical factors may be competing with the influence of hyperarousal on the insomnia experience and presentation in older adults. A model of late-life insomnia should account for the effects of comorbid conditions, normal age-related alterations in sleep, and an array of biopsychosocial factors, including hyperarousal.

Risk Factors for Late-Life Insomnia

Comorbidities

Multiple comorbid medical (e.g., cardiovascular and pulmonary diseases), psychological (e.g., depression, anxiety disorders), and pain-related conditions (e.g., osteoarthritis) are common precipitants to insomnia. However, insomnia is not regarded as "secondary" to the condition. Insomnia co-occurring with another medical or psychiatric condition is termed "comorbid" because the evidence suggests that insomnia, even if precipitated by an illness, can often become independent and self-sustaining as the patient responds to the sleep disturbance with well-meaning but self-defeating compensatory behaviors (sometimes called safety behaviors) and cognitions that ultimately perpetuate the disturbance (National Institutes of Health [NIH], 2005).

Social and Behavioral Changes

Many psychosocial and lifestyle factors tend to change in older adulthood, such as the transition to retirement, loss and bereavement, and decreased activity (Wolkove, Elkholy, Baltzan, & Palayew, 2007). The body's natural drive to maintain a balance between sleep and wake, also known as the sleep homeostat, can be negatively affected by these changes by reducing sleep drive.

Cognition

Within the definition of insomnia, the patient must perceive and report their sleep as disturbing. The perception and appraisal of one's sleep disturbance is a key cognitive factor in the transition from acute to chronic insomnia. Cognitive activity that is emotionally laden or highly arousing may perpetuate the insomnia. The normal age-related changes in the quality of cognitive processing (e.g., reduced processing speed and controlled attention) may increase the risk for perceptions and appraisals of sleep as disturbed. Dzierzewski et al. (2010) proposed that reductions in controlled attention specifically may alter the perception of initial and middle of the night sleep onset through disrupting the normal deactivation of sensory processing and consciousness centers. Furthermore, once a sleep disturbance is ongoing, the poor sleep may interact with current cognitive functioning and perpetuate the problem.

Socioeconomic Status

Poverty and low levels of educational attainment are related to greater sleep disturbance and insomnia complaints (Patel, Grandner, Xie, Branas, & Gooneratne, 2010). In a recent analysis of the National Health and Nutrition Examination Survey (2007–08) that examined the unique effects of various socioeconomic status (SES) indicators, lower educational attainment, no health insurance, and low food security were associated with increased likelihood of sleep complaints (Grandner et al., 2013). Although not thoroughly investigated, the pathways through which SES relates to insomnia symptoms may include low social support (Troxel, Buysse, Monk, Begley, & Hall, 2010), an unhealthy lifestyle (Gerber, Brand, Holsboer-Trachsler, & Puhse, 2010), and food insecurity (Grandner et al., 2013).

Hypnotic Dependence

Although not necessarily a traditional risk factor, hypnotic dependence is related to maintenance of chronic insomnia. Hypnotic-dependent insomnia is the presence of insomnia symptoms and complaints despite chronic use of hypnotic medications to treat the sleep disturbance. Often when a patient attempts to withdraw from the hypnotic, the insomnia temporarily worsens which incentivizes the patient to continue using hypnotics despite little to no efficacy (Dzierzewski, O'Brien, Kay, & McCrae, 2010). Because older adults seeking treatment for insomnia are likely to receive hypnotic medications as the first-line treatment, their risk of developing hypnotic-dependent insomnia is high.

Special Populations

Certain neurological diseases that are more prevalent in the elderly (i.e., dementia, Alzheimer's disease, Parkinson's disease) tend to interfere with the sleep and wakefulness of these patients (Rose & Lorenz, 2010). Caregivers to these patients are not immune to sleep disturbances themselves and often have multiple risk factors for insomnia, including nighttime disruptive behaviors from their patients (i.e., sundowning in Alzheimer's), caregiving-related stress, and age-related comorbidities. Hypnotic medications are often prescribed to patients with neurological diseases (McCrae, Dzierzewski, & Kay, 2009). However, their efficacy is not well established, and hypnotics are associated with a slew of side effects known to affect cognitive functioning (Deschenes & McCurry, 2009).

Assessment

Because insomnia in older adults is often comorbid with other chronic conditions, thorough assessment of other diagnoses, including other sleep disorders, is necessary to determine all medical, substance-related, and psychiatric factors that may be contributing to the insomnia complaint. Further, the geropsychologist must determine whether the complaint matches that of normal age-related changes in sleep or is beyond these changes.

Interventions

Pharmacological

Older adults with insomnia are most commonly prescribed hypnotic medications (Dzierzewski et al., 2010). A range of medications are indicated for the treatment of insomnia (e.g., benzodiazepine receptor agonists, sedating antidepressants, melatonin); however, they are not without their side effects. Even the newer benzodiazepine receptor agonist drugs (e.g., zolpidem, zaleplon, zopiclone, eszopiclone), which were designed to reduce negative side effects, are associated with impaired cognitive functioning, daytime sleepiness, an increased risk of falls, and parasomnia-like symptoms, such as sleep walking and eating. Both the increased risk of falls and sleep walking are particularly salient to older adults. Most hypnotics are indicated for short-term use (e.g., a week or two). Beyond that timeframe the patient's potential for tolerance and dependence increases (McCrae, Nau, Taylor, & Lichstein, 2006). If psychological treatments are unsuccessful or the insomnia is in its acute phase, then hypnotics should be considered for the short term.

Several hypnotic medications have demonstrated efficacy for 3–6-month use from double-blind, randomized, placebo-controlled trials; however zaleplon is the only medication that was tested in older adults for those lengths of time (Ancoli-Israel et al., 2003). In a meta-analysis of 24 randomized controlled trials of various durations of hypnotic administration among older adults, hypnotic medications once again demonstrated efficacy in improving sleep quality and reducing nighttime awakenings (Glass, Lanctot, Herrmann, Sproule, & Busto, 2005), but the magnitude of the improvements was small to moderate (Cohen's d of 0.14 and 0.63, respectively). Additionally, there were more adverse events with the medications in comparison to placebo. The most commonly reported events were motor vehicle accidents, falls, daytime fatigue, and cognitive events. Glass and colleagues indicated that the benefit–risk ratio for hypnotic use among older adults with insomnia was not favorable.

An alternative pharmacologic treatment for older adults is melatonin. Melatonin is a common over-the-counter sleep aid that is not regulated in the United States though it is licensed in Europe and other countries. Prolonged-release melatonin has been found to improve sleep and morning alertness among middle-aged to older adults with no evidence of withdrawal effects or rebound insomnia upon discontinuation (Lemoine, Nir, Laudon, & Zisapel, 2007), but here too, treatment effects are small (reduction in sleep-onset latency of 12 min; Buscemi et al., 2005).

Psychological

The symptoms and etiologies of late-life insomnia are often numerous and complex, requiring a multifaceted treatment approach. Cognitive and behavioral treatments for insomnia, such as sleep education, relaxation therapy, sleep hygiene, stimulus control, sleep restriction, and cognitive therapy (see Table 22.2; Carney & Edinger, 2010), have demonstrated efficacy, with a collective package of these treatments having the most impact. This package is termed cognitive-behavioral therapy for insomnia (CBT-I). CBT-I has demonstrated substantial treatment efficacy across many trials for both primary and comorbid insomnia (moderate-to-large effect sizes: 0.65–0.94) on outcomes of insomnia symptoms (Irwin, Cole, & Nicassio, 2006), as well as daytime and mood-related symptoms. Approximately 70–80% of patients exhibit improvements in sleep, post-treatment (Morin, Culbert, & Schwartz, 1994). Older adults with insomnia also have shown significant improvement in their insomnia symptoms (Edinger & Sampson, 2003; Pallesen et al., 2003). Because of the evidence, CBT-I is now regarded by national agencies as the first-line treatment for chronic insomnia above and beyond that of pharmacological interventions.

Psychological and Pharmacological Approaches Combined

A combined treatment approach with CBT-I and hypnotic medication may be beneficial for older adults. A four-condition study (CBT-I, CBT-I + temazepam, temazepam, and placebo) found that all treatments improved insomnia at similar magnitudes compared to placebo (Morin, Colecchi, Stone, Sood, & Brink, 1999). Though the participants reported they preferred CBT-I, and over 2-year follow-up, CBT-I alone was more efficacious than the other active treatment conditions. Variation in the efficacy of combined treatment (CBT-I + zolpidem) compared to CBT-I or zolpidem alone was also found in a study of older adults (Morin et al., 2009). At post-treatment, all treatment conditions produced equivalent improvements in sleep continuity as well as comparable rates of response and remission; though combined treatment had an earlier response. However, at follow-up, the efficacy of the combined therapy when participants continued to take zolpidem was not as optimal compared to participants that discontinued medication after initial treatment. This result led Morin and colleagues to recommend that hypnotic administration occur first followed by behavioral treatment and hypnotic discontinuation. Overall, combination therapy is not consistently better than CBT-I alone; therefore, the AASM recommended that, in practice, CBT-I alone should be used whenever possible (Schutte-Rodin et al., 2008). If combined therapy for older adults does occur in practice, then lower doses of hypnotic medications should be used as well as strategic timing of medication administration for other comorbid conditions.

CBT-I and Hypnotic Reduction

Even without discontinuation of hypnotic medication, CBT-I is effective in improving insomnia (Soeffing, Lichstein, & Nau, 2008). Simultaneous CBT-I and discontinuation of hypnotic medications among hypnotic-dependent participants has also been found to improve sleep, and treatment benefits were maintained at 1-year follow-up (Lichstein et al., 2013). CBT-I, as a strategic tool for hypnotic medication discontinuation among dependent patients, has also been found to be effective (Baillargeon et al., 2003). Overall, the evidence suggests that CBT-I can be used effectively for

TABLE 22.2 Multicomponent CBT-I

SLEEP HYGIENE
1. Eliminate or reduce caffeine use after 12 pm **2.** Do not drink alcohol within 2h of bedtime **3.** Do not use tobacco within 2h of bedtime **4.** Do not eat heavy meals within 2h of bedtime **5.** Do not exercise within 2h of bedtime (though routine exercise is encouraged)
STIMULUS CONTROL
1. Lie down to go to sleep only when you are sleepy **2.** Do not use the bed for anything except sleep and sex. Do not eat, read, watch television, or worry in bed **3.** If you cannot fall asleep within 10 min, get up and go to another room. Only return to bed when you feel sleepy again **4.** If you return to bed and still cannot fall asleep, repeat Step 3. Do this as often as necessary throughout the night **5.** Set your alarm and get up at the same time every morning regardless of how much you slept during the night. This will help your body acquire a constant sleep rhythm **6.** Do not nap during the day
SLEEP RESTRICTION/SLEEP COMPRESSION
• Aims to match the patient's time spent in bed to their actual time spent sleeping • Prescribe bed and wake times that more closely reflect time spent asleep • Sleep restriction abruptly tailors the time in bed to reflect sleep needs • Sleep compression gradually reduces time spent in bed to match sleep time
RELAXATION
• Diaphragmatic breathing, biofeedback, imagery, and meditation are all appropriate relaxation approaches for insomnia treatment • Progressive muscle relaxation (PMR) is an empirically supported treatment by the AASM • Leading patients through a deep breathing exercise, followed by alternatively tensing and relaxing muscle groups (e.g., arms, neck, back, legs) while attending to feelings of relaxation during and after the process
COGNITIVE THERAPY
• Identifying maladaptive beliefs about sleep and replacing them with more adaptive thoughts and attitudes • Integrates basic education about sleep; understanding normative sleep patterns and experiences can be helpful in addressing mistaken beliefs about sleep

sleep improvement in the case of simultaneous hypnotic use and medication tapering and withdrawal.

Advanced Sleep Phase Disorder

Development

Desynchronization between environmental factors (such as the light–dark cycle) and internal circadian timing mechanisms is at the root of circadian rhythm disorders. For shift work disorder or jet lag, the desynchronization occurs as a result of environmental factors such as working night shift. For circadian rhythm disorders such as ASPD, however, the desynchronization is a result of a disrupted internal timing system (Reid & Zee, 2011). As a result, the sleep–wake cycle of an individual with ASPD becomes out of sync with their external environment.

Major Theories

Several hypotheses have been proposed to explain the development of ASPD in older adults including shortening of the endogenous length of the sleep period, alterations in response to light, and gene polymorphisms. First, researchers have investigated the hypothesis that the intrinsically driven circadian period shortens with age. That is, if the 24-h period encompassing sleep and wake was shortened in older adults, they may experience a phase advanced relative to younger adults. Conflicting results from both animal and human studies suggest that the circadian period is likely not shortened with age, and, therefore, not responsible for a higher prevalence of ASPD in older adults (Welsh & Ptacek, 2010). Second, age-related behavioral and physiological changes affecting exposure to light may contribute to ASPD in older adults. Older adults, especially those residing in long-term care settings, may receive less bright-light exposure or light exposure in the evening which could help to delay the circadian phase. Even when older adults are exposed to light, changes in vision with age such as the formation of cataracts and macular degeneration can diminish the amount and spectral composition of light absorbed (Kim et al., 2014). Third, genetic analyses using familial studies of ASPD have identified genetic factors implicated in ASPD (i.e., the circadian clock gene *hPer2* (Toh, Jones, He, Eide, & Vinz, 2001), CKI-delta mutation (Xu et al., 2005); Reid & Zee, 2011).

Assessment

ASPD may be under-diagnosed as symptoms of ASPD may appear similar to symptoms of other disorders. For example, older adults may complain of unwanted early morning awakenings similar to symptoms of depression. Also, older adults may identify the unwanted early wake time as insomnia, when, in fact, their sleep is good but just advanced. Lastly, complaints of excessive daytime sleepiness may: (i) reflect the advancing of the sleep phase rather than decreased alertness during the day (Reid & Zee, 2011) or (ii) could reflect a resistance to the ASPD that results in later bedtimes and less sleep time, resulting in daytime sleepiness (Neikrug & Ancoli-Israel, 2010). Unlike delayed sleep phase disorder, which can interfere with morning activities, the earlier bedtimes seen with ASPD are less likely to interfere with societal demands and, therefore, ASPD may be underreported (Welsh & Ptacek, 2010). Assessment for ASPD consists of monitoring sleep over an extended period (e.g., 14 days) using sleep diaries or actigraphy to identify a consistent advance of the sleep period (AASM, 2005).

