Consequences of Age-Related Cognitive Declines

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Abstract

Adult age differences in a variety of cognitive abilities are well documented, and many of those abilities have been found to be related to success in the workplace and in everyday life. However, increased age is seldom associated with lower levels of real-world functioning, and the reasons for this lab-life discrepancy are not well understood. This article briefly reviews research concerned with relations of age to cognition, relations of cognition to successful functioning outside the laboratory, and relations of age to measures of work performance and achievement. The final section discusses several possible explanations for why there are often little or no consequences of age-related cognitive declines in everyday functioning.

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INTRODUCTION

> An intriguing discrepancy exists between the competencies of older adults, assumed on the basis of everyday observations, on the one hand, and their competencies inferred from laboratory results, on the other hand. The laboratory results tend to portray older adults as distinctly inferior to young adults on a number of presumably basic cognitive abilities, and yet we are all aware of competent, and even remarkable, accomplishments of people well into their 60s, 70s, and beyond. One is thus faced with the question of how to account for this apparent discrepancy between the rather pessimistic results of the laboratory and the more encouraging observations of daily life. (Salthouse 1987, p. 142)

The quotation above describes a question that has concerned researchers in the field of cognitive aging for decades. The discrepancy of interest is illustrated with a figure (**Figure 1**) portraying the proportion of people at each age between 20 and 75 (*a*) in the U.S. population; (*b*) in the top 25% of the distribution of scores in a composite measure of reasoning ability from one of the most popular cognitive ability tests, the Wechsler Adult Intelligence Scale-Fourth Edition (WAIS-IV); and (*c*) who are chief executive officers (CEOs) of Fortune 500 companies in late 2009. The function with U.S. population information provides a baseline of what might be expected if a random sample were drawn from the population. The reasoning function reflects the age distribution that might be expected if selection were based exclusively on this measure of reasoning. Finally, the CEO function indicates the actual distribution of ages of the primary decision makers in major corporations. Note that the reasoning function has a peak before age 30, whereas the peak age for the CEO function is close to 60. The different trends in **Figure 1** have at least two implications: (*a*) reasoning ability as it is assessed with cognitive tests is apparently not the major basis for selection into important decision-making positions in society, and (*b*) age-related declines can presumably occur in important cognitive abilities without major consequences for functioning in society.[1] The primary question in the current article is how this second implication might be explained.

WAIS-IV: Wechsler Adult Intelligence Scale-Fourth Edition; one of the most widely used tests of adult intelligence

CEO: chief executive officer responsible for overall management of an organization

The article is organized into four sections, with assessment of cognition covered in the first section and a discussion of the importance of cognition in life outside the laboratory in the second section. The third section consists of a brief review of research on the relation of age to cognition, and the final section examines consequences of age-related cognitive declines for real-life functioning.

Reviews on topics related to the current one have focused on lifespan development (Baltes et al. 1999), development in midlife (Lachman 2004), and the aging brain (Park & Reuter-Lorenz 2009). However, because

[1]One reason for the later age peaks for CEOs is that achieving a leadership position requires not only cognitive abilities, but also a network of acquaintances and relevant leadership experience (cf. Posner 1995, p. 162–163).

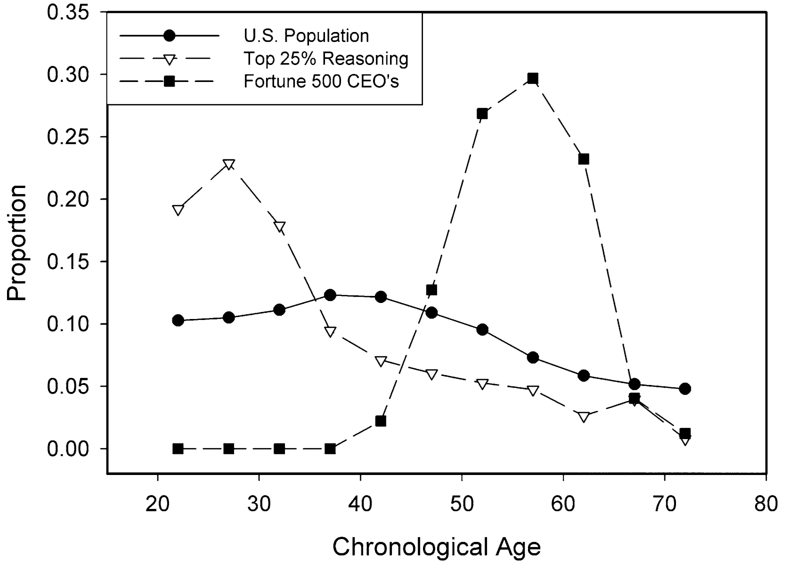

Figure 1

Distributions at each age between 20 and 75 from the U.S. population (2000 Census), the top 25% of the scores on the reasoning composite from the Wechsler Adult Intelligence Scale-Fourth Edition, and CEOs of Fortune 500 companies as of December 2009.

prior reviews have not contained systematic discussions of the consequences of age-related cognitive declines, the current review includes historical background as well as discussion of recent research.

ASSESSING COGNITION

The topic of individual differences in cognition is somewhat controversial in contemporary society because cognitive ability is one of the most valued human characteristics, and consequently there is considerable reluctance to discuss individual or group differences in this characteristic. Because some of the controversy could be attributable to a misunderstanding of the meaning of cognition as the term is used by researchers, it may be helpful to begin by describing some of the types of tests used to assess cognition within the psychometric tradition. Most tests are somewhat abstract because they are deliberately designed to minimize the role of differential experience that would complicate comparisons across people. The tests often involve simple materials but novel manipulations, such as arranging blocks to match specified patterns, repeating a sequence of elements in a different specified order, identifying the pattern relating a set of elements, or transforming parts into a new configuration.

Major Types of Cognition

Two major categories of cognitive tests have been distinguished. Those used to evaluate proficiency in reasoning, memory, and speed are designed to assess efficiency or effectiveness of processing at the time of assessment. Other tests are designed to assess the cumulative products of processing carried out in the past, typically in the form of evaluations of acquired knowledge with tests of general information or vocabulary. The latter are sometimes designated as measures of crystallized ability, with tests of reasoning and novel problem solving considered to provide measures of fluid ability.

