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Cognitive Development in Midlife

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The group of middle-aged adults between the ages of roughly 40 and 65 years gains growing interest from the public and scientists alike because it currently represents one of the largest age groups in Europe and the United States. A better understanding of midlife cognitive development and related factors might become increasingly important as these cohorts reach old age, and cognitive aging affects an increasingly large proportion of the overall population. In this chapter, we review selected literature on cognitive development in middle adulthood. Our focus is on cognitive development because cognition is one of the key competencies needed in young and old age to meet the challenges of education, job demands, and everyday life (M. M. Baltes & Lang, 1997; Martin & Mroczek, in press).

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Studies of cognitive development in midlife can be characterized by two main approaches. On one hand, the decline of cognitive resources is a main concern for persons from middle age onward (Lawton et al., 1999). Thus, studies on midlife cognition have focused on the question of whether groups at risk for decline in early old age could be identified. The timely identification of at-risk individuals would permit preventive measures targeted at early stages of decline (see Schaie, 2000). One could speculate that middle age would be an ideal time for preventive measures because the performance around a lifetime peak level increases the likelihood of training gains. In addition, even though declines in performance are from a high starting level, these first signs of decline might be salient enough to motivate persons to participate in cognitive trainings. On the other hand, midlife might be characterized by cognitively demanding activities and relatively high levels of cognitive performance. Thus, there is an interest in examining if and how demanding activities and a wide spectrum of interests in middle age may protect middle-aged adults from cognitive decline or at least provide compensatory potential for the later years of life.

Although studies observe high mean levels of cognitive performance across middle age, it can be argued theoretically that middle age differs from both young and old age in several ways. First, different developmental tasks and everyday demands (Havighurst, 1948/1982; Sternberg, Grigorenko, & Oh, 2001) in midlife versus young and old age make person-environment interactions hardly comparable between midlife and other ages. For instance, it is hard to see in which way the challenge of schooling in young age or of retirement in old age is comparable to challenges at midlife, which consist of work and family environments requiring the particular skills of organizing, planning, problem solving, and multitasking (Schooler, 1999). For example, family obligations peak in middle-aged adults who are in good health, have numerous elderly kin, and have children just moving out and establishing their own families (Hogan, 1987; Rossi & Rossi, 1990). In the same vein, raising children is a typical demand around the ages of 25 to 40, but rarely so at age 60 (Hogan, 1987). In the work domain, average job demands and workloads increase from age 25 to age 40 and then decrease toward age 60 to 70 (Townsend, 2001).

Second, in young age, cognitive development is strongly influenced by formal training and characterized by shared and homogeneous environments such as school classes or peer groups (Espy, Molfese, & DiLalla, 2001).

In old age, cognitive development becomes increasingly dependent on physiological factors such as sensory and sensorimotor functions (P. B. Baltes & Lindenberger, 1997; Li & Lindenberger, 2002; Lindenberger & Baltes, 1994; see also Hofer, Berg, & Era, 2003). In middle adulthood, after having reached a high level, cognitive performance will be shaped strongly by individual environments (see Sternberg et al., 2001). Different job environments have been shown to influence development of cognitive skills (Kirlik & Bisantz, 1999). This can be explained by assuming that in particular job environments, individuals will engage in similar cognitive activities, for example, reading particular instructions, thinking about how to achieve particular goals, planning particular behaviors, or regulating success or failure in achieving subgoals. All individuals may achieve their goals, all will have used at least some of the same underlying abilities, and all will have practiced particular skills. Thus, compared to young and old age, in midlife one would expect more differentiated, that is, less correlated, patterns of particular cognitive functions. This expected differential influence of developmental contexts, such as from professional, family, or social life, would suggest large individual differences within age groups and across middle adulthood that are potentially enlarged by individual differences in activities aiming at improving or maintaining current levels of cognitive functioning, such as participating in memory trainings (West & Tomer, 1989).

Third, developmental potential in young age is needed to support natural maturation and academic achievement (Rees & Palmer, 1970) and to prepare for job demands (Havighurst, 1948/1982). In old age, cognitive training may serve to prevent consequences of age-associated decline, although effects are typically small (Ball et al., 2002; Willis & Schaie, 1986). In middle age, cognitive potential is typically used to develop job-specific skills, thus contributing to the development of highly job-specific and individualized change trajectories (Moen & Wethington, 1999). In addition, the effects of and transfer from cognitive trainings are likely to be higher in midlife than in young or old age (Kliegl, Philipp, Luckner, & Krampe, 2001), and different biological or hormonal changes may influence cognition in middle compared with young and old age (Seeman, Singer, Ryff, Dienberg-Love, & Levy-Storms, 2002).

Fourth, cognitive development in middle age can be characterized by rather high mean levels of cognitive performance (Willis & Schaie, 1999). In young age, the level of cognitive performance across many different tasks increases; thus, development is generally characterized by increases in performance from low to high levels. In old age, cognitive performance

eventually demonstrates declines; thus, development is characterized by decreases in performance from a high starting level. Overall, the high or even peak level of performance at middle age (Willis & Schaie, 1999), combined with a different direction of mean change, may represent a qualitative difference from other age groups. In fact, changes from peak performance are less likely to influence everyday life, and thus might not be comparable to increases from a lower level, such as in young age groups, or decreases from a high level until potentially affecting the level of independence in everyday life as in very old age.

Cognitive Development Across Middle Age

The Seattle Longitudinal Study (Schaie, 1996) has provided detailed insights into the developmental trajectories of several intellectual functions across middle age (see Willis & Schaie, 1999). The data suggest that for inductive reasoning, vocabulary, verbal memory, and spatial orientation, the average performance peaks occur in the ages from the early 40s to 60s, with fluid intelligence abilities showing earlier declines than crystallized abilities. For perceptual speed and numerical ability, performance peaks before midlife and declines through midlife and into old age. Willis and Schaie conclude that "for four of the six abilities studied, middle-aged individuals are functioning at a higher level than they did at age 25" (p. 238). Examining the mean trajectories of the four abilities peaking in midlife would suggest that middle adulthood could be characterized as stable with relatively small mean changes. This explains why a number of longitudinal studies include middle-aged adults as a comparison group, but only few include the examination of changes in cognitive performance across midlife (Bosma, van Boxtel, Ponds, Houx, & Jolles, 2003; Finkel, Pedersen, & Harris, 2000; Lamar, Resnick, & Zonderman, 2003; Maitland, Intrieri, Schaie, & Willis, 2000). However, the data based on mean changes of all six cognitive and intellectual functions demonstrate that within the same time period, patterns of increases, declines, and stability can be observed with substantial intraindividual variability. This suggests that middle age should not be taken as a period of the life span that is mainly, or only, characterized by stability. Instead, in middle age, different types of cognitive change occur within and across abilities (Dixon, De Frias, & Maitland, 2001). Thus, the different types of changes in particular cognitive functions across middle age require explanations.

Examining Different Types of Change

The question of whether cognitive performance changes during middle adulthood is not just a yes-or-no question. In fact, change in cognitive performance may manifest itself along several dimensions, each of which covers different aspects of change. One might distinguish between structural change, absolute change, differential change, change in divergence, and general versus specific change (Hertzog & Dixon, 1996). In what follows, we discuss these different aspects of change and related empirical findings in turn. Note that although the emphasis is on longitudinal change, one might argue that some of these aspects of change might also be examined by comparing different age groups, conditional on the assumption that cohort effects do not play a major role in cognitive development in middle adulthood.

Structural change (or stability) refers to the persistence of covariation patterns among variables across time or in different age groups. Although in principle it is possible to compare the equality of covariance matrices directly (Perlman, 1980), the usual procedure is to utilize factor analysis techniques in order to exclude covariance differences due to measurement error (Bollen, 1989). Within factor analysis models, structural stability is labeled measurement invariance, which implies that the variables in question are unbiased with respect to specific selection variables, for example, time of measurement or age at measurement.