Interventions

Two approaches are primarily recommended for the treatment of ASPD: chronotherapy and phototherapy (Morgenthaler et al., 2007). Chronotherapy uses sleep-scheduling to delay the timing of the sleep–wake cycle. Bedtime is delayed until a desired time to fall asleep is reached. For example, if the individual currently falls asleep at 6 pm, they would successively delay the onset of sleep, starting with 7 pm, followed by 8 pm the next night, 9 pm the next night, and so on until the desired bedtime is reached. As delaying sleep onset can be difficult due to excessive sleepiness, engaging in sufficiently stimulating activities can help to prolong wakefulness. Phototherapy is a second approach to treating ASPD. Generally, phototherapeutic approaches involve limiting exposure to morning light and increasing exposure to evening light (Morgenthaler et al., 2007). The older individual should sleep in a darkened room and limit early morning light exposure through the use of blackout curtains. Sunglasses can also be used to reduce morning light exposure while outside. They should seek outdoor light exposure in the late afternoon and early evening and use bright lights during the evening (Welsh & Ptacek, 2010).

Sleep-Disordered Breathing

Development

Upper airway collapse resulting in OSA events is often due to several anatomic and neuromuscular factors, such as age-related loss of muscle and muscle tone, excessive bulk of tissues, and/or abnormality in craniofacial structures (i.e., maxillomandibular malformation, enlarged adenoids or tonsils). Therefore, loss of airway patency with age increases risk for developing SDB (AASM, 2005).

Type—OSA Versus Central Sleep Apnea

In contrast to OSA, central sleep apnea (CSA), another major type of SDB, consists of recurrent episodes of apnea resulting from a loss of ventilatory drive (Bloom et al., 2009). No obstruction of the airway occurs in CSA. CSA is induced by one of two physiological mechanisms. The first is post-hypocapnia (reduction in arterial carbon dioxide [$PaCO_2$]) hyperventilation, and the second is hypoventilation due to instability in the neuromuscular output from the respiratory control system (Aurora et al., 2012). CSA events occur most often during wake to sleep transitions when $PaCO_2$ levels may be insufficient to maintain alveolar ventilation. Medical conditions associated with CSA events are neurological diseases, pulmonary diseases, congestive heart failure, stroke, and renal failure. All of these diseases are also more common in older adults. Persons with insomnia may also be susceptible because of the numerous transitions from wake to sleep that occur with sleep fragmentation.

Risk Factors

One of the major risk factors for OSA is older adulthood. Other risk factors include excess weight especially located at the neck, a family history of OSA, smoking, hypothyroidism, Down's syndrome, and menopause. Although menopause is a risk factor that raises women's incident rates to similar levels as men, men at all ages are at greater risk for OSA (Bixler et al., 2001). In a recent meta-analysis, African-Americans were also found to be at greater risk for both prevalent OSA and more severe OSA than non-Hispanic Whites; a result not moderated by age (Ruiter, DeCoster, Jacobs, & Lichstein, 2010). Patient factors that can exacerbate OSA include nasal congestion, alcohol, and use of other substances with sedative properties, such as sleep medications and anxiolytics (ICSD-2). Sleep medication use is significantly higher among older adults compared to younger adults (Espiritu, 2008); therefore, it is a particularly important contributory factor.

Assessment

To verify the presence of OSA, PSG recording is necessary. To meet clinical criteria for the diagnosis, the patient must have five or more scoreable apnea or hypopnea events per hour of sleep lasting at least 10 s with accompanying respiratory effort as evidenced by increased esophageal pressure. A recent update of the criteria for scoring respiratory events is outlined in Berry et al. (2012). Along with this objective evidence, the patient must complain of at least one of the following: excessive daytime sleepiness, unintentional sleep bouts, fatigue, insomnia, or nonrefreshing sleep (AASM, 2005). Both the ICSD-2 and the DSM-V require that OSA is not better explained by another disorder. Older adults may misattribute their symptoms to another ongoing medical or psychiatric conditions as well as appraise their symptoms as part of the aging process (e.g., snoring, nocturia, fatigue, cognitive dysfunction, unintentional napping, etc.). As a consequence, they may not seek medical attention readily. Geropsychologists ought to regularly screen for SDB in older adults.

Intervention

Continuous positive airway pressure (CPAP) devices are the gold standard treatment for

OSA in older adults. CPAP devices are portable machines that deliver positive pressure through the normally obstructed airway via facial mask. By maintaining an open airway, CPAP devices reduce the AHI, normalize blood oxygen saturation, reduce nighttime arousals associated with apnea or hypopnea events, increase deep sleep, and decrease self-reported symptoms, such as gasping for breath, snoring, and observed apneas (Sawyer et al., 2011). In older adults, CPAP has been shown to reduce self-reported daytime sleepiness and to improve cardiac functioning. Each patient may vary in the level of positive pressure they need to receive to maintain airway patency, so PSG is needed to adequately titrate the CPAP device.

Given the demands of use of the CPAP device and the higher prevalence of complicated, comorbid conditions, older adults may have difficulty with adhering to CPAP. The lowest recommended standard for adequate adherence is 4h per night on 70% of nights (Sawyer et al., 2011). Greater duration and frequency is associated with better sleep and health-related outcomes. Factors that are associated with poor adherence in older adults include depression, nocturia, nasal irritation, smoking, claustrophobia, and mask intolerance (Weaver & Chasens, 2007; Weaver & Sawyer, 2010). Combined education on the benefits of CPAP use and risk of non-use, individualized treatment plans, and follow-up on any issues with CPAP that arise within the first few days of treatment are associated with high adherence rates in older adults (Sawyer et al., 2011; Weaver & Chasens, 2007; Weaver & Sawyer, 2010). A study on the efficacy of CBT for CPAP adherence (i.e., goal development, managing treatment expectations, and addressing negative cognitions associated with CPAP use) plus education about OSA and CPAP found that the intervention increased CPAP adherence within the first month of treatment compared to patients who received treatment as usual (Richards, Bartlett, Wong, Malouff, & Grunstein, 2007).

EXPECTANCIES REGARDING INTERVENTIONS AND OUTCOMES IN OLDER ADULTS

Evidence-Based Treatments

Does CBT-I Work for Older Adults?

The resounding answer to this question is "yes." Two reviews of the evidence found that CBT-I is appropriate and effective in older adults causing moderate to substantial improvements in insomnia among older adults (≥55 years) with effects lasting up to 2 years (Irwin et al., 2006; Morin et al., 1999). CBT-I for older adults is now deemed a standard, evidence-based treatment for older adults (NIH, 2005).

Treatment for Comorbid Insomnia in Older Adults?

Historically, insomnia comorbid with medical and psychological conditions was not directly treated. The common assumption was that treatment of the medical or psychological condition would result in the resolution of the insomnia (McCrae et al., 2009). However, evidence suggests insomnia can be considered as an independent disorder (as was recently recommended in the DSM-V), because the insomnia presentation can be perpetuated by maladaptive behaviors and cognitions even after the resolution of, or reduction in the severity of, the comorbid illness (Harvey, 2005). This is often the case with older adults, because comorbid insomnia is more common than primary insomnia in this population. Fortunately CBT-I is effective for insomnia comorbid with a wide array of medical and psychiatric conditions. There are indications that CBT-I in older adults improves sleep directly, *and* it may indirectly improve some of the comorbid conditions' symptomatology including psychological distress, quality of life, and various measures of daytime functioning (Bloom et al., 2009). Implementation of CBT-I in older adults as opposed to pharmacological treatments also reduces the risk of polypharmacy that is often a potentially dangerous issue with comorbid insomnia.

Treatment of Comorbid Apnea and Insomnia?

Considering the high prevalence of sleep fragmentation and SDB in the elderly population, comorbid insomnia with SDB is a highly likely scenario (Luyster, Buysse, & Strollo, 2010). Proper treatment is crucial; however, there is very little research on treatment of concurrent apnea and insomnia. In a trial of the effect of CBT-I and SDB treatment (i.e., CPAP, oral appliances, surgery) for comorbid insomnia and SDB, sleep measures and daytime functioning improved, and there was a higher insomnia remission rate (Krakow et al., 2004). CBT-I alone was not as effective for remission or for sleep-related daytime functioning improvement. In a study comparing CBT-I with surgical treatment for OSA in patients with insomnia and mild OSA, results indicated that surgical treatment resolved insomnia symptoms in a third of patients; whereas, patients receiving CBT-I alone had no remission (Guilleminault, Davis, & Huynh, 2008). However, CBT-I received after surgical intervention improved sleep further than SDB treatment alone. These results imply that simultaneous treatment of SDB and insomnia may be the best treatment approach. This conclusion is further bolstered by results from an observational study of insomnia symptoms before and 2 years after the initiation of CPAP treatment for OSA (Björnsdóttir et al., 2012). Results indicate that complaints of difficulty maintaining sleep were reduced with CPAP treatment, but difficulty initiating sleep and early morning awakenings persisted.

Benzodiazepines for the treatment of concurrent insomnia and apnea have not been thoroughly studied, most likely because these medications have respiratory suppressant effects that could worsen OSA severity (Luyster et al., 2010). On the other hand, the more recently developed GABAergic non-benzodiazepine drugs, such as zaleplon, zolpidem, and eszopiclone, do not appear to affect respiration or upper airway muscle tone (Berry & Patel, 2006; Rosenberg, Roach, Scharf, & Amato, 2007). However, these drugs are still not without their side effects. Close monitoring and great care in the dosing of these hypnotics must be taken, particularly when they are used in conjunction with other medications. Additionally, physiological habituation, dependency, and rebound insomnia upon withdrawal are concerns that must be taken into account.

Caregiver Involvement and Treatment

Dementia Patients and Caregivers

Approximately two-thirds of older adult caregivers of patients with forms of dementia report sleep disturbances (McCurry, Logsdon, Teri, & Vitiello, 2007). The chronic need to be vigilant both day and night to their patient's needs, and frequent nighttime awakenings by the patient can create a context ripe for insomnia manifestation in caregivers who are predisposed and vulnerable. Given that many caregivers are older adults who may have medical conditions themselves, and the need to be functional during the night if necessary, pharmacological interventions are less preferable. Two nonpharmacological options are more desirable: behavioral treatment programs to improve the patient's sleep and programs to improve the caregiver's sleep. A randomized trial of a sleep hygiene and behavior management program for caregivers to deliver to patients with dementia led to greater reductions in nighttime awakenings and duration compared to general education and caregiver support (McCurry, Gibbons, Logsdon, Vitiello, & Teri, 2005). A brief CBT-I protocol has also demonstrated improvements in sleep quality and sleep efficiency in elderly caregivers of dementia patients (McCurry, Logsdon, Vitiello, & Teri, 1998).

CONCLUSIONS AND FUTURE DIRECTIONS

Education, assessment and/or diagnosis, and treatment represent several ways that geropsychologists can contribute to the care of sleep and sleep disorders in older adults. Geropsychologists can provide needed education to patients, their families, and other health care professionals who work with elderly patients. Education about sleep, sleep disorders in old age, the importance of sleep, and adaptive expectations of sleep in later life are all important topics that geropsychologists can raise. A large proportion of the patients that geropsychologists treat are likely to be experiencing some form of sleep disturbance. Hence, geropsychologists are in a prime position to routinely screen for sleep disorders in their patients and to refer them for further assessment and treatment. Lastly, geropsychologists may want to treat sleep disturbances in their patients themselves. To do so, specialized training in sleep psychology, a newly recognized specialty in psychology, is needed. To become certified in behavioral sleep medicine, providers should visit the American Board of Sleep Medicine website to determine what type of training is required for certification (www.absm.org). Most of the providers that are certified are psychologists; however, the overall number of certified providers is only a couple of hundred. Clearly, there is great need for the dissemination of these evidence-based psychological interventions for sleep. Although sleep psychology was recently recognized as a formal specialty by the American Psychological Association, it is still in its infancy. With time and further growth of this new specialty, more opportunities will be available for geropsychologists to receive training in assessment and treatment of sleep disorders in older adults. If this training is not feasible for the provider, then a referral list of sleep psychologists and local sleep clinics is recommended. A list of certified behavioral sleep medicine providers and their locations can be found on the American Board of Sleep Medicine website (http://www.absm.org/BSMSpecialists.aspx).

Future research on the dissemination and implementation of evidence-based interventions for late-life sleep disorders is crucial given projected increases in the proportion of older individuals in the US and worldwide populations. Although the efficacy of these interventions has been established for some time, dissemination has not occurred rapidly. This is mainly because of the lack of geropsychologists and other psychologists trained to provide such services as mentioned earlier. Other reasons may be barriers to the implementation of these interventions in current health care systems. Researchers are actively investigating ways to overcome these barriers to foster greater recognition of late-life sleep disturbances and treatment at the point of patient presentation—primary care. This research has focused on the fidelity and disseminability of briefer versions of CBT-I (less than eight sessions), and motivational interviewing for CPAP adherence that are adapted for primary care settings. Investigations of different modalities for delivering treatment are also underway with particular emphasis on mobile and online delivery systems (i.e., telephone, video-conferencing, online programs, smart phone applications). As more geropsychologists become trained in behavioral sleep medicine, additional research will be needed to investigate the best methods for integrating geropsychologists in primary care settings to increase treatment access for older adults afflicted with disordered sleep. Other important lines of future research are exploring community-based and public health interventions for sleep screening and treatment, implementing interventions in full-time care facilities, developing and testing interventions for high-risk and highly comorbid older adult patients, and testing the effectiveness of treatments designed to improve the sleep of both caregivers and patients alike.

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CHAPTER

23

Psychosocial Interventions for Older Adults with Dementia and Their Caregivers

Linda Teri[1], *Glenise McKenzie*[2], *and Christina A. Coulter*[3]

[1]University of Washington School of Nursing, Psychosocial & Community Health, Seattle, WA, USA [2]Oregon Health & Science University School of Nursing, Ashland, OR, USA [3]University of Washington School of Nursing, Biobehavioral Nursing & Health Systems, Seattle, WA, USA

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INTRODUCTION

Dementia, now referred to as a "major neurocognitive disorder" is characterized by multiple cognitive deficits, including memory impairment that significantly and adversely affects social and occupational functioning (American Psychiatric Association, 2013). Although this most current definition does not address the plethora of behavioral problems that beset the individual with dementia and with which the caregiver must cope, such problems have been known to exist since the original article by Alois Alzheimer (Dahm, 2006). Behavioral issues typically dominate the challenges of caring for a person with dementia (PWD), increase rates of morbidity and mortality for both the PWD and their caregiver, and are associated with long-term care placement and escalating health care costs (Hurd, Martorell, & Langa, 2013).