There is some debate whether the results of interactions of one's ability with environmental opportunities should be considered an ability as opposed to an achievement. To illustrate, one position is that "Abilities are not the bodies of knowledge that people amass but their aptness in amassing them" (Gottfredson 2003, p. 3). However, the distinction between ability and achievement is somewhat blurred. For example, despite claims that tests used for college selection, such as the Scholastic Aptitude Test (SAT) and American College Testing (ACT) exam, measure achievement more than aptitude, they have been found to have strong correlations with measures of general cognitive ability (e.g., Frey & Detterman 2004, Koenig et al. 2008). Nevertheless, because measures of knowledge and measures of novel problem solving or processing efficiency have different relations with age, and possibly also with everyday functioning, they are kept distinct in the current discussion.

SAT: Scholastic Aptitude Test used as a college entrance selection exam

ACT: American College Testing program test used as a college entrance selection exam

Organization of Cognitive Variables

Cognitive variables can be postulated to have an organizational structure based on the patterns of correlations among the variables. Nearly all of the correlations among different types of cognitive variables are positive, but they vary in strength such that an organization can be specified, with variables having higher correlations located closer to one another in the hypothesized structure. There is currently a consensus for a hierarchical structure of cognitive abilities, with many first-order abilities, a single general factor at the highest level, and different numbers at intermediate levels. Although this type of structure is widely accepted among researchers within the psychometrics field (e.g., Carroll 1993, Deary et al. 2010, Gottfredson 1998, Gustafsson 1988, Jensen 1998, Neisser et al. 1996), the idea of a general factor is sometimes vehemently challenged. A primary concern is that it may be a misleading oversimplification to reduce human variation in such an important characteristic to a single dimension. Although in the studies discussed below several variables are often combined to obtain a broad index of cognitive ability, which some researchers would consider equivalent to the general factor, the theoretical debate about the existence or meaning of a general factor is not directly relevant in the current context and is ignored.

Many proposals for a broader conceptualization of cognitive ability than that represented by existing psychometric tests have been offered, but few of the suggestions have been accepted by mainstream psychometric researchers either because of methodological concerns (e.g., little information about reliability or validity) or substantive concerns (e.g., should variations in any domain be considered to reflect a dimension of intelligence, or should the term be reserved for particular types of cognitive domains?). A relatively narrow definition of cognition from the psychometric abilities perspectives adopted here, but it is recognized that many other characteristics need to be considered as possible determinants of functioning outside the laboratory, including practical intelligence, social intelligence, emotional intelligence, dispositions to think in a certain way, creativity, empathy, and aspects of personality. In other words, the current perspective does not deny the potential importance of these other factors but instead questions whether there is any advantage of categorizing them as aspects of cognitive ability.

In the remainder of this article, the practice in the field of industrial-organizational psychology is followed in which use of the term intelligence is avoided because it has a connotation in society of a fixed genetically determined potential (e.g., Hunter 1986). Instead, the term general cognitive ability, or often simply cognition, is used to refer to the overall level of performance across several different types of cognitive tests.

IMPORTANCE OF COGNITION

Cognition would be of little interest if it were not associated with differential functioning outside the laboratory or assessment setting, and therefore this section summarizes some of the research on the association between cognitive ability and real-life functioning. A very large number of studies have reported relations of cognitive test scores to miscellaneous life outcomes. For example, cognitive ability has been related to aspects of decision making (e.g., Demaree et al. 2010, Mata et al. 2007, Pachur et al. 2009, Peters et al. 2006, Shamosh & Gray 2008), to performance in simulations of complex systems (e.g., Ackerman & Cianciolo 2002, Gonzalez et al. 2005, Kroner et al. 2005, Wittmann & Hattrup 2004), and to specific outcomes such as the likelihood of staying on a job with a financial penalty for an early exit (e.g., Burks et al. 2009). (See Kuncel et al. 2010 for a review of much of the recent literature.)

Rather than attempting to compile a list of studies reporting relations of cognitive ability to many different types of outcomes, this section briefly summarizes research on work performance, research on indicators of competence for independent living among older adults, and research on life outcomes such as health and mortality studied within the rubric of cognitive epidemiology. The coverage is by no means exhaustive, but these areas are illustrative of the range and magnitude of the relations of cognition with functioning outside the laboratory.

Work Performance

A large literature has accumulated since the 1920s on predictors of occupational level and success. However, until recently interpretation of the results was complicated because many of the early studies were based on relatively small samples, different types of jobs, different types of cognitive measures, and different measures of work performance. To illustrate, work performance has been assessed in terms of occupational level achieved, measures of productivity, evaluations of work samples, supervisor ratings, and indicators of success in training.

Several reviews of the relation of cognitive ability to occupational level have documented that higher average cognitive ability is associated with higher occupational level or income (e.g., Gottfredson 1998; 2004a,b; Nyborg & Jensen 2001; Schmidt & Hunter 2004; von Stumm et al. 2010; Zagorsky 2007). Relations of cognitive ability to occupational level have also been found in longitudinal studies (see Strenze 2007 for a meta-analysis). For example, Judge et al. (1999) reported that cognitive ability at age 12 had a correlation of 0.51 with occupational level between 41 and 50 years of age, and Wilk & Sackett (1996) found greater upward mobility among individuals with higher levels of cognitive ability. Furthermore, Judge et al. (2010) recently reported that higher cognitive ability was not only associated with a higher initial level of income and occupational prestige, but also with greater increases in these characteristics over time.

Cognitive epidemiology: new subdiscipline concerned with cognitive functioning as a predictor of outcomes such as morbidity and mortality

Relations of cognitive ability to work performance are frequently examined as validity coefficients, which represent the relation between the cognitive measure and some measure of work performance in the form of a correlation coefficient. For many years, general cognitive ability was assumed to have a relatively modest validity for job performance measures. For example, Ghiselli (1973) reported an average validity coefficient of 0.24 for cognitive ability across a wide variety of jobs. However, beginning in the 1980s, Hunter, Schmidt, and others reported a series of meta-analyses that led to different interpretations. The small sample sizes in many of the studies resulted in considerable variation in the correlations; thus, meta-analyses were particularly helpful because the aggregation across many studies allowed the "signal" corresponding to the relation to be extracted from the variability or "noise." The newer analyses also included adjustments for unreliability of the cognitive measures and of the work measures when examining relations between the two sets of variables, which led to better estimates of the true relations by minimizing influences of measurement error.