Measurement invariance is an issue of degree (Bollen, 1989; Meredith, 1993) regarding the level of invariance obtained and is based on whether increasingly stringent constraints result in model misfit. *Configural invariance* refers to the same pattern of factors and factor loadings in different subgroups (e.g., age groups). Configural invariance holds, for example, if in a sample of persons aged 40 and a sample of persons aged 60, a battery of six cognitive measures would be described adequately by two correlated factors with the same measures loading on the first factor (say, Tests 1–3) and the same measures loading on the second factor (say, Tests 4–6) in both age groups. *Metric or pattern invariance* requires the (unstandardized) factor loadings to be equal in different subgroups. On a conceptual level, metric or pattern invariance ensures that there is no interaction between group membership and factor scores. Such an interaction would be a form of bias because for a given factor score on a latent variable, the

regression of observed scores on it would depend on group membership. In addition to metric invariance, *strong invariance* requires the latent intercepts of the observed indicators to be equal across groups. Conceptually, the requirement of equal latent intercepts tests whether one group scores consistently higher (or lower) on the measures than other groups for each value of the factor (weighted by the factor loadings). Eventually, *strict invariance* adds the requirement of equal residual variances across groups. To understand the requirement of equal residual variances on a conceptual level, suppose that a test is utilized for an admission decision and a certain ability level as measured by the factor is needed. If the decision were based on the observed scores, the number of incorrect admissions and incorrect rejections would be higher in groups with larger residual variances.

As Meredith (1993; see also Meredith & Horn, 2001) has demonstrated, for structural stability to hold, strong invariance should be established; in other words, across time or across different age groups (or both), the configuration of factors, the factor loadings, and the latent intercepts of the manifest indicators should be equal. As some developmental psychologists argue (P. B. Baltes, Reese, & Nesselroade, 1977), the importance of structural stability stems from the fact that it represents a prerequisite for interpreting change (or stability). Specifically, only the existence of strong invariance renders the comparison of cognitive measures meaningful, either across time or across different age groups (or both). Thus, strong invariance or structural stability has to be established before other forms of change (or stability) can be investigated.

Empirical research on structural stability of cognitive abilities in middle adulthood is sparse at present. Taub, McGrew, and Witta (2004), for example, found metric invariance to hold for the Wechsler Adult Intelligence Scale-3rd edition (WAIS-III) across 13 age groups in 2,450 individuals aged 16 to 89, implying that, across the whole adult lifespan and, thus, also across middle adulthood, factor loadings of the WAIS-III subtests remained stable. Schaie, Maitland, Willis, and Intrieri (1998) investigated longitudinal measurement invariance of six primary mental abilities (Inductive Reasoning, Spatial Orientation, Perceptual Speed, Numeric Facility, Verbal Ability, and Verbal Recall) across a 7-year period in a sample of 984 individuals, disaggregated into six age groups (32, 46, 53, 60, 67, and 76 years at first testing). They found that, longitudinally, strong invariance was present in the middle-aged groups only. Schaie (1996) established metric invariance for the same primary mental abilities in a sample of 1,621 individuals subdivided into nine age groups (29–90).

Horn and McArdle (1992) reported that in the standardization sample ($N = 1,880$) of the Wechsler Adult Intelligence Scale-Revised (WAIS-R), strong invariance was found for a complex two-factor model of the subtests in four age groups (16–22, 30–40, 50–60, and 67–72 years of age). To summarize, previous findings indicate that the structure of cognitive abilities is rather stable in middle adulthood in the sense that metric invariance or strong invariance seems to hold. Note, however, that different degrees of factorial invariance have to be reexamined and, possibly, reestablished in every new sample and for the measures used in a study to assess cognitive abilities. Thus, measurement invariance is an essential part of research that should be investigated in studies that aim to examine the other aspects of cognitive change in middle adulthood.

A special field of empirical research with respect to structural change or stability is the question of differentiation or dedifferentiation of cognitive abilities with advancing age (Ghisletta & Lindenberger, 2003; Zelinsky & Lewis, 2003). Note that differentiation or dedifferentiation of cognitive abilities in middle adulthood does not exclude structural stability, because (de-)differentiation commonly involves the covariances between measurement-invariant factors. Hence, structural stability and (de-)differentiation do not contradict each other, but, again, a prerequisite for (de-)differentiation is structural stability. Some cross-sectional studies have provided empirical support for cognitive dedifferentiation in the elderly (Babcock, Laguna, & Roesch, 1997; P. B. Baltes et al., 1980; Hertzog & Bleckley, 2001). By contrast, in other cross-sectional studies, contrary findings (i.e., a differentiation of cognitive abilities with age) have been reported (Cunningham, Clayton, & Overton, 1975; Schmidt & Botwinick, 1989; Tomer & Cunningham, 1993), or results supported neither differentiation nor dedifferentiation (Bickley, Keith, & Wolfe, 1995; Cunningham & Birren, 1980; Juan-Espinosa, García, Colom, & Abad, 2000; Juan-Espinosa et al., 2002; Park et al., 2002). Thus, the question of dedifferentiation would profit from a longitudinal examination. To our knowledge, the only longitudinal study examining dedifferentiation, albeit in old age, was conducted by Anstey, Hofer and Luszcz (2003). In a sample of 1,823 individuals aged 70 years and older, they did not find consistent patterns of dedifferentiation. Hence, at present, the evidence for dedifferentiation in middle adulthood is sparse.

Absolute change (or stability) refers to constancy in the quantity or amount of a cognitive ability over time or across age. Although one might be interested in cognitive change in individual persons, absolute change

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is usually examined using average (i.e., sample values of groups of) persons. Traditionally, sample means of cognitive abilities have been compared across time or in different age groups in order to test for absolute continuity (Schaie, 1996). Using latent growth models, Finkel, Reynolds, McArdle, Gatz, and Pedersen (2003) found that across a 6-year period, the longitudinal rate of decline in a sample of 590 adults aged 44 to 88 years accelerated from middle to later adulthood for four of five cognitive abilities, the common element of which was perceptual speed. A single-slope estimate provided sufficient description of the data for another five cognitive measures, meaning that the rate of decline in these abilities did not differ by age group. Thus, accelerating decline at the transition from middle to late adulthood seems to be evident for some, but not all, cognitive abilities. Similarly, Finkel, Pedersen, Plomin, and McClearn (1998) reported that middle-aged adults (55 years) performed significantly better than old adults (83 years) in all of a battery of 14 cognitive variables. The largest age differences in mean performance were found for measures of perceptual speed. Soederberg Miller and Lachman (2000) investigated whether midlife is a time of peak performance in the area of cognitive functioning. Comparing the average performance of 84 young adults (25–39 years), 108 middle-aged adults (40–59 years), and 67 older adults (60–75 years) in speed reasoning, short-term memory, and vocabulary, they found that middle-aged adults showed little or no cognitive declines on speed, reasoning, and short-term memory measures relative to the young and outperformed the young on vocabulary. Relative to the elderly, middle-aged adults scored higher on all tasks except vocabulary, for which there were no differences.