Effective treatment of behavioral problems in PWD still eludes us. Although most often treated pharmacologically, such treatment is not without risk and a number of professional organizations (including the American Psychiatric Association and American Geriatrics Society) strongly advocate using environmental and non-pharmacological approaches before engaging in pharmacotherapy (Schneider, Dagerman, & Insel, 2005). Indeed, the use of typical and atypical antipsychotic medications to manage such problems offers little more than established placebo rates and carry with it significant cardiovascular risk and elevated rates of morbidity and mortality in elderly patients (Gareri, De Fazio, Manfredi, & De Sarro, 2013). Therefore, focusing on psychosocial treatments of behavioral problems in PWD is essential if we are to improve the quality of life (QOL) and care for both the PWD and their caregiver, as well as reduce the ever-growing financial and emotional burden of this disease on affected individuals, their caregivers, and our larger society.

For the purposes of this review, we used the terms: (i) "behavioral problems" to encompass the range of challenges experienced by PWD and their familial and formal caregivers and (ii) "psychosocial interventions" to include any intervention that "emphasizes psychological or social factors rather than biological factors" (Ruddy & House, 2005). Psychosocial interventions targeting the behaviors of the PWD and interventions aimed at improving skills and/or coping of the caregiver related to these behaviors were both included in recognition of the interactive and synergistic features that frequently occur when providing care for a PWD.

To maximize the potential of this chapter to move the field of dementia care and research forward and provide an opportunity for investigators to determine critical areas of future research as well as allow practitioners to engage in evidence-based clinical care, we included only studies that met Administration on Aging (AoA) criteria of intermediate level evidence based (published in a peer-reviewed journal and proven effective with older adult populations using a control condition and provide some basis for translation/implementation by community-level organizations). We also only included studies that were published in English language journals within the past 10 years with a primary focus on PWD behavioral and/or caregiver outcomes; encompassed the array of settings (e.g., private home, congregate care) and the diversity of providers (familial and formal: both professional and nonprofessional), working with PWD and addressed the problems common among PWD (such as depression, agitation) and their caregivers (depression, burden, etc.). We excluded studies that did not provide sufficient details about the intervention; used non-validated, idiosyncratic measures; involved sample sizes fewer than ten individuals per cell; focused on cognitive remediation or with cognition as primary outcomes (because they are addressed elsewhere in this volume); and were included in the last

Handbook chapter (Knight & Losada, 2011). Using these criteria, we identified five predominant psychosocial approaches: person-centered (addressing unmet needs, providing meaningful activity, individualized reminiscence, $N = 16$); physical activity (PA, aerobic, strength and flexibility training, $N = 15$), caregiver training (skill building for staff and family, $N = 28$), emotion-focused (CBT, support and counseling, $N = 19$), and social enhancement (music, games and animal-assisted, $N = 14$).

Table 23.1 provides a summary of all of the studies reviewed here; it provides the primary focus of the interventions and key methodological characteristics, including the study design, sample characteristics and duration of study; setting and country in which the study took place; intervention procedures, and control conditions. It should be noted that cataloging these study characteristics was based upon our interpretation of information provided in the published articles. Some studies provided insufficient detail for us to be completely confident that we captured all treatment components. In many cases, more than one approach and more than one target were included in a single study. Consequently, we had to make decisions regarding where a given study "belonged." Information in the table should be viewed as a guide, not definitive. Any errors in categorization are ours. In the text of this chapter, we summarize areas of commonality, differences, and critical findings across these studies rather than abstract individual study characteristics, due to the number of studies and page limitations as well as to maximize readers' understanding of current trends and future directions.

Person-Centered Interventions

Rationale and Theory

Person-centered care practices focused on assuring and maintaining individuality, choice, respect, independence, and a sense of community for individuals across settings. The interventions included in this category were diverse, however they shared a common theme of adapting and individualizing activities, approaches, and/or care based on the background, unmet needs and/or functional abilities/strengths of the PWD. Three types of interventions were evident: (i) activities adapted to support the PWD (self-identify and respect); (ii) reminiscence individualized to the PWD and (iii) multidisciplinary assessment and planning to address unmet needs (physical, emotional and social) of the PWD.

Studies

Patient-centered interventions demonstrated significant improvements in mood and behavioral outcomes for the PWD and in some cases improvement in burden and QOL for their family caregiver. Each study included an assessment component aimed at identification of preferences, unmet needs and/or functional level of the PWD upon which treatment was based. All but one of the studies were conducted in residential settings. Two that compared psychosocial and pharmacological interventions reported similar findings in improved behavioral and affective outcomes, with psychosocial interventions offering the advantage of little to no adverse side effects, medication interactions and decreased costs of primary care visits. Reminiscence-based studies reported either modest or neutral improvements in social engagement and mood for the PWD with one reporting increased anxiety for family caregivers. Recent reviews also noted the limited number of effectiveness studies on reminiscence with PWD (Cotelli, Manenti, & Zanetti, 2012).

PA Interventions

Rationale and Theory

Stimulated by the growing body of evidence supporting the association of cognitive

TABLE 23.1 Psychosocial Intervention Trials

Citation	Study design: (sample size) (control)	Setting (country)	Intervention components – Interventionist – Duration & frequency
PERSON CENTERED			
Needs-based activities			
Gitlin et al., 2008	RCT (*N* = 60 dyads) Treatment = TAP Control = none	Home (US)	Tailored Activity Program (TAP)—Occupational therapy intervention with activities determined by functional testing – OT – 6 home visits (90 min each) and 2 (15-min) telephone contact over 4 months
Phillips, Reid-Arndt & Pak, 2010	Quasi-experimental repeated measures (*N* = 56) Treatment = Storytelling Control = Usual care	LTC-4 SNF and 2 AL (US)	"TimeSlips"—group creative storytelling, not reliant on accurate memory – "facilitator" (not otherwise described) – 6-week treatment period, twice weekly 1-h sessions
Richards, Beck, O'Sullivan & Shue, 2005	RCT (*N* = 139) Treatment = ISAI Control = Usual care	SNF (US)	Individualized social activity intervention (ISAI) – Certified Recreation specialists – 1–2 h of ISAI daily in 15–30-min increments for 21 consecutive days
Kolanowski, Litaker, Buettner, Moeller, & Costa, 2011	Randomized double-blind clinical trial (*N* = 128) Treatment A = Functional Treatment B = Personality Treatment C = Functional and Personality Control = Active control	Community-based nursing homes (US)	Needs driven – activities adjusted based on functional level and personality style – Nurses and facility staff – 20 min twice per day (morning and afternoon) 5 days each week for 3 weeks
Reminiscence			
Serrani Azcurra, 2012	RCT (*N* = 135) Treatment = Life-story Active control = Counseling Passive control = Informal social activity	SNF (Argentina)	Life-story approach – Clinical psychologists – Bi-weekly 1-h sessions for 12 weeks
Lai, Chi & Kayser-Jones, 2004	RCT (*N* = 101) Treatment = Life story Attention control = Friendly discussion Control = Usual care	SNF (China)	Life story – Social workers and OT – Weekly 30-min sessions for 6 weeks

Politis et al., 2004	RCT ($N = 37$) Treatment = 1-on-1 reminiscence activities Control = 1-on-1 with activity therapist	Dementia Care unit (US)	Kit-based activities for dementia in LTC – Activity therapist – Three times a week for 30 min, over 4 weeks
Wang, 2007	RCT ($N = 102$) Treatment = Reminiscence Control = Usual care	SNF (Taiwan)	Group reminiscence therapy – Master's level nurses who attended 32-h training in the intervention – 8 weekly 60-min sessions
Woods et al., 2012	Pragmatic RCT ($N = 350$) Treatment = REMCARE Control = Usual care	SNF (UK)	REMCARE – Trained facilitators – Weekly for 12 weeks, followed by monthly maintenance sessions for 7 months
Unmet needs			
Ballard et al., 2009	Secondary analysis of a sub-group ($N = 318$) Treatment = "BPST" Control = None	LTC (UK)	"Brief psychosocial therapy" [BPST]—Social interaction, personalized music, or removal of environmental trigger – chosen for the person based on assessment. – Research nurses or undergraduate psychology students – Weekly sessions (1 h to 15 min each) for 4 weeks
Bird, Jones, Korten, & Smithers, 2007	Naturalistic case–control repeated measures ($N = 33$) Treatment = Causality-focus Control = Usual care	Residential facilities (Australia)	Identification of Behavior "cause"—Needs based, "Causality-focused approach"—behavior occurs based on physical, medical or psychosocial reason – Nurse and psychologist – 5-month trial period; variable frequency
Chenoweth et al., 2009	RCT cluster ($N = 324$) Treatment A = PCC Treatment B = DCM Control = Usual care	Residential facilities (Australia)	Person-centered care (PCC) or dementia-care mapping (DCM) – Trained care staff and managers – 4 months of implementation of each care strategy
Cohen-Mansfield, Thein, Marx, Dakheel-Ali, & Freedman, 2012	RCT ($N = 125$) Treatment = TREA Control = Placebo inservice with staff	SNF (US)	Treatment Routes for Exploring Agitation (TREA)—specifics of the treatment were chosen to fit the need, past identity, preferences, and abilities – Research assistants – 2 weeks
Davison, Hudgson, McCabe, George, & Buchanan, 2007	Pre post ($N = 31$) Treatment = Behavior therapy Control = None	Psychogeriatric unit (Australia)	Multicomponent intensive behavior therapy based on assessment of individual—"needs deficit" and plan based on appropriate way to meet unmet needs – Psychiatric nurses and psychologists – Duration ranged from 47 to 231 days, with a median time of 90 days

(*Continued*)

TABLE 23.1 (Contd)

Citation	Study design: (sample size) (control)	Setting (country)	Intervention components – Interventionist – Duration & frequency
Low et al., 2013	RCT randomized at site level (*N* = 398, 35 SNF) Treatment = SMILE Control = Usual care	SNF (Australia)	SMILE-Sydney Multisite Intervention of ElderClowns; humor therapy – Trained clowns and trained staff – 9–12 weekly sessions
Orrell et al., 2007	RCT (*N* = 192) Treatment = Intervention Control = Usual care	Care homes (UK)	Intervention to identify and address unmet needs – Key staff member with consultation by a mental health nurse and clinical psychologist – 20-week intervention
PHYSICAL ACTIVITY			
Group			
Aman & Thomas, 2009	Prospective comparative (*N* = 40) Treatment = Structured exercise Control = None	Memory Care Unit (US)	Structured aerobic and resistance exercise program – Interventionist not described – 30 min 3x weekly for 3 weeks
Conradsson, Littbrand, Lindelof, Gustafson, & Rosendahl, 2010	RCT cluster (*N* = 191) Treatment = HIFE Control = OT directed activities group	Residential facilities (Sweden)	High-intensity functional exercise (HIFE): Designed by physical therapists, 41 structured, weight-bearing exercises designed to increase functionality – OT/PT – 45-min sessions, 5 sessions in each 2-week period for 13 weeks
Edwards et al., 2008	Pilot pre-post (*N* = 36) Treatment = Chair exercises Control = None	SNF memory care units (US)	Chair-based exercises – Exercise physiologist – 30 min 3x weekly for 12 weeks
Fan & Chen, 2011	Quasi-experimental (*N* = 59) Treatment = Silver Yoga program Control = Not described	Residential facilities (Taiwan)	Silver Yoga-yoga program designed for older adults – "certified SY instructors" – 3x per week, 55 min each time for 12 weeks
Hokkenen, 2009	RCT (*N* = 29) Treatment = DMT Control = Placebo social group	Residential facilities (Finland)	Dance/movement therapy – Interventionist not described – 9 weekly sessions 30–45 min each
Pitkälä et al., 2013	RCT (*N* = 210) Treatment A = Group exercise at adult day care Treatment B = Home-based individual exercise Control = Usual care	Community (Finland)	FINALEX-multi, focus on endurance, balance, strength training, and functional exercises – Physiotherapists – 1 h of training/exercise 2x week for 1 year. Mean exercise time was 1 h/day

Rolland et al., 2007	RCT ($N = 134$) Treatment = Structured exercise program Control = Usual care	SNF (France)	Structured Group Exercise program—Aerobic, strength, flexibility, and balance (walking was at least half) – OT – 1-h afternoon sessions 2x weekly for 12 months
Stella et al., 2011	RCT ($N = 32$) Treatment = Group exercise program in community sites Control = Usual care	Community (Brazil)	Structured exercise program at a center 3 times weekly for 60 min – "Expert in physical education" – 60 min 3x weekly for 6 months
Van de Winckel et al., 2004	RCT ($N = 25$) Treatment = Daily group musical exercise Control = Conversation	Gero-Psych units (Belgium)	Music-based exercise – "Exercise therapist" – Daily 30 min sessions for 3 months
Individual			
Eggermont et al., 2010	RCT ($N = 112$) Treatment = Daily walking Control = Social visit	SNF (Netherlands)	Walking – Student research assistant – 30-min sessions 5x weekly for 6 weeks
McCurry et al., 2011	RCT ($N = 132$) A = Walking B = Bright light C = Both Control = Contact	Community (US)	Walking and bright light – Master's level health care professional – 8 week treatment period
Roach et al., 2011	RCT ($N = 82$) Treatment A = Functional exercise Active control = Supervised walking Control = Conversation	LTC (US)	Activity-specific exercise focusing on functional activities – Not specifically stated – 30 min 5x weekly for 16 weeks
Steinberg et al., 2009	RCT ($N = 27$) Treatment = Instruction in exercise program and goals for Cg to complete with PWD Control = Home safety visits and recording of activity	Community (US)	Home-based exercise program delivered by family Cg with aerobic (walking), strength (resistance bands and ankle weights), balance and flexibility. – Exercise physiologist – Cg given exercise goals for PWD to equal 5 activities per week

(*Continued*)

TABLE 23.1 (Contd)