The new procedures resulted in validities for general cognitive ability in the 0.4 to 0.6 range across many types of jobs (e.g., Hunter 1986; Hunter & Hunter 1984; Hunter & Schmidt 1996, 1998; Schmidt et al. 1986, 1988; Schmidt & Hunter 2004). Furthermore, the major validity results regarding cognitive ability have been replicated in other data sets with somewhat different analytical methods (e.g., Higgins et al.

IADL: instrumental activities of daily living presumed to be essential for living independently

2007, Kuncel et al. 2004, Ng & Feldman 2008, Ree et al. 1994, Ree & Earles 1991), in different countries (e.g., Hulsheger et al. 2007, Salgado & Anderson 2002, Salgado et al. 2003), and with other outcomes, such as leadership (e.g., Judge et al. 2004) and salary (e.g., Judge et al. 2009, Ng & Feldman 2008).

In part because the cognitive ability relations have been found to be higher for more complex jobs (e.g., Hunter 1986, Hunter & Schmidt 1996, Schmidt & Hunter 2004), they have been hypothesized to be largely mediated through job knowledge (e.g., Hunter & Schmidt 1996, Schmidt et al. 1986). That is, one proposed mechanism is that cognitive ability is related to efficient learning, and thus in addition to greater adaptability to new situations and better ability to prioritize, individuals with higher cognitive ability have been hypothesized to have greater and faster acquisition of knowledge relevant to the job (e.g., Hunter 1986, Schmidt & Hunter 2004).

In summary, it is now well established that cognitive ability has moderate positive relations with a variety of measures of work functioning, including success in training, different measures of performance in the job, and level of occupation achieved. The mechanisms responsible for the relations are still largely speculative, but the research is consistent in documenting that level of cognitive ability is one of the strongest predictors of work success currently available.

Independent Living Among Older Adults

Although the primary interest in the current review is the period between about 20 and 75 years of age, many relations of cognition have been investigated among older adults because their declining levels of cognition make them particularly vulnerable to consequences of low cognitive functioning. Most of the relevant research has been on domains related to instrumental activities of daily living (IADL) such as shopping, arranging transportation, handling finances, and comprehending medication instructions because these activities are assumed to be necessary to maintain independent functioning.

A number of early studies reported relations of general cognitive ability, often assessed with the Mini-Mental Status Exam (Folstein et al. 1975) used to screen for dementia, and self-reported IADL problems (see reviews in Burton et al. 2006, Willis 1991, Willis et al. 1992). The correlations have ranged from 0.3 to 0.8, but interpretation of the results is complicated by the inclusion of individuals with dementia in the samples, a measure of cognition that is not very sensitive for most healthy adults, and reliance on self-reports to assess difficulties in performing IADLs.

More recent research has examined relations of basic cognitive abilities with a variety of tests designed to assess everyday functioning. For example, the Everyday Cognition Battery consists of tests constructed to involve real-world stimuli related to medication use, financial planning, and food preparation (e.g., Allaire & Marsiske 1999, Weatherbee & Allaire 2008). Correlations of factors from this battery with established psychometric cognitive abilities have ranged between 0.42 and 0.86. Allaire & Marsiske (2002) also found that much of the variance in a composite measure of self-rated everyday functioning was accounted for by a combination of basic cognitive abilities and measures from this Everyday Cognition Battery.

The Educational Testing Service (ETS) Basic Skills Test was intended to assess cognitive skills presumed to be essential for functioning in society. The items were created to assess understanding labels on household articles, reading a street map, understanding charts and schedules, comprehending paragraphs, filling out forms, reading newspaper and phone directory ads, understanding technical documents, and comprehending newspaper text. Schaie & Willis (1986) and Willis & Schaie (1986) reported that scores in the Basic Skills Test were strongly correlated with fluid or reasoning ability (0.58) and correlated to a lesser extent with crystallized measures of knowledge (0.29). Willis et al. (1992) also reported that

Basic Skills performance at a second occasion was significantly correlated with fluid reasoning performance seven years earlier. Another paper-and-pencil test, the Everyday Problems Test, contains items designed to assess the IADL domains, including food preparation, medication use and health behaviors, financial management, and transportation. Scores on this test have been found to be correlated 0.87 with the overall score on the ETS Basic Skills Test (Willis 1996) and have also been found to have moderate correlations with a variety of cognitive variables (Burton et al. 2006).

One of the limitations of paper-and-pencil tests of everyday functioning is that they involve the same method of assessment as most cognitive tests, and thus the correlations may reflect a common method of assessment rather than the existence of a common construct. Partially in response to this concern, the Observed Tasks of Daily Living Test was developed in which the examiner observes performance of 31 tasks in the examinee's home with real-life materials (Diehl et al. 1995, 2005). Among the tasks are calculating days of pill supply and activating a call-forwarding mechanism. This test was found to have a correlation of 0.67 with the Everyday Problems Test, which suggests that the two tests may measure some of the same common factors. Of greatest interest in the current context were the moderate relations between cognitive ability factors and Observed Tasks of Daily Living factors, with standardized path analysis coefficients of 0.48 for fluid reasoning and 0.22 for crystallized knowledge.

In summary, several different approaches have been used to assess the competence of older adults to live independently. All of the methods are approximations because there are currently no direct measures of the capability of living independently. However, results from each of the assessment methods have been found to be significantly related to psychometric measures of cognitive abilities, and somewhat surprisingly, the strongest relations have been found with novel problem-solving (or fluid) rather than with knowledge (or crystallized) measures of cognition.

Life Outcomes

A considerable amount of research has examined relations between cognitive ability and different types of life outcomes. Because research with social outcomes is often difficult to interpret due to a confounding of cognitive ability with social class and opportunity, the focus here is on recent research within the emerging subdiscipline of cognitive epidemiology that is concerned with the impact of cognitive ability on health outcomes. This specialty within epidemiology differs from other epidemiological fields in that cognition is viewed as an antecedent, or predictor variable, instead of a consequence, or outcome variable.

A relatively large literature has been concerned with the terminal decline phenomenon in which level of cognitive functioning is often lower several years prior to death (e.g., Backman & MacDonald 2006, Bosworth & Siegler 2002, Lavery et al. 2009, Small et al. 2003, Wilson et al. 2009). However, when the assessment of cognition occurs in old age, it is difficult to rule out reverse causality in which health problems contribute to low levels of cognition. In contrast, interpretations are less ambiguous when cognition is assessed at young ages and mortality occurs decades later; those are the studies of primary interest here.