An alternative procedure would consist of establishing structural stability and then testing for differences in factor means across time or different age groups. Doing so would minimize the influence of measurement error and, at the same time, assure that the measures used are unbiased with respect to time and age. Horn and McArdle (1992), for example, after establishing strong invariance, found that compared to young (16–22 years) and old (67–72 years) adults, the average verbal cognitive component in the WAIS-R was highest in both middle-aged adults groups (30–40, 50–60 years), whereas the average performance cognitive component was highest in the younger age group and the younger of the two middle-aged cohorts. Specifically, the effect size for the verbal cognitive component was about Cohen's $d = .40$, indicating a small to medium performance difference favoring middle-aged adults (Cohen, 1987). A similar

effect size was found for the performance cognitive component, showing that the 50- to 60-year-old participants scored, on average, about $d = .38$ below the younger adults and the 30- to 40-year-olds. Schaie et al. (1998), after establishing strict invariance, reported that across a 7-year longitudinal time period, those aged 60 to 67 declined on the primary mental ability factors Inductive Reasoning, Spatial Orientation, Verbal Comprehension, Numeric Facility, and Perceptual Speed, but not Verbal Recall; those aged 53 to 60 remained stable on five of the six cognitive abilities with statistically significantly decline evidenced only for Numeric Facility; and those aged 46 to 53 were stable on four of the six abilities and showed improved performance for the Verbal Comprehension and Verbal Recall factors (see also Schaie, 1996, pp. 126–129). Overall, with respect to the more crystallized or pragmatic cognitive abilities, middle-aged adults show a peak performance, whereas for the more fluid or mechanic cognitive abilities at the end of the period of midlife, a decline in performance is present.

A limitation of comparing means across time, different age groups, or both is that mean stability in middle adulthood might mask individual differences in cognitive development. That is, mean stability might appear in the presence of individually differing changes; for example, one half of the sample might increase in cognitive abilities and the other half decreases to the same amount (Hertzog & Dixon, 1996). To check for individual differences in change, stability of individual differences over time is required. That is, examining absolute change in middle age requires longitudinal data to determine the influence of environmental factors on cognitive development, the effects of chronic stressors on cognitive performance, the interaction between changes in different cognitive domains, and cohort differences between early and late middle age in the amount of cognitive performance change.

Differential change (or stability) refers to the consistency of individual differences in cognitive abilities across time. Empirically, the consistency of individual differences is often indexed by a correlation coefficient between two adjacent measurement occasions. For this reason, differential change can only be assessed longitudinally (and not cross-sectionally, i.e., across age groups). Conceptually, differential change implies that some individuals change to a larger (or smaller) amount than others, such that the rank order of individuals is different at different time points. Traditionally, correlations across time have been computed for observed measures of cognitive abilities (e.g., sum scores). Although according to

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classical test theory, random errors should cancel out across repeated assessments such that the correlation of scores should be uncontaminated by (random) measurement error, there might be other systematic influences that may qualify the comparison of observed scores across time. Again, a possible strategy to diminish such unwanted influences might be to establish strong invariance and to calculate the correlation across time between factors. However, to protect against unique systematic influences such as some forms of retesting effects (e.g., reduced test anxiety, learning, etc.), no statistical approach is optimal. Rather, this would require considering possible retesting effects in the design of a study, for example, by including independent samples at later measurement occasions (Schaie, 1996).

A problem with differential change is that it is difficult to judge when stability is low enough to consider it practically important. Thus, a stability of .90 might be considered high enough by some researchers to regard change of relative positions as negligible, whereas other researchers may emphasize the fact that stability is not perfect, from which one could conclude that there is differential change.

A strength of examining differential change is that relative change, that is, the degree to which individuals' cognitive performance changes in similar directions over time, is considered. However, from a low stability implying pronounced differential change, we do not know whether the sample of persons—let alone an individual person—increases or decreases in their cognitive ability level. Moreover, using correlations, we also do not know whether variances (i.e., the amount of interindividual differences) change across time.

Change (or stability) of divergence refers to the fact that using correlations, we do not know whether variances change over time. That is, across time there might be perfect differential stability and no absolute change, but variances might increase or decrease (Preece, 1982). This would still be indicative of individual differences in change, although both the mean level and rank order of individuals might be perfectly preserved across time (Hertzog & Dixon, 1996).

Examination of the age-related changes in variances in cognitive performance across middle age is needed to determine the degree to which there might be differential developments between populations at risk for further and stronger declines and populations repeatedly profiting from gains in performance because they are starting from high levels of performance. A better understanding of the processes leading to this dissociation of

development could point to events or ages in the life course when persons respond particularly strongly to] even small improvements or declines in performance, thus setting the stage for a developmental trajectory of life-long gains or lifelong losses in performance.

General versus specific change (or stability). Change in different cognitive abilities might or might not be correlated across persons. The question is whether or not there is an overall commonality in change of different cognitive abilities. If changes in cognitive abilities are highly related, this would suggest one factor, or at least very few factors, responsible for the individual changes observed; this factor would explain a similarly large degree of cognitive change in most individuals. This could occur in stable environmental conditions leading to very similar cognitive activations or when similar physiological processes are strongly influencing performance despite environmental variations between persons and over time (Pedersen & Lichtenstein, 1997; Pedersen, Spotts, & Kato, Chapter 3, this volume).

Intraindividual variability (or stability). Until recently, most longitudinal studies of cognitive aging have focused on mean changes and declines in cognitive performance as people age (Schaie & Hofer, 2001). Although the focus on mean change has not emphasized between-person differences in intraindividual variability in cognitive functioning, intraindividual variability has long been considered an interesting outcome in itself (Nesselroade, 1991). There is now sufficient empirical evidence to establish that intraindividual variability is a substantial source of systematic performance variability between people, especially in adults (Hultsch, Hertzog, Small, McDonald-Miszczak, & Dixon, 1992; Martin & Hofer, 2004; Nesselroade, 2001). In fact, recent studies suggest that intraindividual variability may predict later cognitive difficulties in older age (MacDonald, Hultsch, & Dixon, 2003; Rabbitt, Osman, Moore, & Stollery, 2001; Rowe & Kahn, 1997; Schaie, 2000). Even within the middle adult age range, there seem to be substantial interindividual differences in intraindividual change in particular cognitive functions (Ghisletta, Nesselroade, Featherman, & Rowe, 2002; Zimprich & Martin, 2002). Willis and Schaie (1999), in their review of longitudinal data on cognition, point out that there are significant individual differences above and beyond differences depending on design (i.e., cross-sectional vs. longitudinal) and length of longitudinal interval. This renders it meaningful to examine individual differences in change in cognitive functioning across midlife.

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Once sufficient data on midlife cognition are available, it can be established to which degree individual differences in developmental changes might be due to (a) individual differences in usage and training (Bosma et al., 2003; Hultsch, Hertzog, Small, & Dixon, 1999), (b) individual differences in the interaction between environmental demands and age-related levels of performance (Sparrow & Davies, 1988), or (c) individual differences in resilience (Staudinger, Marsiske, & Baltes, 1995) and compensatory processes individuals apply to maintain a high level of everyday functioning (Freund & Baltes, 2002). It would also be possible to examine the role of individual differences in the effects of differentiation in early middle age and dedifferentiation processes in the transition from middle to old age (Reinert, Baltes, & Schmidt, 1965). Finally, it could be examined to which degree interindividual differences in intraindividual change across middle adulthood are related to changes in other cognitive (and noncognitive) domains.

It should be noted that as the six aspects of change discussed so far refer to groups of persons (the way persons are investigated empirically), it is impossible to conclude that the same change takes place for all individuals. Strictly speaking, with the exception of general versus specific change, the change observed in groups of middle-aged individuals might not capture the change of any individual person. Assuming, however, that the group change is representative of individual changes, the merit of examining groups is the generalizability of findings due to more representative selections of samples and more reliable measurements of cognitive functioning.