Citation	Study design: (sample size) (control)	Setting (country)	Intervention components – Interventionist – Duration & frequency
Teri et al., 2003	RCT ($N = 153$) Treatment = RDAD Control = Usual care	Community (US)	Reducing Disability in Alzheimer's Disease (RDAD)—Exercise component included aerobic/endurance, strength training, balance, and flexibility with goal of 30 min/day. Behavior management component included ABCs, education, and pleasant events. – Healthcare professionals experienced in dementia care – 1-h sessions, 2x weekly for 3 weeks, weekly for 4 weeks, EoW for 4 weeks, with follow-up visits monthly after
Williams & Tappen, 2008	Repeated measures quasi-experimental with random assignment ($N = 45$) A = Comprehensive exercise program B = Supervised walking C = Equivalent time conversation	SNF (US)	Comprehensive individual exercise with strength, balance, and flexibility exercises, walking. – Graduate nursing or PT students – 30 min 5x weekly for 16 weeks
CAREGIVER TRAINING			
Caregiver focused			
Belle et al., 2006	RCT ($N = 642$) Treatment = REACH Control = Information packet and limited phone "check-in"	Community (US)	REACH: Specialized one-on-one education and support for informal caregivers – "Certified interventionists with at least a Bachelor's degree" – 6 months with 12 sessions with the interventionist and 5 support group calls
Burgio, Stevens, Guy, Roth, & Haley, 2003	RCT ($N = 118$) Treatment = STC Control = Minimal support intervention	Community (US)	Skills Training Condition (STC): Three foci-behavioral management techniques, problem-solving to increase self-care, social engagement and pleasant events, and cognitive restructuring – "REACH interventionist" – 12 months beginning with a group workshop followed by 16 in-home visits over 12 months
Davis, Burgio, Buckwalter, & Weaver, 2004	RCT ($N = 61$) Treatment A = In-home training Treatment B = Telephone training Control = Friendly call	Community (US)	Caregiver support-in home versus telephone – "Trained staff interventionists" – Weekly intervention sessions for 45–60 min for 12 weeks

Farran et al., 2004	RCT ($N = 272$) Treatment = Caregiver Skill Building (CSB) Control = Information and Support Oriented (ISO)	Community (US)	Comparison of skill building and support – Extensively trained professional staff (nurses, social workers) with geriatric experience – 5 group sessions, 7 individual phone contacts, 2 group boosters, and as needed phone contact for 12 months
Finkel et al., 2007	RCT ($N = 36$) Treatment = Ecare Control = Printed information	Community (US)	Ecare: An online psycho-educational program for family caregivers of PWD (based on REACH) – "Technology (online)-based intervention" – 6 months with 2 in-home visits and 12 screen phone encounters
Finnema et al., 2005	RCT ($N = 146$) Treatment = Emotion-oriented care Control = Usual care	SNF (Netherlands)	Integrated emotion-oriented care—Individualized care plans and bios-training staff in empathetic communication skills 24/7 – "Nursing assistants trained in emotion-oriented care" – 7 days spread over 7 months, with "homework"
Gavrilova et al., 2009	RCT ($N = 60$) Treatment = Cg education and training Control = Usual care	Community (Russia)	Caregiver training and support—In person focusing on dementia assessment, education, and training regarding addressing BPSD – Multi-purpose health worker – 5 weekly 30-min sessions
Gitlin, Winter, Dennis, Hodgson, & Hauck, 2010a,2010b	RCT ($N = 209$) Treatment = COPE Control = Limited attention	Community (US)	Care of PWD in their Environments (COPE) – Occupational therapist and nurse team – 10 sessions with OT and 2 sessions with a nurse over 4 months
Gitlin, Winter et al., 2003	RCT ($N = 190$) Treatment = HES program Control = Usual care	Community (US)	Home Environmental Skill Building (HES) – Occupational therapists trained in REACH protocols – Five 90-min home visits and one 30-min over 6 months
Gitlin et al., 2010a,2010b	RCT ($N = 272$) Treatment = ACT Control = Usual care	Community (US)	Advanced Caregiver Training (ACT) – Occupational therapist and nurse team – 16-week active phase of 9 OT sessions, 2 nursing sessions – maintenance phase of 16–24 weeks of 3 brief OT phone contacts to reinforce treatment
Gonyea, O'Connor, & Boyle, 2006	RCT ($N = 80$) Treatment = Project CARE Control = "Standard" psycho-educational group	Community (US)	Project CARE (multi-session training)—Behavioral training—skills training—for Family Cg with primary outcomes for Cg. – "Therapists trained in the intervention" – 90-min group sessions 1x/week for 5 weeks
Graff et al., 2007	RCT ($N = 135$) Treatment = In-home OT Control = Not specified	Community (Netherlands)	In-home OT: Training for caregivers regarding activity and environmental adjustments – Occupational therapists – 10 1-h sessions over 5 weeks

(*Continued*)

TABLE 23.1 (Contd)

Citation	Study design: (sample size) (control)	Setting (country)	Intervention components – Interventionist – Duration & frequency
Hepburn, Lewis, Tornatore, Sherman, & Bremer, 2007	RCT multi-site (*N* = 52) Treatment = SAVVY Cg Control = Waitlist	Community (US)	SAVVY Caregiver: Training program for informal caregivers in the community focusing on skills, knowledge, and outlook – "Persons with educational or clinical background in family caregiving and dementia" – 6 2-h sessions
Huang, Shyu, Chen, Chen, & Lin, 2003	Pilot (*N* = 48) Treatment = Caregiver training Control = Social contact only	Community (Taiwan)	Training of family caregivers of PWDs in behavior, environmental, and stress reduction – Gerontological research nurses – Initial 2–3-h training followed by another 2–3-h visit the following week
PWD Focused			
Huang et al., 2013	RCT (*N* = 129) Treatment = Home-training Control = Information only	Community (Taiwan)	Individualized training of family caregivers of PWDs in behavioral and environmental strategies. – Gerontological research nurses – Initial 2–3-h training with care manual followed by another 2–3-h visit the following week with follow-up phone calls after and then monthly during follow-up
Karlin et al., 2013	Pilot (*N* = 64) Treatment = STAR Control = None	LTC (US)	STAR-VA: Staff Training in Assisted Living Residences focusing on behavioral principles for direct care workers. – Doctoral level mental health provider – Initial training workshop with clinicians over 2.5 days. And weekly follow-up consult phone calls 90 min, for 6 months
Kurz et al., 2010	RCT multi-site (*N*=292) Treatment = Education and skill training Control = Not described	Community (Germany)	Informal caregiver training focusing on knowledge building and individual problem solving – Psychologists or social workers – 7 bi-weekly group sessions 90 min each, then 6 bi-monthly refresher meetings over 15 months
Liddle et al., 2012	RCT (*N*=29) Treatment = Training DVD Control = Usual care	Community (Australia)	DVD training program using memory and communication strategies – DVD – Two 45-min baseline trainings, provision of the DVD
Martín-Carrasco et al., 2009	RCT (*N*=115) Treatment = PIP Control = Usual care	Community (Spain)	PIP—Psycho-educational Intervention Program—individual training – Clinical psychologist, nurse, or social worker – 8 individual sessions for 90 min approximately every 1–2 weeks, over 4 months

Martín-Carrasco et al., 2013	RCT (*N* = 238) Treatment = Group PIP Control = Usual care	Community (Spain)	PIP—Psycho-educational Intervention Program—group training – Clinical psychologist, nurse, or social worker – Bi-weekly 7 group sessions of 90–120 min
McCurry, Gibbons, Logsdon, Vitiello, & Teri, 2005	RCT (*N* = 36) Treatment = NITE-AD Control = Contact control	Community (US)	NITE-AD: Program for informal caregivers focusing on knowledge, sleep hygiene principles, and behavioral management – Geropsychologist – Six 1-h in-home sessions over 2 months
McCurry, LaFazia, Pike, Logsdon, & Teri, 2012	RCT (*N* = 47) Treatment = SEP Control = Usual care	Adult Family Home (US)	Sleep Education Program (SEP) – Master's level gerontological social worker – 4 weekly workshops delivered to AFH staff
Moniz-Cook et al., 2008	RCT pragmatic (*N* = 113) Treatment = Training in home Control = Usual care	Community (UK)	Psychosocial education and support to decrease behavioral symptoms – Community mental health nurse – 4 consecutive weekly in-home visits and follow-up as needed over 18 months
Moore et al., 2013	RCT (*N* = 100)Treatment = PEPControl = Information and support	Community (US)	Pleasant Events Program (PEP) – Master's level mental health clinicians – 4 in-home 1-h therapy sessions with 2 follow-up phone calls after the tx
Teri, McCurry et al., 2005	RCT (*N* = 95) Treatment = STAR-C Control = Usual care	Community (US)	STAR-C—Training of community consultants to provide skills and behavior management for informal caregivers in the community – Clinical geropsychologists – 8 weekly sessions followed by 4 monthly phone calls
Teri, Huda et al., 2005	RCT (*N* = 120) Treatment = STAR Control = Usual care	LTC (US)	STAR: Staff Training in Assisted Living Residences, dementia-specific behavioral management and skill building for direct care workers – Clinical psychologist and nurse – 2 half-day workshops and 4 individual sessions
Ulstein, Sandvik, Wyller, & Engedal, 2007	RCT (*N* = 171) Treatment = Education Control = Usual care	Community (Norway)	Psycho-educational program re: Dementia and structured problem-solving – Physicians (geriatricians and psychiatrists) – 4.5 months, initial 3-h session, then 6 group 2-h sessions
Visser et al., 2008	RCT (*N* = 52 Staff; *N* = 76 PWD) Treatment = Education Placebo = Peer support Control = Usual training	Residential facilities (Australia)	Formal caregiver education – Not specifically stated – 8 sessions delivered twice weekly for 90 min

(*Continued*)

TABLE 23.1 (Contd)

Citation	Study design: (sample size) (control)	Setting (country)	Intervention components – Interventionist – Duration & frequency
EMOTION FOCUSED			
Cognitive behavior therapy			
Akkerman & Otswald, 2004	RCT ($N = 38$) Treatment = CBT Control = Wait-list	Community (US)	Group CBT for anxiety management – Psychologist – 9 weekly sessions for 2 h
Coon, Thompson, Steffen, Sorocco, & Gallagher-Thompson, 2003	RCT ($N = 169$) A = Depression management B = Anger management Control = Wait-list	Community (US)	Small group workshops using cognitive behavioral, assertiveness training, and goal setting – Trained facilitators – 8 weekly 2-h workshops and 2 boosters at 1 and 2 months
Fialho, Köenig, Santos, Barbosa, & Caramelli, 2012	Pre-post ($N = 40$) Treatment = CBT Control = None	Community (Brazil)	Group CBT—Training of Social Skills (TSS) – Neuropsychologist and OTs – 8 weekly 2 h sessions
Gallagher-Thompson & Coon, 2007	RCT ($N = 55$) Treatment = IHBMP Control = Telephone support	Community (US)	In-home behavioral management program (IHBMP) modified for Chinese caregivers – Chinese health and mental health professionals – 6 modules delivered in 1 or 2–90-min sessions
Márquez-González, Losada, Izal, Pérez-Rojo, & Montorio, 2007	RCT ($N = 74$) Treatment = MDTC Control = Wait-list	Community (Spain)	Group Intervention—The Modification Of Dysfunctional Thoughts Associated With Caregiving (MDTC) modified for Spanish caregivers (based on Gallagher-Thompson) – Psychologists – 8 weekly 2-h sessions
Counseling			
Burns et al., 2005	RCT ($N = 40$) Treatment = IPT Control = Usual care	Community (UK)	IPT adapted for PWD (early stage) – Psychotherapist – 6 weekly 50-min sessions
Cheston, Jones, & Gilliard, 2003	Pre-post ($N = 42$) Treatment = Psychotherapy Control = None	Community (UK)	Dementia Voice Group Psychotherapy Project—For PWD; focused on underlying emotional significance of group discussions – Psychologist with experience co-facilitator – 10 weekly 90-min sessions

Eisdorfer et al., 2003	RCT ($N = 225$) A = SET B = SET + CTIS Control = Telephone-delivered minimal support	Community (US)	SET (Structural Ecosystems Therapy) (family therapy) and CTIS (Computer-Telephone Integrated System) (technology-based supportive services)—A REACH site. Included Spanish translation for Cuban Americans. – "Therapists" – SET—4 weekly sessions, 4 bi-weekly sessions and 6 monthly sessions (60–90-min sessions over a total of 12 months). In SET + CTIS—Telephone counseling was used in the last 6 months
Mittelman, Roth, Haley, & Zarit, 2004	RCT ($N = 406$) Treatment = Enhanced counseling and support Control = Usual care	Community (US)	Enhanced Counseling and Support—Individual and family counseling for first 4 months; support groups; telephone support with counselors. – "Counselors" – 6 sessions over 4 months, followed by weekly support groups ("indefinitely"), and "continuous" availability of phone counseling
Mittelman, Haley, Clay, & Roth, 2006	RCT ($N = 406$) Treatment = Enhanced counseling and support Control = Usual care	Community (US)	Enhanced counseling and support for spouses. – Same as above (same sample and intervention; different outcome measure reported)
Mittelman, Brodaty, Wallen, & Burns, 2008	RCT ($N = 158$) A = Counseling + Donepezil B = Counseling + Telephone Support + Donepezil Control = Donepezil	Community (US & UK & Australia)	Counseling and support intervention combined with cholinesterase inhibitor therapy (Donepezil). – Counselor – 5 sessions within 3 months
Tappen & Williams, 2009	RCT ($N = 30$) Treatment = Therapeutic conversation Control = Usual care	LTC (US)	Therapeutic conversation—Modified counseling approach for the PWD (moderate to late). Sharing of concerns and feelings. – Trained graduate nursing student – 30-min sessions 3 times a week for 16 weeks
Caregiver support			
Gallagher-Thompson et al., 2003	RCT ($N = 213$) Treatment = Coping with caregiving Control = Enhanced support group	Community (US)	Coping with Caregiving (Psychoeducation) compared with Enhanced Caregiving (Support), tailored for Anglo and Latino caregivers—groups – Trained interventionists – 10 weekly 2-h sessions, then 8 monthly boosters
Andren, and Elmståhl, 2008	Quasi-experimental pre–post design with control—not randomized ($N = 308$) Treatment = Education and support Control = No intervention	Community (Sweden)	Group psychosocial therapy to develop and apply skills and knowledge – Geriatric RN, trained group leaders – 5 weeks of group education (2-h sessions once a week) followed by group support (90-min sessions, every other week for 3 months)