Perhaps the earliest study in this field was a report by O'Toole & Stankov (1992) of Australian men who were administered a cognitive aptitude test at about age 18 and whose survival was monitored up until age 40. The major finding was that higher cognitive ability assessed prior to age 22 was associated with a lower risk of death, and particularly motor vehicle death, between 22 and 40 years of age.

Another early study was by Whalley & Deary (2001), who capitalized on the availability of cognitive ability scores originally acquired in 1932 from a large number of 11-year-old Scottish children. A search of the death records from 1932 to 1997 yielded mortality information that could be related to childhood cognitive ability. Even after controlling for father's occupation, lower cognitive ability at age 11 was found to be associated with greater risk of mortality up to age 76.

SES: socioeconomic status

Several reviews of the relations between cognition and mortality have recently been published (e.g., Batty & Deary 2004, Batty et al. 2007, Deary 2005, Gottfredson & Deary 2004). As an example, Batty et al. (2007) described nine studies in which relations between early-life cognitive ability and later mortality risk were examined. All nine studies reported that higher levels of cognitive ability were associated with decreased risk of mortality.

Some of the most impressive findings on cognition-mortality relations were based on analyses of data from nearly one million Swedish men whose cognitive ability was assessed at age 18 and for whom mortality was monitored up to about age 45 (e.g., Batty et al. 2009a,b). Because of the very large sample size, it was possible to examine the relations by type of mortality and also adjust for factors such as blood pressure, body mass index, and socioeconomic status (SES). The researchers were also able to identify a dose-response relation, with higher rates of mortality at successively lower levels of cognitive ability.

A few studies have also reported relations of cognitive ability to health status and not merely with mortality. For example, Der et al. (2009) found that higher cognitive test scores were associated with lower depression scores, better general health, and significantly lower odds of having 6 of 9 diagnosed conditions and 15 of 33 health problems. Walker et al. (2002) also reported that higher cognitive test scores at age 11 were associated with less psychiatric contact up to age 77.

Several hypotheses for the cognition-mortality relations have been discussed by Deary and colleagues (e.g., Batty & Deary 2004, Deary 2005, Whalley & Deary 2001). Among these were that (*a*) both cognition and mortality are a consequence of insults such as birth complications, (*b*) cognition predicts advantageous social circumstances that are the primary factor affecting mortality rates, (*c*) cognition is a proxy for stress management skills, and (*d*) cognition is associated with the acquisition and maintenance of health-conducive behaviors. Some support for this latter hypothesis was provided by Deary et al. (2009), who found that higher verbal ability was associated with greater persistence in taking medications over a two-year period. Stilley and colleagues (Stilley et al. 2004, 2010) also reported that higher levels of cognitive ability were associated with better medication adherence as measured by electronic bottle cap monitors. In addition, Sabia et al. (2010) found that controlling health variables such as smoking, alcoholic consumption, fruit and vegetable consumption, and hours of physical exercise reduced the relation between cognitive ability and mortality, which is consistent with the role of healthy lifestyle as a mediator of the relations.

The interpretation of the cognition-mortality relationship favored by Deary (e.g., Deary 2005, Deary et al. 2009; also see Gottfredson & Deary 2004) is that health self-care is analogous to a complex job in that it requires a variety of cognitive abilities such as knowledge, problem solving, planning, and decision making. A similar view emphasizing cognitive ability, in the form of numeracy, in the context of medical decision making was expressed by Reyna et al. (2009): "Low numeracy distorts perceptions of risks and benefits of screening, reduces medical compliance, impedes access to treatments, impairs risk communication (limiting prevention efforts among the most vulnerable), and . . . appears to adversely affect medical outcomes" (p. 943).

Because many of the cognition relations might be attributable to amount of education or to SES, the role of education and SES on cognition-mortality relations was explicitly discussed by Deary (2008). He noted that although there were some cases in which the cognition-mortality relation was reduced when these factors were controlled, this was not always the case. For example, significant cognition relations were found after controlling for father's occupation (Whalley & Deary 2001), after controlling for father's social class at birth (e.g., Leon et al. 2009), and after controlling for a measure of SES (e.g., Batty et al. 2009a, Jokela et al. 2009, Shipley et al. 2005). Deary (2009) also cautioned that statistical control results can be ambiguous because there is still uncertainty about the causal direction between education (and SES) and cognitive ability, and therefore it is possible that they all reflect cognitive ability.

In summary, many relations have been documented between cognitive ability and important life outcomes, and at least some of these relations do not appear to be attributable to social class or educational level. In a commentary on some of this research, Lubinski (2009) noted, "There is an old saying in applied psychology: for a difference to be a difference it must make a difference. Cognitive differences make real differences in life" (p. 627). The reasons for these linkages are not fully understood, but Gottfredson (2004a,b) noted that many aspects of contemporary life require cognitive abilities, such as filling out job applications or government forms, figuring out a bus or train schedule, and interpreting maps, and that although no single aspect is critical, they can accumulate over one's life to have large consequences.

AGE TRENDS IN COGNITION

Some researchers, including several industrial-organizational psychologists interested in job performance, have assumed that there are little or no age relations on cognition until age 65 or older. For example, Murphy (1989) stated: "Although ability levels may gradually change over one's lifetime, it is reasonable to treat a worker's level of general cognitive ability, over the period of that worker's job tenure, as a constant" (p. 185). However, an extensive research literature has documented sizable relations between age and level of cognitive functioning prior to age 65.

For the current purposes, results based on contrasts of cross-sectional data are referred to as declines even though it is not known if there is decline at the level of individuals because the relevant data are not longitudinal. Nevertheless, the terminology of decline is less cumbersome than is awkward reference to negative age differences.

Because there are many different types of cognitive variables in which performance is expressed in different units, the original scores in cognitive tests are frequently converted to z-score units to facilitate comparisons across variables. This conversion is carried out in **Figure 2**, which illustrates the age trends in composite measures of novel processing (or fluid cognition) and knowledge (or crystallized cognition) from studies by Salthouse and colleagues and from the nationally representative sample used to provide norms for the WAIS-IV (also see Salthouse 2009a). These data clearly indicate that there are two distinct patterns of age trends for the two major types of cognition, with a monotonic decrease for measures of reasoning and other process abilities, and stability followed by decline for measures of acquired knowledge.