Changes in Cognitive Performance in Early and Late Middle Age

To examine changes in cognitive performance across middle adulthood, a number of different approaches and data may be used. For illustrative purposes, we will be using longitudinal data from the Interdisciplinary Study on Adult Development (ILSE; Martin, Grünendahl, & Martin, 2001). ILSE is an ongoing interdisciplinary longitudinal study of the psychological, physical, and social antecedents and consequences of aging among two groups of participants: a cohort born in the years 1930 to 1932 and a cohort born 1950 to 1952. Earlier analyses with the older cohort demonstrated substantial amounts of interindividual differences in several aspects of cognitive change over time (Martin & Zimprich, 2003; Zimprich, Martin, & Kliegel, 2003). However, similar questions have not yet been

addressed with the early middle-aged cohort of the study. Currently available for this cohort are data from two measurement occasions, the first (T1) in 1995 and the second (T2) in 1999, that is, a longitudinal time period of approximately 4 years. We selected those $N = 479$ participants from the 1950–1952 cohort—of originally 501 participants at T1—who had complete data records for the variables of interest at both measurement occasions. Mean age of the sample at T1 (1995) was 43.8 years ($SD = 0.91$ years). Of the 479 participants, 226 (47%) were female.

Measures

Processing Speed

Processing speed was assessed using the Digit Symbol Substitution subtest of the German Version of the WAIS-R (Tewes, 1991) and the d2-Test (Brickenkamp & Zillmer, 1998). The Digit Symbol Substitution (DS) subtest requires using a code table of numbers paired with symbols in order to fill in as many correct symbols under the numbers of the answer sheet as possible. Scored are the numbers of correctly copied symbols within 90 seconds (possible range: 0–67 points). The d2-Test is composed of items that consist of the letters “d” or “p” with one, two, three, or four dashes arranged either individually or in pairs above and below the letter. There are 14 lines of 47 characters each for a total of 658 items. The participant is given 20 seconds to scan each line and mark all “d’s” with two dashes. According to the authors, the d2-Test measures processing speed, rule compliance, and quality of performance (Brickenkamp & Zillmer, 1998). For the analyses (described next), two manifest indicators of processing speed were constructed from the d2-Test by summing the results of the first seven lines (d2_1, possible range: 0–329 points) and the results of the second seven lines (d2_2, possible range: 0–329 points). All three indicators of processing speed were divided by 10 in order to make them numerically more comparable to the memory indicators (see Marsh, Hau, Balla, & Grayson, 1998).

Memory

At both measurement occasions, memory was assessed using three different measures—an immediate picture recall task (PR), an immediate word recall task (WR), and a delayed word recognition task (DW)—from a major German gerontological test battery (Nuremberg Inventory of Old Age; Oswald & Fleischmann, 1995). For the immediate picture recall

task (PR), seven pictures of objects were presented to the participants for 3 seconds each. Immediately after presentation of all pictures, participants were asked to recall as many objects as possible. Scored was the number of correctly recalled objects (possible range: 0–7 points). For the immediate word recall task (WR), a list of 12 common, two-syllable German words was read aloud to the participants. Instantly after presentation, participants were asked to recall as many words as possible. Scored was the number of correctly recalled words (possible range: 0–12 points). For the delayed word recognition task (DW), after a 30-minute interval, 24 words (12 identical to previously presented words and 12 distractor words) were read aloud to the participants. Participants had to decide which words they had been presented already in the immediate word recall task. Scored was the number of correctly recognized words (possible range: 0–12 points).

Modeling Different Types of Change in Early Middle Adulthood

The goal of our analysis was to examine absolute change, differential change, change of divergence, general change, and specific change in the age group of persons in early middle adulthood, that is, in their forties. Despite relatively high individual levels of performance that could potentially lead to ceiling effects in memory assessments, the examination of different types of changes in early middle age may highlight the importance of examining change in an age group that has mostly been seen as stable in their performance. The final model displays the relations between measures at the two measurement occasions. Before discussing the implications, we will briefly go through the findings.

Structural Stability

In a first model, configural invariance across the 4-year period was tested by specifying the same confirmatory factor model, that is, a processing speed and a memory factor at both measurement occasions, but without any across-time constraints. To scale the latent variables, the means and variances were fixed to zero and one, respectively, for processing speed and memory at T1 and T2. Additionally, we freely estimated the across-time covariances between the residuals of the d2-Test indicator (d2_2) at T1 and T2, the digit symbol substitution test (DS) at T1 and T2, the picture recall test at T1 and T2 (PR), and the delayed word recall test (DW) at T1 and T2 (see Figure 6.1). Model 0 achieved an excellent fit

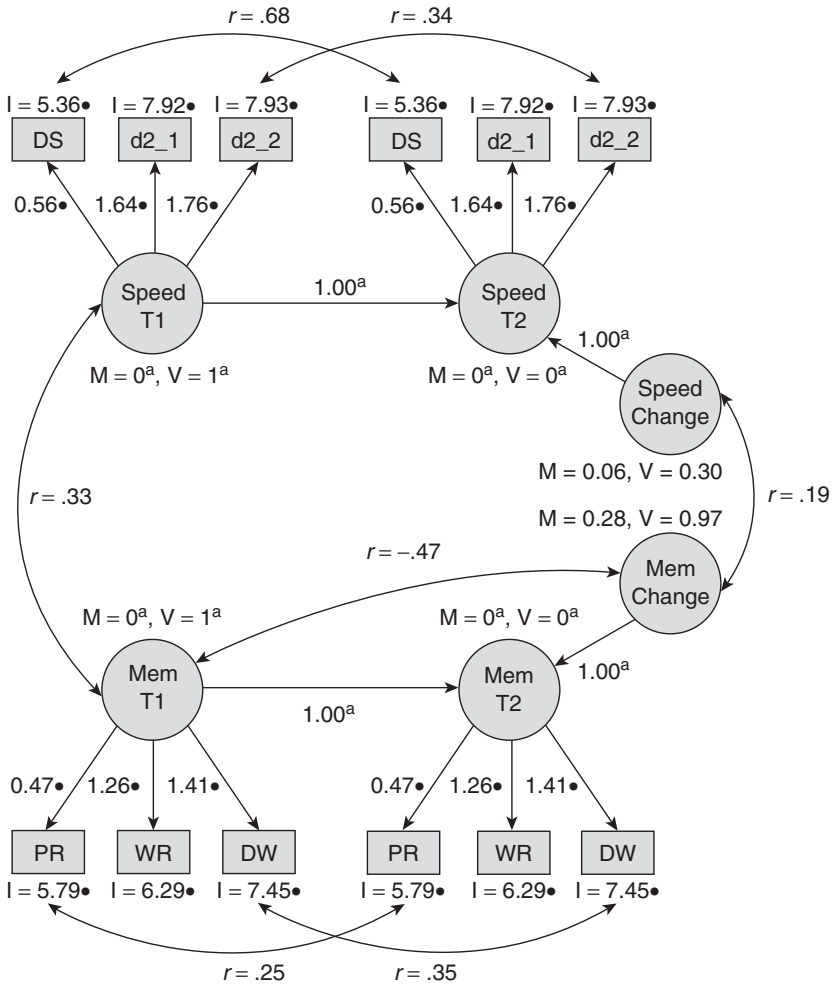


Figure 6.1 A Longitudinal Model of Different Aspects of Cognitive Change in Early Midlife Based on Data From 41- to 43-Year-Olds Followed Up for 4 Years

NOTES: $N = 479$, $\chi^2 = 146.14$, $df = 61$, $p < .05$, CFI = 0.996, RMSEA = 0.054. I = intercept, M = mean, V = variance, • denotes a parameter constrained to be equal over time, ^a denotes a fixed parameter. Except from correlations, all parameter estimates are nonstandardized. DS = Digit Symbol Substitution, d2_1 = First half of the d2-Test, d2_2 = second half of the d2-Test, Mem = Memory, PR = Picture Recall, WR = Word Recall, DW = Delayed Word Recognition.