(*Continued*)

TABLE 23.1 (Contd)

Citation	Study design: (sample size) (control)	Setting (country)	Intervention components – Interventionist – Duration & frequency
Dröes, Meiland, Schmitz, & van Tilburg, 2004	Multi-site controlled trial ($N = 112$) Treatment = MCSP Control = Regular day care	Community/ daycare (Netherlands)	Meeting Centres Support Programme (MCSP)—PWD and caregiver both supported by one professional staff member – Social club 3 days a week for PWD; 8–10 informational and a bi-weekly discussion groups for caregivers; duration of 6 months
Mahoney, Tarlow, & Jones, 2003	RCT ($N = 100$) Treatment = TLC Control = No treatment	Community (Netherlands)	Telephone Linked Care (TLC)—Computer-mediated automated interactive support intervention for caregivers. REACH site. – Research assistant trained Cg on use of TLC – Access to system for a 12-month period
Nobili et al., 2004	Pilot RCT ($N = 69$) Treatment = Structured support Control = Day care only	Community (Italy)	Structured support and information for family Cg delivered in their home – Psychologist and OT – One home visit: psychologist visited 60 min, OT visited 90 min
Senanarong et al., 2004	Parallel group intervention ($N = 50$) Treatment = Counseling Control = Usual care	Community (Thailand)	Group counseling and support for non-professional Cg – Two nurses (leader and co-leader) – 45-min session every 6–8 weeks for 6 months
Winter & Gitlin, 2006	RCT ($N = 103$) Treatment = Support group Control = No treatment	Community (US)	Telephone support group for female Cg – Trained social workers – 1-h session, weekly for 6 months
SOCIAL ENHANCEMENT			
Music			
Choi, Lee, Cheong, & Lee, 2009	Non-randomized control comparison ($N = 20$) Treatment = Music Control = Usual care	LTC (South Korea)	Group Music intervention—Active participation, singing, song writing making and playing instruments. – Certified professional music therapists – 50-min sessions 3 times a week for 5 weeks
Cooke, Moyle, Shum, Harrison, & Murfield, 2010a,2010b	Randomized cross-over trial ($N = 47$) Treatment = Music Control = Reading group	Residential facilities (Australia)	Live group music program and singing for 30 min with 10 min of prerecorded instrumental music. – 2 musicians – 40-min sessions 3 times a week for 8 weeks
Cooke et al., 2010a,2010b	Randomized cross-over trial ($N = 47$) Treatment = Music Control = Reading group	Residential facilities (Australia)	Live group music and singing – Same as above (same sample and intervention; different outcome measure reported)

Guétin et al., 2009	Randomized, controlled, blinded, comparative, single-center study ($N = 30$) Treatment = Music Control = Reading activity	SNF (France)	Individual receptive music therapy, musical style chosen by patient; music streamed via headphones. – Headphones and taped music – 20-min sessions weekly for 16 weeks
Hicks-Moore, 2005	Quasi-experimental ($N = 30$) Treatment = Mealtime music Control = None	LTC (US)	Relaxing taped music played during mealtime – DVD – Evening mealtime every day in weeks 2 and 4. No music during meal weeks 1 and 3.
Holmes, Knights, Dean, Hodkinson, & Hopkins, 2006	RCT ($N = 32$) A = Live music B = Pre-recorded music Control = Silence	SNF (UK)	Passive listening to live music – Musicians and DVD – One 90 min session with each condition (live, pre-recorded and silence) lasting 30 min.
Ledger & Baker, 2007	Non-randomized control comparison ($N = 45$) Treatment = Group music Control = Standard care	SNF (Australia)	Group music therapy—Active requesting and singing songs, playing instruments, discussing feelings – Qualified music therapists – 30–45-min weekly sessions for at least 42 weeks in 1 year
Raglio et al., 2008	RCT ($N = 59$) Treatment = Music therapy Control = Educational and entertainment activities	SNF (Italy)	Music therapy (MT)—Nonverbal MT—using both rhythmical and melodic instruments – MNusic therapist – 30 MT sessions (30 min/session) within 16 weeks
Sung, Chang, Lee, & Lee, 2006	RCT ($N = 36$) Treatment = Music Control = Usual care	SNF (Taiwan)	Group music with movement—Pre-recorded familiar and preferred music designed to help participants move their body – Nursing researcher and 2 research assistants – 30-min sessions, 2 times a week for 4 weeks
Sung, Chang & Lee, 2010	RCT ($N = 60$) Treatment = Music Control = Usual care	SNF (Taiwan)	Group music with percussion instruments, pre-recorded familiar and preferred music – Trained research assistants – 30-min sessions, 2 times a week for 6 weeks
Svansdottir & Snaedal, 2006	Case–control ($N = 38$) Treatment = Group music Control = "No change in care"	SNF (Iceland)	Group music therapy—Singing collection of songs (familiar to Icelanders) through twice, discussions between songs – Qualified music therapist – 30-min sessions, 3 times a week for 6 weeks

(*Continued*)

TABLE 23.1 (Contd)

Citation	Study design: (sample size) (control)	Setting (country)	Intervention components – Interventionist – Duration & frequency
Animal			
Richeson, 2003	Pilot quasi-experimental time-series design within subject ($N = 15$) Treatment = AAT Control = None	SNF (US)	Animal-Assisted Therapy (AAT)—Group visits with therapy dog, active interaction with dog and discussion of memories and feelings – Therapeutic recreation staff, therapy dog and dog handler – 1 h Mon–Friday at change of shift for 3 weeks (15 total sessions)
Theraputic games			
Cohen, Firth, Biddle, Lloyd Lewis and Simmens, 2008	Single group, within-subject design ($N = 33$) Treatment = Game Control 1 = Typical visit Control 2 = Visit with review of a magazine	SNF (US)	"Making Memories Together"—Cards made by family and friends, game to be played by family members and the PWD strength-based approach – Family and friends of PWD – Sequence of all three conditions over one 30-min session (during family visit)
Hatakeyama et al., 2010	Pilot randomized trial ($N = 28$) Treatment = Personalized video Control = Random scenes from nature	LTC (Japan)	Personalized digital videos of family pictures and greetings from family members. – DVD – 15-min video shown 1 time a day for 4 weeks

Bx, Behavior; Cg, caregiver; RCT, randomized controlled trial; BPSD, behavioral and psychological symptoms of dementia; SNF, skilled nursing facility; AL, assisted living; LTC, long-term care; OT, occupational therapy; PT, physical therapy.

and functional status with physical health and activity (Burns, Anderson, Smith, & Donnelly, 2008; Erickson & Kramer, 2009) these studies investigated the effectiveness of physical activity interventions to reduce the physical disability and associated behavioral problems experienced by PWDs.

Studies

The majority of these studies targeted the PWD and were conducted in long-term care settings and in groups. Of the five studies conducted in the community, four utilized the staff caregivers as a facilitator of the intervention (McCurry et al., 2011; Pitkala, Savikko, Poysti, Strandberg, & Laakkonen, 2013; Steinberg, Leoutsakos, Podewils, & Lyketsos, 2009; Teri et al., 2003) and one evaluated the impact on the family caregiver (Steinberg et al., 2009). Most programs were comprehensive incorporating aerobic/endurance exercise with strength/balance activities; these interventions, such as the Finnish Alzheimer Disease Exercise Trial (FINALEX) and the Reducing Disability in Alzheimer's Disease (RDAD) intervention (Teri et al., 2003) focused on preserving physical function and improving affect by engaging the PWD in daily exercise. Both yielded significant benefits in physical function (Aman & Thomas, 2009; Pitkala et al., 2013; Roach, Tappen, Kirk-Sanchez, Williams, & Loewenstein, 2011; Rolland et al., 2007; Teri et al., 2003), and improved mood (Edwards, Gardiner, Ritchie, Baldwin, & Sands, 2008; Stella et al., 2011; Teri et al., 2003; Williams & Tappen, 2008). Studies that involved a single activity, such as walking, dance, or yoga demonstrated fewer significant improvements than comprehensive programs; with neither dance nor walking interventions reporting significant outcomes on sleep, behavior, or mood (Eggermont, Blankevoort, & Scherder, 2010; Hokkanen et al., 2008; McCurry et al., 2011; Van de Winckel, Feys, De Weerdt, & Dom, 2004).

Caregiver Training Interventions

Rationale and Theory

Caregiving training interventions targeted family, formal or informal caregivers and focused primarily on improving their understanding of dementia, increasing their skills for managing common dementia-related behaviors, and decreasing their own levels of burden and stress.

Studies

The majority of these programs were delivered individually; others employed either a hybrid of group and individual sessions or solely group format. Content ranged from focusing solely on family caregiver stress and coping while others focused on skills more directly related to caring for the PWD. The latter included behavioral modification strategies, education about dementia and the disease process, training to address environmental adjustments/adaptations and safety, pleasant events, problem-solving skills, communication, and recognizing physical symptoms. Content aimed at improving the caregivers coping skills included techniques to address stress or burden, strategies to self-manage mood, methods to improve social or support engagement, cognitive restructuring processes, and self-care monitoring.

Of all the areas addressed in this review, caregiver programs were the most plentiful and varied. The most successful caregiver interventions were specific in the content covered and tailored to the method or site in which treatment was provided; multi-component programs were individualized to the needs of the dyad and content focused on caregiving skills, such as behavioral problem-solving, environmental adaptations, and communication reported better outcomes than those providing just information and/or support alone (Ayalon, Gum, Feliciano, & Arean, 2006; Brodaty, Green,

& Koschera, 2003; Logsdon, McCurry, & Teri, 2007a, 2007b; Olazaran et al., 2010; Parker, Mills, & Abbey, 2008).

Emotion-Focused Interventions

Rationale and Theory

These programs focused on enhancing caregiver skill in managing their own feelings of anger, depression, and associated problems with the assumption that if the caregiver is calmer, his/her own well-being and care for the PWD will improve.

Studies

These studies utilized one or more of three strategies; cognitive-behavioral therapy (CBT), counseling-based and/or caregiver support. The majority focused on the family caregivers and reported significant reductions in caregiver anxiety, strain/burden and mood, and in PWD mood and behavioral problems; one reported a reduction in nursing home placement. The two studies that focused on counseling interventions for the PWD had promising but inconsistent results. Interventions with longer duration had more positive outcomes compared to shorter-duration interventions.

Social Enhancement

Rationale and Theory

These approaches focused on engaging the individual with dementia in social activity using modalities that may hold meaning and be pleasant for them; they hypothesized that mental health and QOL outcomes will improve based on distracting attention from negative thoughts and by decreasing social isolation.

Studies

A variety of components (music, animal-assisted therapies, and games) were investigated. Music was most often studied (N=10) either in groups or individually, using passive and active participation. Findings were mixed (and conclusions limited by the relatively small sample size and design of these studies) but there appears to be modest support for decreasing agitation, depression, and anxiety and increasing social engagement. A number of recent reviews support these conclusions (Wall & Duffy, 2010); including a recent meta-analysis that suggested music therapy may increase QOL for the PWD (Vasionyte & Madison, 2013).

TRANSLATION AND IMPLEMENTATION OF PSYCHOSOCIAL APPROACHES

The future of psychosocial treatments—and the true potential of research in this area to impact clinical care—is dependent upon the ability of these programs to appeal to providers and consumers in "real" community settings, to adjust to changing health care needs and financing demands, and demonstrate continued clinical effectiveness. Despite the array of programs reviewed here and their strong evidence for efficacy, the majority are not well known outside the academic community and "the majority of older adults with dementia do not receive appropriate treatment" (Chapman, Williams, Strine, Anda, & Moore, 2006). Therefore, we now highlight two programs that have systematically extended their reach beyond the initial controlled trials, have published on their experiences with translation and therefore provide an opportunity to address the challenges and opportunities afforded by this translational work.

The first exemplar includes programs developed and evaluated as part of a series of treatment protocols called the Seattle Protocols (Teri, Logsdon & McCurry, 2005) and selected for translation by a number of different community agencies: Reducing Disability in Alzheimer's Disease (RDAD) (Teri et al., 2003); Staff Training in Assisted-living Residences (STAR) (Teri, Huda, Gibbons, Young, & van Leynseele, 2005); and STAR–Community Consultants (STAR-C) (Teri, McCurry, Logsdon, & Gibbons, 2005). The focus of each of these programs was on training family or formal caregivers to improve care and reduce the behavioral problems and depression of PWD. Strategies incorporated to facilitate translation of RDAD (Teri et al., 2003), STAR-VA (Karlin, Visnic, McGee, & Teri, 2014), and STAR-C (Teri, McCurry et al., 2005) into the community settings provide a glimpse into the complexity involved and included: (i) clearly connecting rationale for protocols to observed clinical needs; (ii) broadening criteria for inclusion of diverse clinical populations; (iii) systematic yet flexible treatment manuals; (iv) clinically relevant measures of outcomes; (v) procedures for assessment of treatment fidelity; and (vi) thoughtful selection of staff/practitioners for initial training (Teri et al., 2012). The Ohio Department on Aging collaborated with seven Alzheimer's Association Chapters to implement RDAD and successfully enrolled 630 families during a 4-year replication study (Primetica, Menne, Bollin, Teri, & Molea, 2013). The agencies involved in translation of RDAD reported positive experiences for family caregivers and identified factors for ongoing sustainability which included: (i) understanding and interest of the community members; (ii) agency readiness and willingness to adopt an evidence-based program; and (iii) establishing funding sources to sustain the program. Similarly STAR-C was chosen for implementation in three counties by the Oregon Department of Human Services in collaboration with two Area Agencies on Aging and the Oregon Chapter of the Alzheimer's Association (Teri et al., 2012). Initial reports of trainers and caregivers were positive and provided evidence of successful translation. Challenges to sustainability were identified and included: (i) how to maintain integrity and effectiveness as programs evolve to meet agency and caregiver needs; (ii) what the minimum data needed to track integrity and effectiveness was; and (iii) what ongoing training was necessary to maintain skills and quality of services. In the final example, STAR was selected by the US Department of Veterans Affairs (VA) health care systems for implementation in their Community Living Centers (CLCs) across the country (Karlin et al., 2013). Working closely with the STAR developer (L. Teri), a taskforce was assembled to modify STAR to meet the particular needs of VA residents and the VA care system. Modifications included tailoring the program to the Mental Health Providers (clinical psychologists) that provide the majority of mental health care to veterans in CLCs and detailing the specific VA structures and policies to insure successful implementation. This program, STAR-VA, was then tested across 24 CLCs with significantly positive clinical outcomes and successful implementation reports obtained. STAR-VA was then expanded to include twice as many VA sites with additional data and modifications made to facilitate scaling up across the VA nationally. This program is currently underway. The reported challenges in many of these sites involved the complexity of introducing a new program in an already overburdened system of care as well as establishing close ties with other health care team members essential to providing good patient care.