Hunt (1995, p. 119) estimated the declines to be about −0.04 standard deviations per year beginning at about age 30 for fluid cognition, with an increase from age 20 to age 65 of 0.03 standard deviations per year for crystallized cognition. However, recent research suggests that both sets of relations are more modest, as the estimates from over 3,000 adults between 20 and 70 years of age in the Salthouse studies are −0.02 for fluid ability and 0.02 for crystallized ability, and estimates of the age relations from the 1,577 adults in the normative WAIS-IV sample are −0.02 for fluid ability and 0.003 for crystallized ability.

Evidence indicates that the cross-sectional age-cognition relations are not only well documented but also quite robust. For example, although the absolute levels of cognitive performance have increased over historical time, the relative age trends have been similar for several generations. That is, parallel age trends are evident over a span of about 50 years in data from Schaie's Seattle Longitudinal Study (e.g., figure 4.5 in Schaie 2005) and over a period of nearly 70 years in the Wechsler tests (e.g., figure 2.6 in Salthouse 2010).

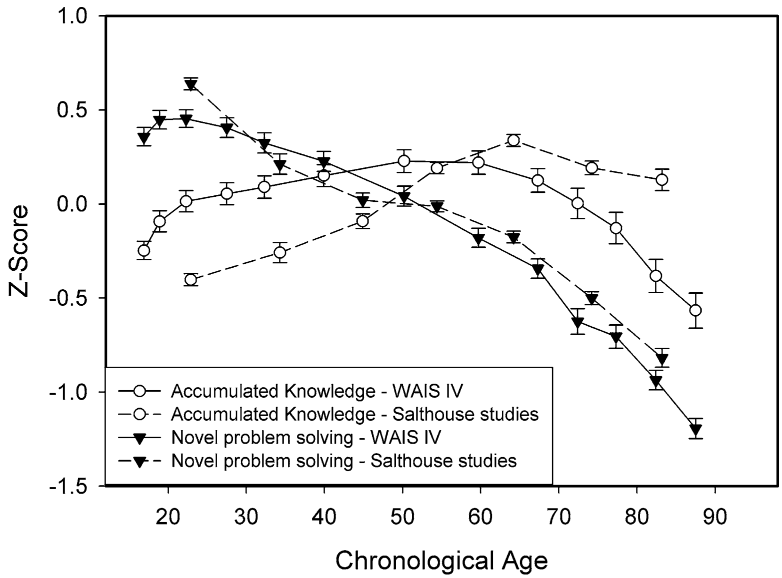

Figure 2

Means (and standard errors) for composite measures of accumulated knowledge and novel problem solving in the Wechsler Adult Intelligence Scale-Fourth Edition (WAIS-IV) standardization sample and in studies by Salthouse and colleagues.

Moreover, the age relations are not restricted to a certain segment of the population because they are evident across different percentiles of the score distribution at each age, with nearly constant standard deviations at different ages (Salthouse 2010). There is also little change in the age relations after controlling for variables such as amount of education, self-rated health, depression, and anxiety (e.g., Salthouse 2009b), and parallel age trends have been reported at different levels of SES (Fozard & Nuttall 1971) and among workers at different levels of job complexity (Avolio & Waldman 1990). Finally, similar trends have been found when examinees were highly motivated because the tests were taken for vocational guidance (Schroeder & Salthouse 2004) or for job selection (Avolio & Waldman 1990, Droege et al. 1963, Fozard & Nuttall 1971, Hartigan & Wigdor 1989, Stein 1962).

Cross-sectional age-cognition relations are sometimes dismissed on the grounds that they reflect many factors other than age. Although the assertion that age is not the only determinant of the cross-sectional trends is certainly true, cross-sectional patterns are arguably the most relevant type of comparison if one is interested in relative level of functioning at a particular point in time. That is, the primary question in the current context concerns the interrelations of age, cognitive functioning, and real-world functioning, and the reasons why people of different ages vary in their level of cognitive functioning is of secondary importance for this particular question.

In summary, nearly monotonic age-related declines in many cognitive variables have been reported between 20 and 75 years of age, with the correlations between age and reasoning or fluid ability often ranging from −0.3 to −0.5. To illustrate, Verhaeghen & Salthouse (1997) reported a meta-analysis of 38 correlations with a total sample size of over 9,000 adults, and their estimate of the age-reasoning correlation was −0.40, which is very close to the correlations of −0.39 in the Salthouse data set and −0.43 in the WAIS-IV normative data. However, different age trends are apparent in measures of acquired knowledge, as the functions typically increase until about age 60 and then gradually decline.

WHAT ARE THE CONSEQUENCES OF AGE-RELATED COGNITIVE DECLINES?

Two major sets of results are described in the preceding sections: a positive relation between cognitive ability and life outcomes (with a correlation in the domain of work of about 0.5) and a negative relation between age and cognitive ability (with a correlation of about −0.4 for measures of novel problem solving). If these two relations are combined in a path analysis model, they lead to an expected correlation of about −0.2 between age and effectiveness of functioning outside the laboratory. In other words, given that increased age is associated with lower levels of performance on certain cognitive tests, and that performance in those tests is positively associated with various measures of real-world functioning, increased age might be expected to be associated with lower levels of functioning outside the laboratory. The current section reviews the evidence relevant to this predicted age relation and considers possible explanations for why it is seldom found.

Age and Achievement

One area in which the results seem consistent with expectations of negative age relations is research on achievement. Interest in the topic of relations between age and achievement dates at least to Quetelet (1835/1842), with the first inverted-U age-achievement figure published by Beard in 1881. **Figure 3** illustrates the typical shape of age-achievement functions with data from Lehman (1962, 1966). Age is represented along the horizontal axis, and the vertical axis is some measure of achievement or productivity, with Lehman usually converting the raw achievement measures to percentages of the maximum across all ages. This inverted-U function is now well established, with most of the 170 figures in Lehman's (1953) book portraying similar functions across different disciplines and historical periods, and numerous replications have been published in different fields and with alternative measures of achievement (e.g., see Simonton 1988).