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($\chi^2 = 88.94$, $df = 44$, $p < .05$, CFI = 0.998, RMSEA = 0.046), implying that configural invariance holds across the two measurement occasions. Next, in Model 1, pattern or metric invariance was imposed by constraining factor loadings to be equal across time, while at the same time the variances of processing speed and memory at T2 were estimated freely. Although Model 1 also evinced an excellent fit ($\chi^2 = 103.89$, $df = 48$, $p < .05$, CFI = 0.997, RMSEA = 0.049), it represented a statistically significant decrease in fit compared to Model 0 ($\Delta\chi^2 = 14.95$, $\Delta df = 4$, $p < .05$). Note, however, that the change in the CFI was only 0.001, which indicated a fit difference of virtually no practical relevance. Thus, from Model 1, one might conclude that pattern or metric invariance holds for both the processing speed and the memory factors across the 4-year period. Subsequently, in Model 2, strong invariance was tested by constraining the latent intercepts of the manifest indicators to be equal across time, whereas the means of processing speed and memory at T2 were estimated freely. Model 3 showed an excellent fit as well ($\chi^2 = 116.29$, $df = 52$, $p < .05$, CFI = 0.997, RMSEA = 0.051), but with a statistically significant loss in model fit compared to the previous model ($\Delta\chi^2 = 12.40$, $\Delta df = 4$, $p < .05$). However, because there was no change in the CFI, one might consider this loss in fit as of no practical importance, implying that the hypothesis of strong invariance could not be rejected. Eventually, in Model 3, strict invariance was introduced by setting across-time equality constraints on the residual variances of all manifest indicators. Despite these restrictions, Model 3 exhibited an excellent fit ($\chi^2 = 143.20$, $df = 58$, $p < .05$, CFI = 0.996, RMSEA = 0.055), even though compared to Model 2, fit had decreased significantly ($\Delta\chi^2 = 26.91$, $\Delta df = 4$, $p < .05$). A comparison of the CFIs of both models ($\Delta CFI = -0.001$) indicated that the loss in fit due to imposing equal residual variances across time was negligible from a substantive point of view ($\Delta CFI = -0.001$). Therefore, we kept Model 3 as adequately describing the data of both the processing speed and memory indicators at T1 and T2. Parameter estimates of Model 3 are depicted in Figure 6.1.

To summarize, a comparison of nested models imposing more and more equality constraints showed that strict variance holds with respect to processing speed and memory across the 4-year longitudinal time period. From this, one might conclude that at both T1 and T2, the measurement of processing speed and memory was identical in the sense that at both occasions, the same entity was assessed. At the same time, the fact that strict invariance was established rendered the analyses of the other aspects of change meaningful.

Absolute Change

After having established strict invariance, the means of the processing speed and the memory factor were tested for statistically significant differences across time. Because the means of both variances were constrained to equal zero at T1, factor means significantly different from zero at T2 reflected a significant change in average performance across time.

The mean of the processing speed factor at T2 was 0.057 ($SE = 0.028$) and significantly different from zero ($p < .05$). Hence, on average, participants increased in processing speed performance across the 4-year period. However, the effect size of this increase was small ($d = 0.05$), implying that, although the average change in processing speed was statistically significant, there were only minor, but reliable, enhancements in processing speed across 4 years.

The statistically significant mean of the memory factor at T2 was estimated as 0.281 ($SE = 0.058$, $p < .05$). This implied that, on average, memory performance increased between T1 and T2. Effect size was $d = 0.27$, which, according to common standards, would be considered a small effect. Compared to the average increase in processing speed, however, the average increase in memory performance was more pronounced, indicating that, longitudinally, participants improved their memory performance more than they improved their speed performance.

To sum up, for both processing speed and memory performance, an average longitudinal increase was found. Although in both cognitive abilities the effect size of this mean increase was small, for memory the average improvement across the 4-year longitudinal period was more pronounced.

Differential Change

Differential change was assessed by correlating the processing speed and memory factors at T1 and T2. For processing speed, the covariance between T1 and T2 factor scores was 0.96 ($SE = 0.03$, $p < .05$), corresponding to a correlation of $r = 0.87$, indicating a relatively high level of differential stability or, in turn, a comparatively small amount of differential change. By contrast, the longitudinal covariance for memory performance was 0.53 ($SE = 0.06$, $p < .05$), corresponding to a correlation of $r = 0.52$. Hence, differential change across the 4-year period was more pronounced in memory performance than in processing speed, implying that relative

positions of participants changed more in memory functioning than in speed of processing.

Change of Divergence

As mentioned earlier, the variances of both the processing speed and the memory factor at T1 were fixed to equal one in order to scale the latent variables. At T2, the variance of the processing speed factor was 1.21 ($SE = 0.06$) and significantly different from zero ($p < .05$). To test for change in the variance of the speed factor across time, the variance of processing speed at T2 was fixed to equal one and the fit of the resulting model was compared to the fit of Model 3. The difference in model fit amounted to $\Delta\chi^2 = 13.4$, which, with $df = 1$, was statistically significant ($p < .05$). Thus, the variance increase of processing speed across the 4-year period was reliable, indicating that individual differences increased over time. The variance of memory at T2 was 1.012 ($SE = 0.11$) and significantly different from zero. Following the same procedure as for processing speed, the difference in model fit was $\Delta\chi^2 = 0.05$, which, with $df = 1$, was not statistically significant. Hence, by contrast to processing speed, the variance of memory did not change reliably across time, showing that the amount of individual differences in memory performance remained stable.

General Versus Specific Change

So far, the investigation of different aspects of change in processing speed and memory in middle-aged adults has led to a rather complex picture. In both cognitive abilities, after establishing structural stability, an average increase of performance was observed across the 4-year period, albeit the increase was more pronounced for memory. With respect to differential change, longitudinal change in relative positions was present in both processing speed and memory; however, it was more pronounced in memory performance. Eventually and only in processing speed was there a change in diversity, indicating that individual differences increased over time.

One way to combine all this information into one model, but from a different perspective, is to utilize latent change models (McArdle & Nesselroade, 1994). In these models, the explicit focus is on change, not stability. Figure 6.1 depicts the finally accepted latent change model for processing speed and memory. By constraining the regression of speed at

T2 on speed at T1 to equal one, perfect stability was imposed on the covariance, mean, and variance for processing speed across time. All departures from perfect stability are then captured in a latent residual variable named "speed change." The same constraint is applied to memory performance, resulting in latent variable named "mem(ory) change." Change is modeled on the latent level, which has the advantage that the contamination by measurement error—a typical problem of differences between manifest variables—is reduced. Note that the means of speed change and memory change latent variables correspond to the mean changes reported earlier. The variances of the speed change and memory change latent variables are different, however, which is due to the fact that perfect stability is imposed. Both variances are statistically different from zero ($p < .05$), implying that there are reliable individual differences in the amount of change across time in processing speed and memory. In other words, diverging from the perspective of testing for a change in variance across time, now the focus is on whether individuals differ in their amount of change across time.

The utilization of latent change models allows for examining the fifth aspect of change, namely, whether cognitive changes are general or specific. For general changes to be present, one would expect that a change in speed would be accompanied by a proportional change in memory. Empirically, this would correspond to a strong correlation between speed and memory changes. For specific changes, in turn, the relation between longitudinal changes in speed and memory should only weakly be correlated, implying that the change in both cognitive abilities is only loosely coupled. For the model depicted in Figure 6.1, the correlation between changes was $r = .19$, showing that, although statistically significant, individual differences in processing speed changes were weakly associated with individual differences in memory changes in early middle adulthood. More specifically, speed and memory changes shared about 4% of common variance, from which one might conclude that the changes in these cognitive abilities are rather independent.