The second exemplar of an evidence-based psychosocial intervention translated into clinical practice settings is a group of interventions from Resources for Enhancing Alzheimer's Caregiver Health II (REACH II). REACH II included education, skills training, and support in the person's home and additional support was provided by telephone with the goal of reducing depression and improving QOL for family caregivers and avoiding nursing home placement for the PWD (Stevens, Lancer, Smith, Allen, & McGhee, 2009; Stevens, Smith, Trickett, & McGhee, 2012). REACH II was selected for translation into community agencies in eight states (Maslow, 2012). Stevens et al (2009, 2012) reported on adapting REACH II components into the community (using trained community volunteers) and in a large hospital and primary care clinic (in collaboration with the Central Texas Area Agency on Aging and delivered by Master's prepared counselors). Strategies to improve translation of REACH II into community settings included delivery by telephone only; use of a computer application to deliver treatment; development of additional modules requested by the settings; and development of systematic outreach and marketing plans (Maslow, 2012). Barriers to sustainability included: (i) recruitment and attrition of enrollees; (ii) ongoing training fidelity; and (iii) lack of cost-effectiveness data (pre- and post-intervention).

The researchers in both the above exemplars (Seattle Protocols and REACH II) have been successful in translating research-based protocols into "real-world" settings. They have experienced similar overarching challenges that require active problem-solving when evidence-based programs are adopted by community and agency settings. The successes and challenges of these programs were reflected in a recent summary looking at challenges to translation of non-pharmacological treatments that addressed six overarching issues: (i) generally there is no third-party payer reimbursement; (ii) recruitment of people with dementia and family caregivers that meet enrollment criteria can be difficult (and may need to be more inclusive than the original clinical trial allowed); (iii) community providers who can deliver the evidence-based treatment as intended may be difficult to find; (iv) concerns of when (and if) it is acceptable to incorporate site-specific accommodations and innovations into an evidence-based treatment without conducting a new clinical trial to establish/confirm efficacy of changes; and (v) issues of how to maintain treatment fidelity when delivery is taken over by community providers (Maslow, 2012). In summary, these early reports on translating evidence-based psychosocial programs were encouraging and established that such translation is not only possible but highly desirable. They also highlighted the need for careful assessment and candid discussions of what is working (and not working) to facilitate the effective translation of more evidence-based programs.

The need for moving these (and other evidence-based) programs into the community is essential. Closing the gap between what is efficacious in a closely monitored clinical trial and "what works" in the real world of a clinical practice is critical for improving the care and experiences of the PWD and their caregivers.

DISCUSSION

The growth of research in the psychosocial treatment of behavioral problems in dementia has grown exponentially in the past 10 years. In 2007, 14 studies in this area were identified (Logsdon et al., 2007b). This review revealed 154 studies which, when restricted to those studies that met our criteria, still yielded 98 studies.

The studies included in this review met high standards of clinical utility and, in general, provided positive empirical evidence. Each met AoA intermediate-level evidence-based criteria and was published within the past 10 years with a primary focus on patient behavioral and/or familial or formal caregiver outcomes. We included studies that encompassed the array of settings providing care for PWD (e.g., private home, long-term care) as well as the diversity of providers (family, professional and nonprofessional staff) and common problems among PWD (such as depression, agitation, general behavioral problems) and among their family or formal caregivers (depression and burden).

Five types of psychosocial treatments were identified: person-centered (16 studies), PA (15 studies), caregiver training (28 studies), emotion-focused (19 studies), and social-enhancement (14 studies). This plethora of psychosocial treatments was diverse in every conceivable way: theories were often not identified but, when they were, they included communication, social learning, person–environment fit, stress and adaptation; the focus of treatment was either the PWD or their caregivers, or both; the location and method of delivery ranged from individually in private homes to in groups and remotely in classrooms, primary care offices, and online; sample sizes ranged from 15 to 642 and, although including both males and females, they were predominately female Caucasians; the measures utilized encompassed a variety of care-recipient and caregiver domains and included (but were not limited to) behavioral problems, emotional distress, burden, depression, and functional limitations. Despite this diversity, the findings from these studies were encouragingly consistent: psychosocial treatments were effective in reducing the behavioral problems common among PWD and the distress and emotional burden experienced by their family or formal caregivers.

Of course, not all psychosocial programs were equal. The most effective interventions were multimodal in scope: they individualized care plans and systematically trained caregivers in a comprehensive set of skills including communication, behavior management, problem-solving, and environmental adaptations. Such programs yielded significant improvements (based on assessment of problems as well as strengths, needs, and preferences of the PWD) for both the PWD (reduced behavioral disturbances, improved mood and sleep patterns, increased social engagement, improved QOL) and for their caregiver (decreased burden and increased QOL). Interventions that incorporated PA with this multimodal skill building were few, but those that did had consistent and significant impact on PWD functional status, behavioral problems, and mood, and on caregiver ratings of burden. Few social engagement studies met our criteria for inclusion: those that did suggested that the introduction of music, games, and animals into the PWD's environment had a positive impact for the PWD (decreasing agitation, depression, anxiety and increasing social engagement). Furthermore, what little data existed on consumer satisfaction or agency response indicated that the programs scaled out into the community were well received.

The richness of this diversity of treatment and the consistency of results offer significant promise for programs that can be tailored to the individual needs of individuals and agencies seeking to improve the care of PWD. Unfortunately, a number of limitations still plague this field. First and foremost, is the lack of significant research funding. Medication trials have been able to enroll thousands of subjects, due in no small part, to abundant funding. It is unusual for psychosocial research programs to include more than 100 subjects and even then, they are often divided across two or more treatment conditions, minimizing the ability to detect differences or determining the characteristics of subjects most likely to benefit. Second, with notable exceptions, the representation of minority and underserved ethnic groups in these studies is abysmal. Research investigating whether these programs work in different groups and developing new programs tailored to different groups is urgently needed. By necessity, we restricted this review to publications in English. However, dementia is a growing burden across the world with current projections indicating an "exponential" growth in developing countries, and a continuing linear increase in wealthy, developed countries (Abbott, 2011). The need for global research is clear. Third, the very nature of psychosocial interventions requires considerable up-front effort to insure standardized and easy-to-employ treatment manuals and provider training techniques. Very few programs engaged in this rigor or provided sufficient details to illuminate the exact nature of the implementation phase of their program (notable exceptions include work discussed in our translation section).

Some study characteristics were both limitations and strengths that pointed to important directions for future studies. In many of the studies reviewed here, subjects resided in the community or long-term care (LTC) settings, thus accurately representing the population of PWD and caregivers seen in such settings. Unfortunately, this also generates significant heterogeneity so that attrition was often an issue and variability in outcomes served to sometimes obscure determinations regarding the characteristics of those most likely to improve. In many of these studies, initial developers of these programs were the investigators who continued to move the field (and their respective program) forward. While this affords the strength of uniformity and (in many cases) excellence, it is limited in scope. New investigators must subject these "established" programs to new questions and increased rigor. Are these programs effective only under the framework of established teams? Can they survive under other leadership and scrutiny?

This last issue ties directly to the need for evidence-based psychosocial programs to be scaled up. As this review demonstrates, we now have evidence-based psychosocial programs with proven excellent outcomes. Unfortunately, as we have already stated, very few of these programs have been scaled up or offered in the community using rigorous translational or dissemination science methodology. The most effective of these programs need to be moved out into the community to improve care and move the field forward. Agencies and researchers need to collaborate closely to establish systematic structures for ongoing quality improvement, evaluation, and policies to enable sustainability.

The need for translation is probably the single most important issue that faces both researchers and clinicians. We have psychosocial programs that work. How do we get them into the field? How do we pay for them? Psychosocial programs are considerably less expensive than long-term care and potentially more effective and less restrictive than pharmacological management (Jones, Edwards, & Hounsome, 2012; Knapp, Lemmi, & Romeo, 2013). Without the strong arm of pharmacological companies to move these treatments "out" they will continue to be underutilized, leading to increased costs, both financial and emotional for our older adults with dementia, their caregivers, and our health care system.

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CHAPTER

24

The Psychology of Death and Dying in Later Life

David E. Balk

Department of Health and Nutrition Sciences, Brooklyn College of the City University of New York, Brooklyn, NY, USA

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INTRODUCTION

To review the psychology of death and dying in later life, it is vital to examine specific environmental and social matters that influence expectations and attributions regarding thanatology and aging; these environmental and social matters form the back story for understanding and analyzing the current framework, particularly in post-modern secularized societies, affecting both societal and individual reactions to the prospects of mortality as we enter the last decades of life.

This chapter, therefore, examines first the secular, technological influences on contemporary understanding and experiences of death

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and dying. Then attention is paid to individual expectations and fears about dying, including empirical data, clinical practices, and proposed policy changes for promoting a good death. Finally, attention turns toward bereavement, grief, and mourning in later life.

PART 1: SECULAR, TECHNOLOGICAL INFLUENCES ON UNDERSTANDING AND EXPERIENCING DEATH AND DYING IN LATER LIFE

Two assumptions undergird contemporary thinking about mortality in developed countries. These two assumptions are (i) transformative sociocultural events have shaped contemporary attitudes toward and experiences of death and dying; (ii) the triumph of the biomedical model has altered dramatically individual expectations about living, about dying, and about death.

The transformative cultural events include the triumph of secular values, the dominance of science and technology, population changes and social controls, and the emergence of the biomedical model as the paradigm for health care practice (Benoliel & Degner, 1995; Starr, 1982). The triumph of secular values has meant a shift to a temporal, historical orientation and the appeal to human ingenuity to explain the universe into which we are thrown. Secular men and women believe in science, and accept as a starting point that human activities and decisions should be based on empirical evidence and facts rather than on an appeal to transcendent, extra-worldly powers. Thus, for instance, natural catastrophes such as the eruption of Mt. St. Helens in the 1980s and the tsunami that overwhelmed islands in the Indian Ocean in the early twenty-first century are explained by knowledge of geology and physics, not as vengeful acts of an angry or capricious divinity. Of some irony is that adherence to secular values is associated with greater anxiety about death than is found in persons with strong religiosity (Corr & Corr, 2012).

The second transformative cultural event is the dominance of science and technology in contemporary society (Benoliel & Degner, 1995). Two major changes of immeasurable significance provide indicators of this second event: social mobility and an increased standard of living. Based on access to vehicular, rail, and air transportation, residents in developed countries have expectations of mobility; persons are not confined to small geographical locations but can travel at will, not only within large urban areas but within their country and to other countries. While extending possibilities, such mobility has also impacted relationships within immediate and extended families. My experience is a case in point: my parents grew up in and lived primarily for the first 36 years of their lives in a small town in Michigan; we moved in 1947 to Cheyenne, the first members of a large extended family to migrate across country; we moved over the next 16 years to Denver, Des Moines, and Phoenix as my father accepted positions of increasing responsibility and authority as a physician in charge of physical medicine departments for Veterans Administration hospitals; now my older sister lives in Denver, my younger sister in New Zealand, and I live in Brooklyn. This example underscores my contention that one of the impacts of social mobility on the psychological experience of dying is loss of physical contact with immediate and extended family members.

An increased standard of living, manifest by products of technology readily available to ordinary (i.e., non-affluent) persons, has also led to an underlying expectation that technological ingenuity will eventually find a way to fix any problem. Considered from a secularist point of view, one of the most pressing problems is mortality; and technology, married to medical research and practice, has worked to push back barriers to continued existence, such as by manufacturing artificial organs enabling otherwise doomed persons to continue living, at least for a while.

The third transformative cultural event involves population changes and controls. Science and technology have contributed to an increase in the total population and to the length of time most persons live. These dramatic effects were partly the product of efficient and effective measures to handle food, water, shelter, and waste disposal; medical science and practice learned how to overcome infectious diseases, such as typhoid, diphtheria, pneumonia, smallpox, measles, and tuberculosis. Mortality statistics indicate that in the first two decades of the twentieth century at least 40% of all deaths were due to infectious diseases, and that over 53% of all reported deaths were to persons 14 years of age and younger; whereas life expectancy in 1900 was 47, life expectancy now is nearly 80. Deaths in 1900 were typically sudden, taking a week or less from the onset of the illness to the end. Today the typical death is due to a slow, lingering, progressive process resulting from a chronic condition such as cancer, heart disease, or circulatory problems (Corr & Corr, 2012; WHO, 2013).

The triumph of the biomedical model is the fourth transformative cultural event affecting our psychological responses to death and dying. The biomedical model is a conceptual framework that looks to material reasons, primarily biochemical, to explain and understand disease. This model sees diseases as physiological and biochemical deviations from established norms; the body is seen as a complicated, highly organized set of inter-related physical systems. The biomedical model triumphed because it was enormously successful in producing new knowledge and conquering medical ailments. Practitioners within the biomedical model view death as the enemy: their primary intent is to rescue persons from acute illnesses, their principal criterion of success is to save (or prolong) life, and their ultimate goal is to gain control over death. On the whole, most people in secularized, developed countries view life, disease, dying, and death within the conceptual scaffolding provided by the biomedical model (Benoliel & Degner, 1995; Starr, 1982).

Practices formulated within the biomedical model introduced new forms of dying within institutional settings. In the first part of the twentieth century, most persons died at home surrounded by family members. By the 1950s the majority of deaths occurred in hospitals or medical centers, and the dying person was surrounded by strangers and was hooked up to many devices. While the percentage of deaths in institutional settings has fluctuated somewhat over the past 60 years, by 2010 the majority of deaths still occurred in institutions (hospitals, medical centers, or nursing homes) with the person surrounded by strangers and hooked up to medical devices (Corr & Corr, 2012; United States Census Bureau, 2013).