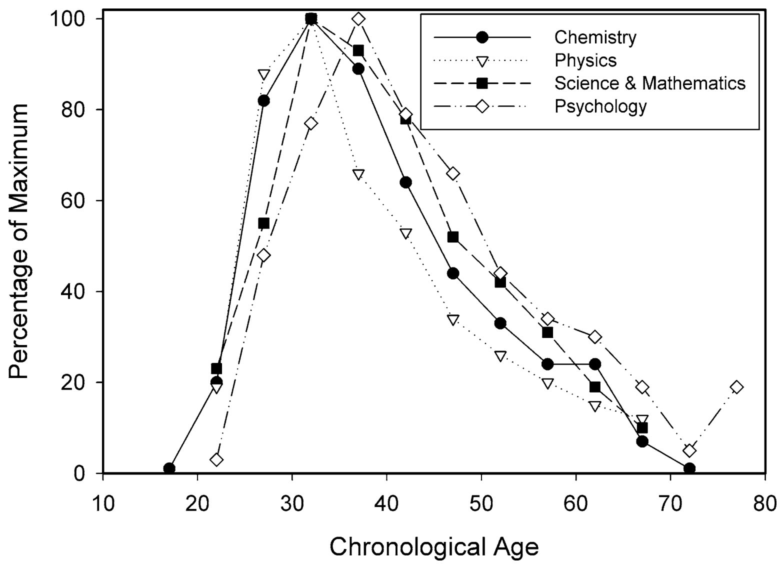

Figure 3

Measures of achievement as a function of age from studies by Lehman (1962, 1966).

The basic phenomenon of a steep increase, a relatively early peak, and a gradual decline has not only proven robust across many different disciplines and historical periods, but also across many types of achievement measures. For example, measures of achievement have ranged from simple counts of products (such as the number of published articles, paintings, inventions, or musical recordings) to consideration of particularly high-quality products (such as highly cited articles or discoveries recognized as the basis for a Nobel Prize). Furthermore, similar functions have been obtained in within-individual comparisons, after control of differences in lifespan to ensure that everyone has potential to contribute at all ages and after control of the size of the competition at different ages to avoid a bias against older contributors when the number of potential contributors is increasing over time (e.g., Lehman 1953, Simonton 1988).

Early interpretations of the age-achievement functions linked them to age-related cognitive declines, and indeed, the functions were originally used to infer age trends in mental faculties. For example, Quetelet (1835/1842) described his rationale for analyses of age and achievement as follows: "We can only appreciate faculties by their effects; in other words, by the actions or works which they produce . . . [and] . . . by bearing in mind the ages at which the authors have produced their works, we possess the necessary elements to follow the development of the mind, or its productive power" (pp. 74–75). Beard (1874) noted, ". . . we have no recognized mental dynamometer by which to measure the comparative cerebral force of the living and the dead. The true and only way by which the subject can be approached is by studying the history of human achievement and comparing the age at which has been done the best work of the world" (p. 4).

However, more recent scholars in the age-achievement field have disagreed with Quetelet and Beard and have generally not assumed that the age-achievement functions were attributable to cognitive declines. For example, Lehman (1953) suggested that multiple causes were operating in producing the functions, and he provided a list of 16 possible causes in the final chapter of his book. The first possibility on his list was decline ". . . in physical vigor, energy, and resistance to fatigue . . . [which he suggested was] . . . probably far more important than such normal age changes as may occur in adult intelligence" (p. 328).

One aspect of age-achievement functions that does appear consistent with a role of cognitive factors is differences across disciplines in the age of the peak and the steepness of the decline (e.g., Lehman 1953, Simonton 1988). Specifically, fields such as lyric poetry, pure mathematics, and theoretical physics, which may place a premium on novel problem solving, tend to have earlier peaks and more rapid declines than do fields with more reliance on accumulated knowledge (e.g., novel writing, history, philosophy). To illustrate, Simonton (1997) noted that the peak age was 26.5 for mathematicians, but 38.5 for historians. Although these differences are intriguing, they refer to differences across disciplines and are not necessarily relevant to the nature of the trajectory within individuals. That is, the key question in the current context is the role of age-related cognitive decline on the declining segment of the functions, regardless of the field in which the function is observed.

A critical issue in evaluating the cognitive decline interpretation of the age-achievement functions is the distinction between quantity and quality because age-related declines in cognitive functioning might be expected to have a greater role in decreases in quality than in decreases in quantity. Simonton (e.g., 1997) has been a strong advocate of what he terms the "constant probability of success" principle, which refers to the idea that although there may be a decrease with age in productivity, each contribution for a particular individual has a nearly equal chance of success regardless of one's age. His argument is based on empirical analyses of the quality and quantity of achievements, and particularly what he termed the quality ratio, which is the number of major works divided by number of total works over a given period. Analyses in several different disciplines revealed that the quality ratio remained approximately constant across most of adulthood (Simonton 1997).

Direct support for the constant probability of success principle was reported by Oster & Hamermesh (1998) in a study of publications of economists. These researchers examined submission rates and the probability of acceptance in a major journal for authors of different ages. As in other studies, there was an inverted-U relation between age and number of manuscripts submitted, but the acceptance probability was nearly constant at all ages. The lower productivity of older economists was therefore not because they had higher rejection rates when submitting their articles (which might serve as an indication of quality), but rather was attributable to a lower rate of submission (which can be viewed as a reflection of quantity).

To the extent that increased age is associated with a reduction in how much is done, but not in the quality of what is done, it implies a need to explain why there is a decrease in quantity with increasing age when attempting to account for age-achievement functions. One frequently mentioned possibility is that productivity decreases with age because of shifting responsibilities and motivations as people advance in their careers and take on more supervisory, mentoring, or collaborative work, which all introduce competing demands for their time (Stephan & Levin 1993). In fact, there is some evidence of more rapid declines of the age-achievement functions for scholars who take on administrative responsibilities (Goodwin & Sauer 1995). Although the mere existence of shifting responsibilities could not explain why some fields have very shallow declines, it is possible that disciplinary differences are attributable to slower information obsolescence in certain fields. Indeed, McDowell (1982) suggested that the relevant knowledge base changes more slowly in fields such as history and philosophy than in fields such as chemistry and physics, and thus scholars in those fields may experience less disruption in their productivity associated with periods away from their primary work.

Although there are similarities in the age trends in novel problem solving and in various measures of achievement in a variety of domains, a limitation of research on achievement is that a very large number of factors influence the outcome variable, which makes it difficult to identify the role of any single factor such as cognitive ability. It is therefore possible that less ambiguous conclusions about the influence of cognitive ability might be reached by studying age trends in a narrower aspect of behavior with fewer, or more controllable, confounds.