Discussion

We started out by claiming that the examination of cognitive development in middle age profits from going beyond a focus on mean changes or mean stability and that it is essential to examine the validity of theoretical approaches to lifespan development. It is, for instance, of theoretical

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importance whether speed and memory changes are related or unrelated across middle adulthood. If unrelated, this suggests a process of differentiation across middle age; that is, performance changes in different domains of cognitive functioning are differentially dependent on particular environmental or individual conditions, such as provided by the work and family environment. A strong relation would suggest a high degree of interdependence of cognitive functions and would also support the view of a common factor explaining most changes in most domains of cognitive functions (Baltes & Lindenberger, 1997). The combination of examining relations between intraindividual changes across several cognitive domains in early versus late middle adulthood also allows us to examine whether, as would be suggested by the lifespan literature and mean-based findings of peak performances in middle age, early middle adulthood is characterized by increasing differentiation and late middle adulthood by increasing dedifferentiation.

Examining different aspects of individual differences in change across middle adulthood can also help to relate changes in cognitive functioning to current theoretical explanations of lifelong cognitive development. Some theoretical concepts have related individual differences in cognitive functioning changes to the onset of physiological decline, for example, by centering the examination of longitudinal change around the occurrence of a particular event that has the potential of influencing many facets of cognitive functioning, such as hormonal changes in midlife or indications of dementia (Sliwinski, Hofer, Hall, Bushke, & Lipton, 2003). Others have suggested relating individual differences in performance changes to differences in usage and training of particular cognitive skills (Schooler, 1999) and have highlighted the potential influence of age by contextual demands effects, for example, when one assumes that the amount of individual training becomes more important for successful job performance. Finally, individual differences in different aspects of cognitive change may be related to individual differences in resilience and compensatory processes to maintain high and stable levels of cognitive performance. In this case, examining individual differences in change, other than mean level changes, allows us to examine individual trajectories of compensatory behaviors, relate trajectories across cognitive functioning domains, and focus on explaining the level of stability in a particular outcome that is achieved by the interaction of these trajectories (Martin & Hofer, 2004; Zimprich, Hofer, & Aartsen, 2004; Zimprich, Martin, & Kliegel, 2003).

The analysis we presented examines different aspects of change in early middle adulthood, and we have related these changes to observed

developmental trends in young old age. We have demonstrated that structural stability in factors explaining cognitive performance exists; that absolute change exists with respect to processing speed and memory over several years of observation; that differential change was much higher for memory performance than for speed; that change in variance of speed, but not in memory, occurred; and that, when examining individual differences in speed and memory changes, changes in speed and memory performance were specific, and not general.

First of all, these results substantiate earlier findings of mean levels of cognitive performance across middle age (Willis & Schaie, 1999). In addition, they provide new information on the types of changes occurring in early versus late middle adulthood. The findings suggest that there are substantial differences in the types, direction, and size of different types of change between early and late middle age. For example, the relation between individual differences in 4-year longitudinal speed and memory changes is minimal in early middle age (4% shared variance) and in the range of 25% in late middle age (Zimprich & Martin, 2002). We also observed more differential change in memory than speed in early middle age. This might suggest that individually different and varying environmental demands and conditions in early middle age are related to memory performance, but not speed. In other words, memory performance is more malleable by environmental factors, whereas speed performance depends on a different, environment-independent influence, such as physical functioning. If that were true, then the question of differentiation and dedifferentiation in adulthood could be asked differently. Differentiation of particular cognitive functions in this case would depend on the influence of different factors, that is, an environmental and a physiological one. It would be important to know if, for cognitive functions that can be influenced by environmental factors, we would find differentiation (due to the differential influence of the environment) or dedifferentiation (due to the influence of shared environments). In fact, we might expect both, depending on the kind of environmental influence and the cognitive domain examined. Once we have more data on the environmental demand characteristics across middle age, including larger age ranges within middle age, and add longer periods of observation, it will be possible to elaborate a clearer picture of the influence of environmental demands on the level of differentiation and dedifferentiation across middle age.

A limitation in the theorizing and empirical examination of cognitive development across adulthood has been the use of more or less extended

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longitudinal studies with single measurement occasions. As Willis and Schaie (1999) have pointed out, there are differences in the reported longitudinal findings due to differences in the length of the longitudinal measurement interval (Zimprich et al., 2004). From a theoretical standpoint, the use of measurement-intensive designs with repeated measures within each measurement occasion might be another aspect of change that, in the future, could provide more insights into the processes responsible for the empirical relation between functioning in different cognitive domains or even between cognitive and noncognitive domains such as emotional or affective development (Martin & Hofer, 2004; Martin & Zimprich, 2003; Neiss & Almeida, 2004). This would support a process-oriented account of longitudinal change in cognitive functioning. In fact, compensatory processes might explain which declines in particular cognitive functions may lead to increases in other domains of cognitive or noncognitive functioning. Within the same person, the burst design allows researchers to examine to what degree individual differences in cognitive functioning can be accounted for by environmental influences such as stress, and may determine the relations between variability of earlier stress, of current stress, and of later stress and cognition or health variables (to see if short-term stress reactivity might be predictive of long-term changes in stress reactivity and long-term effects on cognition or health).

Overall, examining different aspects of change in middle age poses new theoretical challenges and new empirical questions that complement the existing findings on mean level changes in adulthood. In fact, the focus on individual differences in different aspects of change in cognitive functioning across middle adulthood highlights that despite relatively high mean levels of performance, a large amount of developmental change occurs in midlife. Focusing on these aspects of change clearly suggests a need for more data and more specific change theories on development across middle adulthood.

References

- Anstey, K. J., Hofer, S. M., & Luszcz, M. A. (2003). Cross-sectional and longitudinal patterns of dedifferentiation in late-life cognitive and sensory function: The effects of age, ability, attrition, and occasion of measurement. *Journal of Experimental Psychology: General*, *132*, 470-487.
- Babcock, R. L., Laguna, K. D., & Roesch, S. C. (1997). A comparison of the factor structure of processing speed for younger and older adults: Testing the

- assumption of measurement equivalence across age groups. *Psychology and Aging*, 12, 268–276.
- Ball, K., Berch, D. B., Helmers, K. F., Jobe, J. B., Leveck, M. D., Marsiske, M., et al. (2002). Effects of cognitive training interventions with older adults. *Journal of the American Medical Association*, 288, 2271–2281.
- Baltes, M. M., & Lang, F. R. (1997). Everyday functioning and successful aging: The impact of resources. *Psychology and Aging*, 12, 433–443.
- Baltes, P. B., Cornelius, S. W., Nesselroade, J. R., & Willis, S. L. (1980). Integration versus differentiation of fluid/crystallized intelligence in old age. *Developmental Psychology*, 16, 625–635.
- Baltes, P. B., & Lindenberger, U. (1997). Emergence of a powerful connection between sensory and cognitive functions across the adult life span: A new window to the study of cognitive aging? *Psychology and Aging*, 12, 395–409.
- Baltes, P. B., Reese, H. W., & Nesselroade, J. R. (1977). *Life-span developmental psychology: Introduction to research methods*. Monterey, CA: Brooks/Cole.
- Bickley, P. G., Keith, T. Z., & Wolfle, L. M. (1995). The three-stratum theory of cognitive abilities: Test of the structure of intelligence across the life span. *Intelligence*, 20, 309–328.
- Bollen, K. A. (1989). *Structural equations with latent variables*. New York: Wiley.
- Bosma, H., van Boxtel, M. P. J., Ponds, R. W., Houx, P. J., & Jolles, J. (2003). Education and age-related cognitive decline: The contribution of mental workload. *Educational Gerontology*, 29, 165–173.
- Brickenkamp, R., & Zillmer, E. (1998). *The d2 test of attention* (1st U.S. ed.). Seattle, WA: Hogrefe & Huber.
- Cohen, J. (1987). *Statistical power analysis for the behavioral sciences* (Rev. ed.). Hillsdale, NJ: Erlbaum.
- Cunningham, W. R., & Birren, J. E. (1980). Age changes in the factor structure of intellectual abilities in adulthood and old age. *Educational and Psychological Measurement*, 40, 271–290.
- Cunningham, W. R., Clayton, V., & Overton, W. (1975). Fluid and crystallized intelligence in young adulthood and old age. *Journal of Gerontology*, 30, 53–55.
- Dixon, R. A., De Frias, C. M., & Maitland, S. B. (2001). Memory in midlife. In M. E. Lachman (Ed.), *Handbook of midlife development* (pp. 248–278). New York: Wiley.
- Espy, K. A., Molfese, V. J., & DiLalla, L. F. (2001). Effects of environmental measures on intelligence in young children: Growth curve modeling of longitudinal data. *Merrill Palmer Quarterly*, 47, 42–73.
- Finkel, D., Pedersen, N. L., & Harris, J. R. (2000). Genetic mediation of the association among motor and perceptual speed and adult cognitive abilities. *Aging, Neuropsychology, and Cognition*, 7, 141–155.
- Finkel, D., Pedersen, N. L., Plomin, R., & McClearn, G. E. (1998). Longitudinal and cross-sectional twin data on cognitive abilities in adulthood: The Swedish Adoption/Twin Study of Aging. *Developmental Psychology*, 34, 1400–1413.