PART 2: INDIVIDUAL EXPECTATIONS AND FEARS ABOUT DYING, INCLUDING EMPIRICAL, DATA, CLINICAL PRACTICES, AND PROPOSED POLICY CHANGES ABOUT A GOOD DEATH

Following a Piagetian model of cognitive development, psychologists have examined the understanding of death attained by children, adolescents, and adults. Prior to attaining the stage of concrete operations, a human being is said to be incapable of comprehending that death is irreversible, final, and universal; further, relevant causes of death elude understanding prior to the attainment of concrete operations. Those criteria (irreversibility, finality, universality, and causality) are said to comprise a mature understanding of death (Corr, 2010). These four criteria fit well an empiricist set of expectations about reality. However, when children maintain that death leads to noncorporeal continuation in an afterlife, that understanding of death is said to mark an immature understanding (Speece & Brent, 1996). What is of considerable interest is that noncorporeal continuation is a criterion applied to death by the majority of adults in the United States and in many other countries (Birren, 1991).

A supposition is that once attained, a mature understanding of death remains stable. Kastenbaum (2000) not only brings under scrutiny the notions of maturity and immaturity as applied to knowing what death is, but also points out the ethnocentrism present in the Westernized, secular assumptions about understandings of death. Further, building on the Eriksonian construct of wisdom developing in the later years (Erikson, 1959), Kastenbaum concluded that in their later years adults produce "more sophisticated conceptions of death… as a facet of deepening wisdom" (2000, p. 71) open to mystery.

Changes over time from adolescence into old age can be tracked in how people "play with the thought of death" (Kastenbaum, 2000, p. 72). The idea of playing with constructs about mortality brings us to the notion of denial. Aries (1974) argued that the denial of death is a dominant framework influencing contemporary Western attitudes, making death both forbidden and titillating.

One idea proposed to explain denial of death is regret theory (Landman, 1993), which in its bare bones is a rehashing of Janis and Mann's (1977) notion of "satisficing" as a psychological measure to minimize decisional uncertainty. In effect, regret theory asserts that—when faced with decisions with consequences for the future—humans learn to balance among competing choices, choosing what to do based on the relative value alternate choices present. Thus, the decision whether to see a specialist to learn what is causing a tremor in one's hands could be put off because doing nothing is convenient and provides reassurance that nothing worrisome is going on. However, the person could choose to see the specialist because the tremors have become too pronounced to be ignored and are affecting normal daily behaviors such as writing and dressing.

A typical information-processing approach used to explain thinking about death is "awareness versus habituation or denial" (Kastenbaum, 2000, p. 72). Awareness versus habituation or denial involves desire for information and use of automatic defense mechanisms against anxiety. This hypothesis maintains that openness to distress, even activation of empathy toward another's pain, depends on one's level of security (Kastenbaum, 2000). The notion here is that willingness to consider mortality is moderated by the extent to which individuals can protect themselves from anxiety. A corollary to this hypothesis could well be found in the desensitizing effects of exposure to media violence found in children and in adults (Bartholow, Bushman, & Sestii, 2006; Smith & Donnerstein, 1998); that is, to protect themselves from the horrors of witnessing violence, people increase their conscious boundaries of what is acceptable, in effect, dismissing the threat that at an earlier time would have been upsetting.

Becker (1973) wrote that successful cultures develop frameworks that enable individuals to cope with the immobilizing threat of death. One framework in our society is provided by the biomedical model which makes death the enemy and leads to institutionalized death denial illustrated by refusals to accept futility when a life-threatening condition is no longer responsive to treatment. The push back against such institutionalized death denial, manifest primarily in the development of the modern hospice movement and the growing clamor for insuring "a good death," is examined later in this chapter.

Death anxiety has been studied at considerable length. Correlation studies with a variety of populations have produced differing results about the associations between death anxiety and several demographic variables: an inverse relationship between self-esteem and death anxiety, nonsignificant associations between socioeconomic status and death anxiety, a diversity of results regarding religious beliefs and death anxiety as well as gender and death anxiety, and nonsignificant findings about family structure and death anxiety (DePaola, Grifin, Young, & Neimeyer, 2003; Kastenbaum, 2000; Missler et al., 2011–2012; Neimeyer, 1994).

Attachment bonds were involved in associations between death anxiety and elderly females, namely, unlike men, "women showed greater fear for the death of loved ones and for the consequences of their own death on their loved ones" (Missler et al., 2011–2012, p. 358). As for correlations between death anxiety and being old, "no support can be found for the proposition that elderly adults live with an elevated sense of fear, anxiety, or distress centering on the prospect of their mortality" (Kastenbaum, 2000, p. 123). On the contrary, acceptance of death rather than fear or anxiety was a dominant finding, particularly among the old-old. At the same time, an extensive examination of research studies about the elderly and death anxiety uncovered direct associations between death anxiety and psychological difficulties, physical problems, and being institutionalized, but found no relationships between death anxiety and age, gender, or religiosity (Fortner & Neimeyer, 1999).

Another way of looking at human awareness of death is what psychologists have termed a "mortality schema" (Lawton, 2001). Coming to a mature understanding of death, humans realize "I too will die." While this existential awareness has been examined under the guise of "terror management theory" (Greenberg & Arndt, 2012), a related concept is the idea that each of us develops a mortality schema about our own likelihood of dying. When in good health, a person's mortality schema remains preconscious or unconscious; Lawton (2001, p. 593) refers to it in these circumstances as latent. As one's health deteriorates and the end of life appears nearer, one's mortality schema becomes manifest. If a manifest mortality schema induces depression or anxiety, the person will incur greater risk to make unreasonable decisions, such as at one extreme foregoing treatment that likely will help or at the other extreme refusing hospice and insisting on aggressive treatment despite the advice of informed medical personnel.

Individual desires about dying do not match the empirical reality about dying. For instance, when surveyed about what they desire the typical respondent wants to die at home, wants a quick and painless trajectory of dying, wants to be surrounded by loved ones, and wants to be conscious and alert until the end (Kastenbaum, 2000). The reality is far different. Most persons die in an institution (a hospital, medical center, or nursing home), are marked with several debilitating conditions, die from a chronic illness over a lingering trajectory, surrounded by strangers, and in pain (Chapple, 2010; Nuland, 1994).

Individuals say it is not death that bothers them. They fear dying in unremitting, excruciating pain, in unfamiliar surroundings, lacking dignity, and alone (Corr & Corr, 2012; Kastenbaum, 2012). These fears match what has been uncovered about dying (Chapple, 2010; Nuland, 1994). Recognition of the realities that characterize dying in institutions has led to efforts to increase the prospects that persons die "a good death."

Hospice is the primary effort within the mainstream medical establishment to address squarely the realities that persons with terminal illnesses typically die in unalleviated pain, surrounded by strangers, and in unfamiliar settings. The basic principle of hospice is that someone who is dying is a living person who deserves to be treated with dignity; the intent is to promote quality of life by alleviating pain so that the prospect for a good death is enhanced. Hospice focuses on the end-of-life, and it affirms the sacredness and value of life (Connor, 2009; Corr & Corr, 2012).

Hospice organizes care for the dying around a holistic framework that attends to six fundamental aspects of existence. These six aspects are the physical, behavioral, emotional, interpersonal, cognitive, and spiritual. Pain can occur in one or more of these fundamental aspects to existence, and thus the hospice team focuses on the whole person, not just on one aspect such as the physical.

The notion of a good death possesses different meanings contingent on the assumptive worlds dominant in a society. In some societies, such as in Japan or among Navajo Indians, an underlying psychological concern is whether the deceased suffered the wrong kind of death and will wreak vengeance upon the living (Goss & Klass, 2005). In Christianity the idea of a good death refers to what happens to the deceased following death. In some societies, such as mainstream America, there is a growing belief that the health care system is obliged to make possible a good death (Emanuel & Emanuel, 1998; Institute of Medicine, 1997).

In twenty-first century secular societies a good death refers to how one experiences dying. The emphasis is on how a person's life ends. Thus, given the realization that the fears about dying in pain, alone, and in unfamiliar surroundings are the rule rather than the exception, efforts have been exerted to change how medical personnel respond to dying patients. The first systematic effort was the prestigious SUPPORT study (1995).

The SUPPORT study was carried out over 2 years in the 1990s in five teaching hospitals in the United States. The focus was on end-of-life preferences, medical decision-making, and interventions with persons diagnosed with a life-threatening illness. Observations in the first year of the study included substantial shortcomings in communication between dying patients and medical personnel, overuse of aggressive treatment at the very end of life, and unalleviated pain (some inflicted by the medical team) in the last days of life. The second year of the study was aimed at correcting these issues by providing specially trained consultants to insure four objectives—all aimed at alleviating persons' psychological fears about dying. The objectives were (i) hospital staff would know patients' end-of-life preferences, (ii) medical staff would employ better pain control, (iii) communication between patients and physicians would improve, and (iv) hospital staff members' understanding of outcomes of care would be patient-oriented. None of these objectives was achieved. The SUPPORT investigators concluded that "greater individual and societal commitment and more proactive and forceful measures may be needed" (p. 1591) to offer better experiences to seriously ill and dying patients.

Undeterred by these unpromising outcomes from the SUPPORT study, some prestigious organizations launched separate efforts focused on making a good death the expected result in American medical practice. First, the Institute of Medicine (IOM) (1997) began a campaign that defined a good death as one "free from avoidable distress and suffering for patients, families, and caregivers" (p. 5); in this definition it is important to note the outcomes of a good death are seen to affect more than the person who is dying, and that a good death will free family members and caregivers—which includes medical personnel—from avoidable distress and suffering. In its discussion of a good death, the IOM also noted that a good death conforms to the wishes of patients and families and remains "reasonably consistent with clinical, cultural, and ethical standards" (p. 5).

In tandem with the IOM paper on providing a good death, the Commonwealth Fund and the Nathan Cummings Foundation, two prominent non-profit organizations focused on health care and social justice, sponsored an extensive, multidimensional examination of a good death (Emanuel & Emanuel, 1998). The Commonwealth-Cummings project authors argue that medical training should include making a good death the standard of care. Such care needs to start with helping physicians become comfortable in being with the dying, competent in giving quality care to the dying, promoting quality of life, and allowing terminally ill persons to die a good death rather than keeping them alive at all costs (Emanuel & Emanuel, 1998).

The Commonwealth-Cummings project asserted that providing a good death—and by inference, promoting quality of life for dying patients—requires attention to six interlinking aspects of life-threatening illnesses: physical symptoms, psychological symptoms, spiritual/existential beliefs, economic demands and caregiving needs, social relationships and support, and hopes and expectations. The close links between this multidimensional perspective and the holistic framework of the modern hospice movement will not be lost on readers.

The authors almost immediately drew attention to the interactive nature of these six aspects of an illness. Thus, "Patients who are depressed or who are experiencing existential meaninglessness can have a lower threshold for pain" whereas "patients who have spiritual fulfillment or good mechanisms to handle caregiving needs may report less bothersome symptoms" (Emanuel & Emanuel, 1998, p. 22). Longitudinal studies have uncovered that most quality of life indicators diminish as people enter further into the end stages of a terminal illness. Rather than dying a good death, a significant percentage of persons (as high as 70% in some studies) die in pain, isolated, surrounded by strangers, and in unfamiliar surroundings (Lawton, 2001).

The notion of "quality of life" plays a central role in much of the discussion about promoting a good death. For instance, Lawton (2001) embraced holism as a sound approach for encompassing the multiple domains of an individual's quality of life. There is strong similarity between Lawton's notion of quality of life and the holistic dimensions enumerated in end-of-life models for promoting a good death by the IOM, the Commonwealth-Cummings project, and obviously the modern hospice movement. Specifically, to the three domains of the physical, social, and psychological, Lawton adds perceived quality of life, that is, "subjective analogues of social QOL such as family quality, friends quality, time quality, and economic security" (Lawton, 2001, pp. 599–600).

The chief matter at stake for the Commonwealth-Cummings project is dealing with pain. The authors wrote about "total pain" (p. 22), suffering that blocks the prospect of a good death and results from either (i) distress in most if not all six aspects of an illness or (ii) overwhelming distress in one or two aspects. Here are specifics about each aspect.

Physical Symptoms

Physical forms of pain have been studied extensively, and it is estimated that drug-related treatments effectively relieve physical pain in 95% of cases. The Commonwealth-Cummings project estimates that proper pain management remains unused in anywhere from 20% to 70% of dying patients. Besides pain, other distressing physical symptoms include nausea, insomnia, and vomiting.

Psychological Symptoms

These symptoms include depression, anxiety, and anger. The Commonwealth-Cummings project notes that there are medical staff who discount the importance of alleviating these psychological symptoms because (i) they are not skilled in treating them and/or (ii) they consider such symptoms a normal part of dying. The authors (Emanuel & Emanuel, 1998) observe that there are several evidence-based approaches to treating depression, anxiety, and anger.

Economic Demands and Caregiver Needs

There is sufficient research data to conclude that caring for a dying loved one imposes significant financial and emotional burdens on families (Saldinger, 2001; Saldinger & Cain, 2005). Links have been established between severe physical and psychological pain, the increase in demands on caregivers, and economic burdens felt by families (Emanuel & Emanuel, 1998; Hansson & Stroebe, 2007). The long-term outcome of economic demands and caregiver burdens can be that following a death the family is left less capable of coping; inferring that such conditions promote vulnerability to complicated grief is not only logical, but empirical research demonstrates early entrance to hospice fosters resilience against such complications in bereavement (Kris et al., 2006).

Social Relationships and Support

Models of coping emphasize that a key adaptive task is to maintain links with other people, not only for solace and consolation but also for information as well as remaining engaged in the wider world (cf. for instance, Moos, 1986). The hospice experience attests to the value that social support plays in helping terminally ill persons and family members at the end of life. The Commonwealth-Cummings project said much more research is needed to determine the kinds of social support dying patients rely on. The authors also called for inquiries into whether and what types of social support beyond the family help the dying patient. In addition, if social support outside the family helps dying patients, attention needed to focus on how that support works (Emanuel & Emanuel, 1998).

Spiritual/Existential Beliefs

This aspect of existence refers to how persons find meaning, purpose, and value in their lives. The assumption is that religion may form part of this meaning making, but that spirituality and religion are not the same.