One intriguing example of this more focused approach is a recent study of financial decisions by a group of economists (Agarwal et al. 2008). This project involved analyses of an extensive database containing details of borrowing information and characteristics of individual borrowers, including age. The major finding was that borrowing with the fewest fees in several different contexts, including mortgages, home equity loans, auto loans, and credit card interest rates, occurred for middle-aged adults. Moreover, the relationships were evident even after controlling for many variables that might affect loan pricing, such as credit risk, home value, and income. Additional analyses revealed that the age relations in home equity loans were largely attributable to errors in estimating the value of one's home, which led to an increased borrowing rate. That is, the propensity to make a rate-changing mistake had a U-shaped relation with age, but the borrowing rates for consumers who did not make a rate-changing mistake was independent of age. The authors speculated that this peak for favorable financial decisions at about age 53 might have occurred because this may be the age where there is an optimal balance between high reasoning ability, which declines with age, and relevant experience, which increases at least until middle age. By limiting the focus to a specific type of behavior, these researchers had greater control over a variety of potential confounding factors than is possible with cruder achievement outcomes. Nevertheless, the results still cannot be considered definitive evidence for a role of cognitive ability because no direct measures of cognitive ability were available from the individuals, and thus the linkage of borrowing rates to cognitive ability remains somewhat speculative.

General Aptitude Test Battery: cognitive test battery developed by the U.S. Department of Labor to assist in employee selection and guidance

ATC: air traffic controller

Age and Job Performance

Because job performance is the domain with the most extensive linkages to cognitive abilities, strong age-performance relations might be expected in measures of job performance. Indeed, Fozard & Nuttall (1971) noted that there were pronounced age relations on summary scores from the General Aptitude Test Battery, which was developed by the Department of Labor to guide employment selection, and that when these age relations were aligned with the minimum levels proposed for different occupations, the results implied that fewer than 50% of 60-year-olds would qualify for many of the jobs. However, with few exceptions, these pessimistic expectations have seldom been confirmed with empirical research.

One occupation in which negative age-performance relations have been well documented is the field of air traffic controllers (ATCs). Age relations in ATC performance are considered to be so pronounced that in the United States there is a mandatory retirement age of 56 for controllers who manage air traffic, and a maximum age of 30 for entry into ATC school. The sizable age relations among ATCs likely occur because of the unique characteristics of that job. That is, ATCs must monitor and direct movement of aircraft within an assigned air space and on the ground under continuously changing conditions, and these activities require numerous cognitive abilities that have been found to be negatively related to age, such as speed and flexibility of closure, inductive and deductive reasoning, and selective and divided attention.

Age-performance relations in ATC activities have been found even in samples of adults with a very restricted age range. That is, because the maximum age of active controllers is typically in the 50s, most are under 50 years of age. Nevertheless, poorer performance with increased age has clearly been documented in ATC training. To illustrate, Trites & Cobb (1963) reported seven times more failures in ATC training among trainees 39 years of age and older compared to younger trainees, and Trites & Cobb (1964) reported a success rate of 50% for trainees under age 33 but only 20% for trainees over age 33. There have also been numerous reports of poorer performance with increased age in aptitude tests related to ATC activities (e.g., Becker & Milke 1998, Cobb et al. 1971, Heil 1999) and poorer supervisor ratings with increased age among active controllers (e.g., Cobb 1968, Cobb et al. 1971, Heil 1999).

Exceptions to the strong age-performance relations among ATCs have been reported in two recent studies, but each has characteristics suggesting that the conclusions may need qualifications. In the first study, Broach & Schroeder (2006) found no differences in the rate of operational errors for controllers under and over 56 years of age. However, the incidence of operational errors was very low, and the power to detect age differences in them may have been weak. Furthermore, because the mandatory retirement age is 56, with a special exemption typically based on exceptional performance needed to continue to age 61, the older controllers in this project may not have been representative of their age cohort. In the second study, Nunes & Kramer (2009) compared Canadian controllers in two age groups (age 20 to 27 and age 53 to 64) on simulated ATC tasks. (Because Canada does not have mandatory retirement of ATCs at age 56, it was possible to obtain a sample of older controllers in this study.) The major finding was that there was little age difference in performance of the simulated air traffic control tasks for controllers, but a large age difference existed for noncontrollers. However, the young controllers in this project had very limited experience (i.e., a mean of 1.6 years), and factors other than controller experience were likely operating in the simulated tasks because the young noncontrollers performed at a level similar to the two controller groups.

Although age-related declines are apparent in jobs such as ATCs and among elite or professional athletes (e.g., Baker et al. 2007, Schulz & Curnow 1988, Schulz et al. 1994), meta-analyses typically reveal little or no systematic relation of age with measures of job performance (e.g., Davies & Sparrow 1988, Hunter & Hunter 1984, Hunter & Schmidt 1998, McEvoy & Cascio 1989, Rhodes 1983, Sturman 2003, Waldman & Avolio 1986). As an example, in their meta-analysis, McEvoy & Cascio (1989) found the correlations between age and performance ranged from −0.44 to +0.66, with a meta-analytic estimate of 0.06 and a 95% confidence interval from −0.18 to +0.30. The wide range of correlations led to the investigation of possible moderators of the age-performance relations, but there was little evidence of moderation either by type of performance measure (i.e., rating or productivity measure) or by type of job (e.g., blue collar or white collar), and other meta-analyses have also failed to identify strong moderators of the relations between age and job performance.

Many of the studies examining relations of age and work performance can be criticized (e.g., Salthouse 1990, 1994; Salthouse & Maurer 1996) because of selective attrition (in that older workers may not be as representative of their age peers as are younger workers because of advancement of the most competent or dismissal of the least competent) and restricted age range (with few studies containing workers over about 50 years of age). Another frequently mentioned limitation of job performance studies is poor outcome or criterion variables because it is difficult to assess quality of performance in complex jobs, supervisor ratings can be biased, and few objective indicators of performance are available in professional or managerial jobs. Nevertheless, it is important to recognize that some of the same studies that did not find significant relations with age did find significant relations with cognitive ability (e.g., Hunter & Hunter 1984, Hunter & Schmidt 1998), and therefore job performance outcome variables are not completely lacking in reliability or sensitivity.

Why Are There Not Greater Consequences?

The preceding review indicates that with only a few exceptions, there is little evidence of a negative relation of age (at least within the range of 20 to 75 years of age) and indices of overall level of functioning in society. Assuming that the age-cognition and cognition-functioning relations reviewed above are valid estimates of the true population relations, the positive cognition-functioning relation and negative age-cognition relation lead to expectations of negative relations between age and functioning that are rarely observed. The remainder of this section considers four categories of possible explanations for why there are not greater consequences of age-related cognitive declines.