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- Finkel, D., Reynolds, C. A., McArdle, J. J., Gatz, M., & Pedersen, N. L. (2003). Latent growth curve analyses of accelerating decline in cognitive abilities in late adulthood. *Developmental Psychology, 39*, 535–550.
- Freund, A. M., & Baltes, P. B. (2002). The adaptiveness of selection, optimization, and compensation as strategies of life management: Evidence from a preference study on proverbs. *Journals of Gerontology: Psychological and Social Sciences, 57B*, P426–P434.
- Ghisletta, P., & Lindenberger, U. (2003). Age-based structural dynamics between perceptual speed and knowledge in the Berlin Aging Study: Direct evidence for ability dedifferentiation in old age. *Psychology and Aging, 18*, 696–713.
- Ghisletta, P., Nesselroade, J. R., Featherman, D. L., & Rowe, J. W. (2002). The structure, validity and predictive power of weekly intraindividual variability in health and activity measures. *Swiss Journal of Psychology, 61*, 73–83.
- Havighurst, R. J. (1982). *Developmental tasks and education*. New York: McKay. (Original work published 1948)
- Hertzog, C., & Bleckley, K. (2001). Age differences in the structure of intelligence: Influences of information processing speed. *Intelligence, 29*, 191–217.
- Hertzog, C., & Dixon, R. A. (1996). Methodological issues in research on cognition and aging. In F. Blanchard-Fields & T. M. Hess (Eds.), *Perspectives on cognitive change in adulthood and aging* (pp. 66–121). Boston: McGraw-Hill.
- Hofer, S. M., Berg, S., & Era, P. (2003). Evaluating the interdependence of aging-related changes in visual and auditory acuity, balance, and cognitive functioning. *Psychology and Aging, 18*, 285–305.
- Hogan, D. P. (1987). Demographic trends in human fertility, and parenting across the life span. In J. B. Lancaster, J. Altmann, A. S. Rossi, & L. R. Sherrod (Eds.), *Parenting across the life span* (pp. 315–350). New York: De Gruyter.
- Horn, J. L., & McArdle, J. J. (1992). A practical and theoretical guide to measurement invariance in aging research. *Experimental Aging Research, 18*, 117–144.
- Hultsch, D. F., Hertzog, C., Small, B. J., & Dixon, R. A. (1999). Use it or lose it: Engaged lifestyle as a buffer of cognitive decline in aging? *Psychology and Aging, 14*, 245–263.
- Hultsch, D., Hertzog, C., Small, B. J., McDonald-Miszczak, L., & Dixon, R. A. (1992). Short-term longitudinal change in cognitive performance in later life. *Psychology and Aging, 7*, 571–584.
- Juan-Espinosa, M., García, L. F., Colom, R., & Abad, F. J. (2000). Testing the age differentiation hypothesis through Wechsler's scales. *Personality and Individual Differences, 29*, 1069–1075.
- Juan-Espinosa, M., García, L. F., Escorial, S., Rebollo, I., Colom, R., & Abad, F. J. (2002). Age dedifferentiation hypothesis: Evidence from the WAIS-III. *Intelligence, 30*, 395–408.
- Kirlik, A., & Bisantz, A. M. (1999). Cognition in human-machine systems: Experiential and environmental aspects of adaptation. In A. P. Hancock (Ed.),

- Human performance and ergonomics: Handbook of perception and cognition series* (2nd ed., pp. 47–68). San Diego, CA: Academic Press.
- Kliegl, R., Philipp, D., Luckner, M., & Krampe, R. T. (2001). Face memory skill acquisition. In N. Charness & D. C. Park (Eds.), *Communication, technology and aging: Opportunities and challenges for the future* (pp. 169–186). New York: Springer.
- Lamar, M., Resnick, S. M., & Zonderman, A. B. (2003). Longitudinal changes in verbal memory in older adults: Distinguishing the effects of age from repeat testing. *Neurology*, *60*, 82–86.
- Lawton, M. P., Moss, M., Hoffman, C., Grant, R., Ten Have, T., & Kleban, M. H. (1999). Health, valuation of life, and the wish to live. *The Gerontologist*, *39*(4), 406–416.
- Li, K., & Lindenberger, U. (2002). Relations between aging sensory/sensorimotor and cognitive functions. *Neuroscience and Biobehavioral Reviews*, *26*, 777–783.
- Lindenberger, U., & Baltes, P. B. (1994). Sensory functioning and intelligence in old age: A strong connection. *Psychology and Aging*, *9*, 339–355.
- MacDonald, S. W. S., Hulstsch, D. F., & Dixon, R. A. (2003). Performance variability is related to change in cognition: Evidence from the Victoria Longitudinal Study. *Psychology and Aging*, *18*, 510–523.
- Maitland, S. B., Intrieri, R. C., Schaie, K. W., & Willis, S. L. (2000). Gender differences and changes in cognitive abilities across the adult life span. *Aging, Neuropsychology, and Cognition*, *7*, 32–53.
- Marsh, H. W., Hau, K. T., Balla, J. R., & Grayson, D. (1998). Is more ever too much? The number of indicators per factor in confirmatory factor analysis. *Multivariate Behavioral Research*, *33*, 181–220.
- Martin, M., Grünendahl, M., & Martin, P. (2001). Age differences in stress, social resources and well-being in middle and older age. *Journal of Gerontology: Psychological Sciences*, *56*, P214–P222.
- Martin, M., & Hofer, S. M. (2004). Intraindividual variability, change, and aging: Conceptual and analytical issues. *Gerontology*, *50*, 7–11.
- Martin, M., & Mroczek, D. K. (in press). Are personality traits across the lifespan sensitive to environmental demands? *Journal of Adult Development*.
- Martin, M., & Zimprich, D. (2003). Are changes in cognitive functioning in older adults related to subjective complaints? *Experimental Aging Research*, *29*, 335–352.
- McArdle, J. J., & Nesselroade, J. R. (1994). Using multivariate data to structure developmental change. In H. W. Reese & S. H. Cohen (Eds.), *Life-span developmental psychology: Methodological contributions* (pp. 223–267). Hillsdale, NJ: Erlbaum.
- Meredith, W. (1993). Measurement invariance, factor analysis, and factorial invariance. *Psychometrika*, *58*, 525–543.
- Meredith, W., & Horn, J. (2001). The role of factorial invariance in modeling growth and change. In L. M. Collins & A. G. Sayer (Eds.), *New methods for the*