Hopes and Expectations

Research studies and anecdotal reports document that some deaths tend to occur after important family events such as anniversaries, graduations, or births have occurred (Charles A. Corr, personal communication, November 19, 2013; Emanuel & Emanuel, 1998; Phillips & King, 1988). Some dying people hold on to see these moments. However, there is concern that patients tend to over-estimate their life expectancy and thus tend to put off advance care planning (such as selecting a health care proxy or making funeral plans) with their family members and physicians.

Using both focus group interviews and a national survey with a remarkable response rate of 73%, medical researchers learned what seriously ill patients consider very important attributes of a good death. The eight attributes endorsed by 80% or more of seriously ill patients were being mentally aware, being at peace with God, not being a burden to one's family, being able to still help others, praying, having one's funeral planned, not being a burden on society, and feeling one's life is complete (Steinhauser et al., 2000). See Table 24.1 for a breakdown of the percentage of the respondents who endorsed each attribute as very important for a good death.

Elements of personal dignity and personal autonomy as important aspects of a good death also surfaced, particularly in the focused interviews. Not only seriously ill patients but also family members and physicians overwhelmingly agreed on the importance of being prepared and knowing that one's family members were prepared. Being prepared took on such nuances as knowing clearly one's diagnosis, prognosis, and treatment options. A further element in a good death endorsed by focus group members was completing unfinished business, saying goodbye to important persons in one's

TABLE 24.1 The Percentage of Seriously Ill Patients Who Endorsed Eight Attributes They Considered Very Important for a Good Death

Attribute	Patients
Be mentally aware	92%
Be at peace with God	89%
Not be a burden to family	89%
Be able to help others	88%
Pray	85%
Have funeral planned	82%
Not be a burden to society	81%
Feeling one's life is complete	80%

Steinhauser et al., 2000.

life, and talking about the meaning of death with someone willing to listen to a person express fears about dying (Steinhauser et al., 2000).

Of considerable concern are data from the SUPPORT study (1995) that physicians were wrong in at least 33% of cases regarding their patients' preferences toward cardiopulmonary resuscitation; further, spouses were found to agree at most in only 50% of cases involving dying patients' choices. The mismatch between what dying persons want and what medical staff as well as family members perceive they want underscore that promoting a good death as the medical norm necessitates increasing accurate, attentive communication between terminally ill individuals, the medical team, and the family (Lawton, 2001).

PART 3: BEREAVEMENT, GRIEF, AND MOURNING IN CONTEMPORARY SOCIETY

Some Introductory Material

The term *bereavement* refers to a state of loss, such as the death of a friend; *grief* is the term denoting reactions to bereavement, and *mourning* identifies expressions of grief (*Oxford English Dictionary*, 1989). Most research into bereavement has focused on older persons, primarily widows, and by far females are much more likely than males to participate in bereavement research (Hansson & Stroebe, 2007; Stroebe & Stroebe, 1989–1990).

Freud's grief work theory influences the preponderance of bereavement research and clinical practice. First presented in 1917 (Freud, 1957) and then brought into the mainstream of American clinical work by Lindemann (1944), the grief work theory maintains that recovery from bereavement requires consciously and persistently confronting distressing reminders of the death, withdrawing of one's emotional investment in the deceased, and forming a mental representation of the deceased that does not stir up pangs of grief. Freud's argument was that bereavement was an intra-psychic struggle between the Id and the Ego over the reality of the death. While not disavowing the need for confronting the distressing reminders, withdrawing attachment to the deceased, and forming a positive memory of the deceased, Bowlby (1969–1980) made sundered bonds of attachment the crux of bereavement and maintained recovery involved adjustment to an altered interpersonal environment rather than an intra-psychic struggle.

The most influential variations on Freud's model include the dual process model and the notion of continuing bonds. The dual process model accepts the grief work theory up to a point, namely, the need to confront distressing reminders of one's bereavement, and posits that the natural process of coping and recovery also involves engaging with the world of the living. The former process is termed a loss orientation, and the latter a restoration orientation. The authors of this dual process model note that grieving persons naturally oscillate between the two orientations (Stroebe & Schut, 1999).

For decades both clinical lore and the mainstream understanding of bereavement maintained that severing emotional attachments to the one who died was a necessity to recover from bereavement, and as a corollary asserted that ongoing attachments to the deceased signified pathology. Work with bereaved adolescents and bereaved parents (Hogan & DeSantis, 1992; Klass, Silverman, & Nickman, 1996) as well as with bereaved children (Silverman, Nickman, & Worden, 1992; Worden, 1996) introduced the notion that remaining attached to the deceased, that is, a continuing bond, was not uncommon; in short, rather than a sign of pathology, continuing bonds to the deceased formed a normal response in the lives of many grievers. In very short time, the uncritical bandwagon acceptance of continuing bonds moved the construct from an important corrective to the notion of emotional withdrawal to a judgment that the lack of continuing bonds was a sign of pathology. Careful research examining types of attachment eventually introduced the understanding that secure attachments were associated with positive ongoing bonds but insecure attachments called for letting go of bonds to the deceased (Stroebe & Schut, 2005).

The myth that all deaths elicit ongoing distress has been put to rest. The deaths of oppressive, abusive husbands are greeted as liberating according to the testimony of several widows (Elison & McGonigle, 2003). The research of Wortman and Silver (1989) falsified the expectation that the deaths of loved ones would necessarily entail various forms of distress, including depression, and that only a period of working through one's grief would provide recovery from bereavement; this finding very likely is explained by the discovery of a resilient grief trajectory in which the majority of bereaved individuals quickly return to healthy functioning (Bonanno, 2009).

Based on longitudinal research gathered in the Changing Lives of Older Couples (CLOC) study, three dominant patterns of responses over time to bereavement have been uncovered (Bonanno, 2009). A plurality—and in some other studies a majority of persons studied—rebound quickly from the death of a spouse, other family member, or friend; by quickly is meant within a few weeks. It is not that the death does not matter to the griever, but more that the death does not shatter the person's assumptive world and challenge their coping skills when facing adversity. A second trajectory comprises how approximately 43% of persons respond to the death of a loved one; called a recovery trajectory, this pattern begins with difficulty adjusting to the death, but within 18–24 months a griever's distress noticeably lessens and the person more readily reengages in relationships with others and the wider external world. It is very likely that persons in a recovery trajectory are what Freud and many who have written about bereavement considered the typical or normal course of responding to a loss. The third trajectory, termed enduring grief, is found in around 12% of bereaved persons who have been studied. Persons in the enduring grief trajectory manifest what are known as symptoms of complicated grief; it is an element of clinical lore that without assistance from skilled professionals, primarily using cognitive behavioral therapy, persons in an enduring grief trajectory will continue to be "stuck in their grief." More recently terms to identify complicated grief include *prolonged grief disorder* and *persistent, pervasive grief disorder* (Bonanno, Wortman, & Neese, 2004; Prigerson, Vanderwerker, & Maciejewski, 2008).

Debates have swirled within psychiatric and psychological circles about whether persons in the first 2 months of bereavement should be treated for clinical depression. From the early 1990s until 2013, the *Diagnostic and Statistical Manual of Mental Disorders* (DSM) excluded diagnosis (and, by implication, treatment) for depression in the first 2 months of bereavement unless the depression was related to something other than the death being grieved. The argument was that normal bereavement mimics depression but that the central features of depression are absent; in short, the person does not feel utterly worthless or helpless. If after 2 months the bereaved individual manifests signs of clinical depression, the protocol was to use evidence-based procedures that are effective against clinical depression. The 5th edition of the DSM has removed this caution and now permits persons who are grieving to be diagnosed for clinical depression within the first 2 weeks of their bereavement (American Psychiatric Association, 2013; Shear et al., 2011).

Within the past 20 years prominent bereavement researchers have become skeptical that phenomena central to bereavement were being examined. Several psychological markers of distress such as depression and anxiety were studied, but the question rose whether the core phenomena were being overlooked or overwhelmed with a focus on typical symptoms of psychological distress (Burnett, Middleton, Raphael, & Martinek, 1997; Neimeyer & Hogan, 2001; Neimeyer, Hogan, & Laurie, 2008). In longitudinal research with bereaved adults and children, a team of researchers led by Beverly Raphael winnowed core bereavement phenomena to 17 items that factor analysis indicated group into three distinct facets of loss: frequent thoughts and images of the deceased, a sense of acute separation, and distress related to reminders of the death.

The first category—frequent thoughts and images of the deceased—includes seven items such as intrusive thoughts about the deceased and preoccupation with thoughts and images of the deceased. The second category—a sense of acute separation—includes five items such as yearning for the deceased and feelings of distress when realizing the deceased will not come back. The third category—distress related to reminders of the death—includes five items such as loneliness attributed to reminders from photos or other sources and loss of enjoyment produced by reminders from photos or other sources. It is of central importance to note that these core bereavement phenomena are seen as normal responses to the loss of a loved one, not pathological reactions (Burnett et al., 1997).

With that introductory overview about bereavement, I will turn to some of the specific findings regarding bereavement in the later years of life. One area of investigation has examined whether age presents a risk factor for poor bereavement outcomes. Do older adults fare worse than younger following the death of a loved one?

An underlying problem with much research into aging and bereavement is the lack of a developmental perspective; for example, there are studies that use cross-sectional designs, gather data retrospectively, and lack non-bereaved control groups (Hansson & Stroebe, 2007). However, some convincing studies have uncovered that younger adults are at greater risk of distress following the death of a spouse than are older adults. For instance, Parkes' (1972/1996) study of older and younger widows in Boston found poorer psychological outcomes in the younger and poorer physical outcomes in the older. Later gerontological studies have replicated these findings (for instance, Murdock, Guaranaccia, Hayslip, & McKibbin, 1998; Schulz et al., 2001). In losses other than the deaths of spouses (such as the deaths of children), younger rather than older adults manifest more adaptive coping (Rubin, 1993).

Curvilinear outcomes suggest longer-term studies than a few months or even a year are needed to draw reliable conclusions about bereavement outcomes for older and younger adults. Hansson and Stroebe (2007, p. 65) have noted that more intense early reactions in younger adults ameliorate "whereas problems for older bereaved may be longer drawn out." There is some evidence that mortality is a greater risk following bereavement for younger adults than older. However, confounding variables have been identified. One example is failing to take into account that healthier younger widows are likely to remarry: there is a strong positive association between better health and longer life in widows who remarry.

Evidence has accumulated that widowers' mortality is at greater risk than is widows', particularly among younger men. There are, however, nagging concerns that the lack of long-term longitudinal studies in this area may have left uncovered issues of curvilinearity in bereavement symptoms (Hansson & Stroebe, 2007).

Comparing findings in outcome studies of older and of younger bereaved adults has led to confidence that the patterns of bereavement are quite alike in both clinical and non-clinical consequences. For instance, there are similar patterns in the report of loneliness, social isolation, struggles with self-efficacy, elevated physical and psychological signs of distress, mild to severe depression, and complicated grief. In both younger and older bereaved widows, research data, for instance, indicate "intense symptoms are to be expected in the first months post-loss, after which (with some important exceptions) they begin to subside as the individual adapts" (Hansson & Stroebe, 2007, p. 94).

A 3-year prospective study with a control group of married non-bereaved adults followed older adults whose spouses had died, and the researchers found signs of increased depression for the bereaved adults in the first year after the death. By the second year, most persons' depression symptoms had left. Compared to the married control group subjects, the percentage of bereaved adults manifesting depression was higher throughout the entire life of the study (Mendes de Leon, Kasl, & Jacobs, 1994). These findings from Mendes de Leon et al. have been replicated in other well-designed longitudinal studies examining depression in older bereaved adults: depression ameliorated in the third year following a spouse's death, particularly for widows who had been able to anticipate their husband's death (Byrne & Raphael, 1999; Carnelley, Wortman, & Kessler, 1999; Turvey, Carney, Arndt, Wallace, & Herzog, 1999).

The CLOC research project has provided extensive evidence documenting the differential bereavement outcomes for older adults based on the timing of the spouse's death (Carr, House, Wortman, Nesse, & Kessler, 2001). The results do not always favor anticipation over having been taken by surprise. While immediate negative effects, such as intrusive thoughts, were common when deaths were sudden and unexpected, extensive experience of a spouse's lingering dying in pain and suffering produced greater anxiety following the death than experienced over sudden deaths or over anticipated deaths that went smoothly. The problems for persons following a lingering, complicated death were attributed to the relentless build-up of stress when caring for a loved one and watching the person's decline. Amy Saldinger (2001) and her colleagues (Saldinger & Cain, 2005; Saldinger, Cain, Kalter, & Lohnes, 1999) have reported similar results in families with the deaths of young parents.

Hansson & Stroebe (2007) summarized the results of several studies that examined effects of caregiving on bereavement outcomes; the results suggested that for many caregivers, particularly for those persons who had support from others and who had attended to their physical and psychological needs, caregiving to the dying did not intensify their bereavement. However, among some caregivers the stress accumulated during the illness never lessened after the death. These studies which examined caregiving in cases of terminal cancer need to be placed against the much more pessimistic outcomes found for partners who provide care for Alzheimer's patients (Emanuel, November 17, 2013; Gonzalez-Salvador, Arango, Lyketsos, & Barba, 1999; Quayhagen & Quayhagen, 1988).

The attachment theory of bereavement refers to secure and insecure bonds (Bowlby, 1969–1980; Stroebe & Schut, 2005). Longitudinal research studies, most particularly the CLOC project, have found greater pining after and yearning for the deceased exhibited in elderly persons whose marriages were marked by secure bonds and less yearning for and pining after in older adults whose marriages were marked by conflict (Carr et al., 2001). Stroebe and Schut (2005) argued from empirical data on types of attachment and bereavement outcomes that continuing bonds were to be encouraged when there had been a secure attachment but that bonds should be loosened when attachments had been insecure. Several widows, as noted above, documented that the deaths of their oppressive, overbearing husbands had been greeted with a feeling of liberation (Elison & McGonigle, 2003).

CONCLUSION

In this chapter I examined issues involved with the psychology of death and dying in later life. The overarching socioenvironmental context imposed by the pervasive acceptance of science, technology, and the biomedical model was reviewed because of the influence this context has on understandings of death, on individual assumptions about reality, and on experiences with dying. Next, I paid attention to individual expectations and fears about dying, including empirical data and proposed policy changes for promoting a good death, with emphasis on quality of life perceived within a holistic framework. Finally, I turned attention toward bereavement, grief, and mourning in later life.

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