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- analysis of change* (pp. 203–240). Washington, DC: American Psychological Association.
- Moen, P., & Wethington, E. (1999). Midlife development in a life course context. In S. L. Willis & J. D. Reid (Eds.), *Life in the middle* (pp. 3–23). San Diego, CA: Academic Press.
- Neiss, M., & Almeida, D. M. (2004). Age differences in the heritability of mean and intraindividual variation of psychological distress. *Gerontology, 50*, 22–27.
- Nesselroade, J. R. (1991). The warp and the woof of the developmental fabric. In R. M. Downs & L. S. Liben (Eds.), *Visions of aesthetics, the environment and development: The legacy of Joachim F. Wohlwill* (pp. 213–240). Hillsdale, NJ: Erlbaum.
- Nesselroade, J. R. (2001). Intraindividual variability in development within and between individuals. *European Psychologist, 6*, 187–193.
- Oswald, W. D., & Fleischmann, U. M. (1995). *Nürnbergger Altersinventar (NAI)* [Nuremberg Age Inventory]. Göttingen, Germany: Hogrefe.
- Park, D. C., Lautenschlager, G., Hedden, T., Davidson, N. S., Smith, A. D., & Smith, P. K. (2002). Models of visuospatial and verbal memory across the adult life span. *Psychology and Aging, 17*, 299–320.
- Pedersen, N. L., & Lichtenstein, P. (1997). Biometric analyses of human abilities. In C. Cooper & V. Varma (Eds.), *Processes in individual differences* (pp. 125–147). London: Routledge.
- Perlman, M. D. (1980). Unbiasedness of the likelihood ratio tests for equality of several covariance matrices and equality of several multivariate normal populations. *Annals of Statistics, 8*, 247–263.
- Preece, P. F. (1982). The fan-spread hypothesis and the adjustment for initial differences between groups in uncontrolled studies. *Educational and Psychological Measurement, 42*, 759–762.
- Rabbitt, P., Osman, P., Moore, B., & Stollery, B. (2001). There are stable individual differences in performance variability, both from moment to moment and from day to day. *Quarterly Journal of Experimental Psychology: Human, 54A*, 981–1003.
- Rees, A. H., & Palmer, F. H. (1970). Factors related to change in mental test performance. *Developmental Psychology, 3*, 57.
- Reinert, G., Baltes, P. B., & Schmidt, L. R. (1965). Faktorenanalytische Untersuchungen zur Differenzierungshypothese der Intelligenz [Factor analytic studies on the differentiation hypothesis of intelligence]. *Psychologische Forschung, 28*, 246–300.
- Rossi, A. S., & Rossi, P. H. (1990). *Of human bonding*. New York: Aldine de Gruyter.
- Rowe, J. W., & Kahn, R. L. (1997). Successful aging. *Gerontologist, 37*, 433–440.
- Schaie, K. W. (1996). *Intellectual development in adulthood—The Seattle Longitudinal Study*. Cambridge, UK: Cambridge University Press.
- Schaie, K. W. (2000). The impact of longitudinal studies on understanding development from young adulthood to old age. *International Journal of Behavioral Development, 24*, 257–266.

- Schaie, K. W., & Hofer, S. M. (2001). Longitudinal studies in aging research. In K. W. Schaie & J. E. Birren (Eds.), *Handbook of the psychology of aging* (pp. 53–77). San Diego, CA: Academic Press.
- Schaie, K. W., Maitland, S. B., Willis, S. L., & Intrieri, R. C. (1998). Longitudinal invariance of adult psychometric ability factor structures across 7 years. *Psychology and Aging, 13*, 8–20.
- Schmidt, D. F., & Botwinick, J. (1989). A factorial analysis of the age dedifferentiation hypothesis. In K. W. Schaie & V. L. Bengtson (Eds.), *The course of later life: Research and reflections* (pp. 87–92). New York: Springer.
- Schooler, C. (1999). The workplace environment: Measurement, psychological effects, and basic issues. In S. L. Friedman & T. D. Wachs (Eds.), *Measuring environment across the life span* (pp. 229–246). Washington, DC: American Psychological Association.
- Seeman, T. E., Singer, B. H., Ryff, C. D., Dienberg-Love, G., & Levy-Storms, L. (2002). Social relationships, gender, and allostatic load across two age cohorts. *Psychosomatic Medicine, 64*, 395–406.
- Sliwinski, M. J., Hofer, S. M., Hall, C., Bushke, H., & Lipton, R. B. (2003). Modeling memory decline in older adults: The importance of preclinical dementia, attrition and chronological age. *Psychology and Aging, 18*, 658–671.
- Soederberg Miller, L. M., & Lachman, M. E. (2000). Cognitive performance and the role of control beliefs in midlife. *Aging, Neuropsychology, and Cognition, 7*, 69–85.
- Sparrow, P. R., & Davies, D. R. (1988). Effects of age, tenure, training, and job complexity on technical performance. *Psychology and Aging, 3*, 307–314.
- Staudinger, U. M., Marsiske, M., & Baltes, P. B. (1995). Resilience and reserve capacity in later adulthood: Potentials and limits of development across the life span. In D. Cicchetti & D. J. Cohen (Eds.), *Risk, disorder, and adaptation* (Developmental Psychopathology, Vol. 2, pp. 801–847). Oxford, UK: Wiley.
- Sternberg, R. J., Grigorenko, E. L., & Oh, S. (2001). The development of intelligence at midlife. In M. E. Lachman (Ed.), *Handbook of midlife development* (pp. 217–247). New York: Wiley.
- Taub, G. E., McGrew, K. S., & Witta, E. L. (2004). A confirmatory analysis of the factor structure and cross-age invariance of the Wechsler Adult Intelligence Scale-Third Edition. *Psychological Assessment, 16*, 85–89.
- Tewes, U. (1991). *Hamburg-Wechsler-Intelligenztest für Erwachsene, Revision 1991* (2. Aufl [Hamburg-Wechsler Intelligence Test for Adults, 1991 revision (2nd ed.)]). Bern, Switzerland: Huber.
- Tomer, A., & Cunningham, W. R. (1993). The structure of cognitive speed measures in old and young adults. *Multivariate Behavioral Research, 28*, 1–24.
- Townsend, B. (2001). Dual-earner couples and long work hours: A structural and life course perspective. *Berkeley Journal of Sociology, 45*, 161–179.
- West, R. L., & Tomer, A. (1989). Everyday memory problems of healthy older adults: Characteristics of a successful intervention. In P. J. Whitehouse &

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- G. C. Gilmore (Eds.), *Memory, aging, and dementia: Theory, assessment, and treatment* (pp. 74–98). New York: Springer.
- Willis, S. L., & Schaie, K. W. (1986). Training the elderly on the ability factors of spatial orientation and inductive reasoning. *Psychology and Aging, 1*, 239–247.
- Willis, S. L., & Schaie, K. W. (1999). Intellectual functioning in midlife. In S. L. Willis & J. D. Reid (Eds.), *Life in the middle* (pp. 234–247). San Diego, CA: Academic Press.
- Zelinsky, E. M., & Lewis, K. L. (2003). Adult age differences in multiple cognitive functions: Differentiation, dedifferentiation, or process-specific change? *Psychology and Aging, 18*, 727–745.
- Zimprich, D., Hofer, S. M., & Aartsen, M. J. (2004). Short-term versus long-term longitudinal changes in processing speed. *Gerontology, 50*, 17–21.
- Zimprich, D., & Martin, M. (2002). Can longitudinal changes in processing speed explain longitudinal age changes in fluid intelligence? *Psychology and Aging, 17*, 690–695.
- Zimprich, D., Martin, M., & Kliegel, M. (2003). Subjective cognitive complaints, memory performance, and depressive affect in old age: A change-oriented approach. *International Journal of Aging and Human Development, 57*, 339–366.