(A) Seldom need to perform at one's maximum. One possible explanation of the discrepancy between the expectation of negative consequences of cognitive declines and the general absence of confirming evidence is related to a distinction between assessments of typical and maximal functioning. The distinction between typical and maximal assessment was apparently first introduced by Cronbach (1949), was later elaborated by Fiske & Butler (1963), Ackerman (1994), Goff & Ackerman (1992), and Dennis et al. (2000), and was discussed from a somewhat different perspective by Posner (1995). The basic idea is that what we do in daily life reflects our typical level of functioning, whereas cognitive tests attempt to assess our maximal level of functioning. To the extent that many outcome criteria reflect typical behavior, whereas the predictions from cognitive tests are based on maximal behavior, it is possible that at least some of the discrepancy between predicted and observed age differences in real-world functioning is attributable to the use of different types of assessments in the predictions and in the observations of everyday functioning.

It is almost certainly true that we do not need to function at our maximum level often; if we did, everyday life would be too stressful. It also seems plausible that relations of cognitive ability or other factors might only be detectable at the highest levels of functioning, when other factors might be relatively less important. Note that this perspective does not deny the possibility of age-related declines that could impact real-world functioning, but instead suggests that they are not detected because people seldom need to function at the level at which deficits might be manifested.

Fluid intelligence (Gf): term introduced by Raymond Cattell referring to undifferentiated abilities that can "flow" into different domains

Crystallized intelligence (Gc): term introduced by Raymond Cattell to refer to the crystallized products of interactions of fluid abilities with environmental exposure

(B) Shift with age from novel processing to reliance on accumulated knowledge. Many cognitive tests can be considered analogous to exercises in mental gymnastics, in that as with physical gymnastics, they are designed to assess agility or flexibility but do not necessarily have direct counterparts in the everyday world. In a similar vein, it has been noted that "... abilities assessed by these types of tests ... [can be] ... characterized as determining the level of performance that can be achieved when one doesn't know what to do and has no relevant experience" (Salthouse 2006, p. 279). In contrast to this emphasis on novelty, it is possible that much of what we do in our daily life is only slightly different from what we have done in the past. That is, novel problem solving ability may become less important to an individual as more of his or her life problems are solved, and consequently higher proportions of one's daily functioning can occur by retrieval of the prior solutions.

This idea that an advantage of greater knowledge overcomes any disadvantage of less effective novel processing has a long history. In 1933, Jones & Conrad suggested that "... much of the effective power of the adult ... is evidently derived from accumulated stocks of information" (p. 254). Among the recent expressions of the idea that knowledge becomes more important with increased age are the following quotations:

> The concerned reader, who might be over 26 years of age, when fluid intelligence first begins to decline, should note the effects are rather gradual. In any event, the improvement witnessed in the individual's crystallized intelligence tends to be nature's compensation. (Matthews et al. 2002, p. 108)
>
> Because job experience and age are often inextricably intertwined, the midlife worker will be more skilled than the younger worker ... thus any loss of Gf abilities will be compensated for by higher levels of job knowledge (Gc). (Kanfer & Ackerman 2004, p. 450)

A very simple empirical example of the potential importance of age-related increases in knowledge is evident in a contrast of the age trends in measures of analytical reasoning with the age trends in a measure of crossword puzzle performance (cf. Salthouse 2010). These two activities are similar in that in both cases the solution requires simultaneous satisfaction of multiple constraints. That is, analytical reasoning problems often specify a number of conditions that must not be violated in order to reach a solution, and solutions in crossword puzzles must simultaneously fit the clue, the number of letters in the target word, and the positions of any letters that have already been identified. As can be seen in **Figure 4**, age trends in the analytical reasoning task closely resemble the monotonic declines evident in novel problem-solving tasks. However, when knowledge is relevant to the task, as in crossword puzzles, the age trends among people with frequent crossword puzzle–solving experiences are actually reversed, with better performance at older ages! These opposite trends in the same individuals are consistent with the view that little or no consequence of cognitive declines may be evident when one can draw upon relevant knowledge.

Closely related to the idea of benefits of accumulated knowledge is the distinction between functioning in new or unfamiliar situations versus functioning in situations in which one has considerable experience. As Droege noted, "Maintenance of ability once acquired is not the same as acquisition of a new ability" (1967, p. 181). This view has been endorsed by a number of researchers, and some have suggested that the distinction might account for the lack of negative age relations in real-world situations (e.g., Hunt 1995). For example,

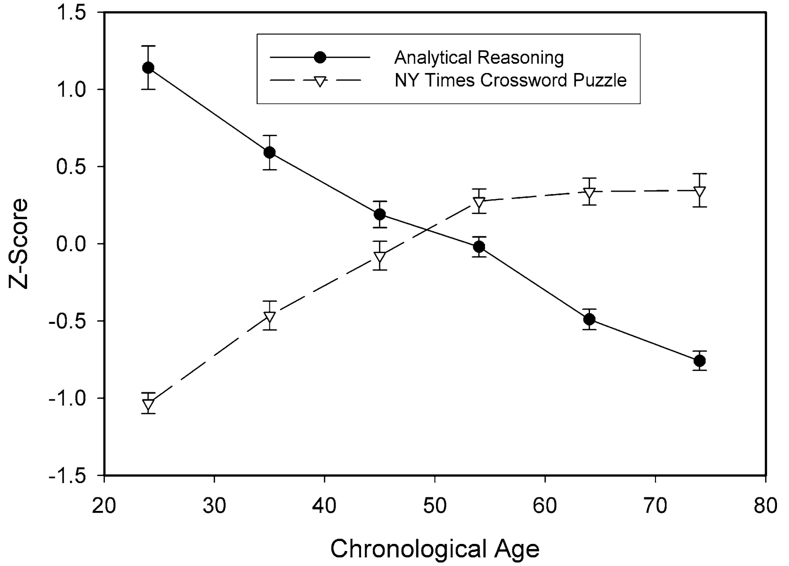

Figure 4

Means (and standard errors) of performance on an analytical reasoning test and on a crossword puzzle test from studies by Salthouse and colleagues.

citing research by Fleischman and Ackerman of reduced correlations between cognitive ability and task performance with increased practice, Murphy (1989) suggested that cognitive ability is primarily important in periods of transition in which new information must be acquired rather than relying on past experience.

However, other researchers, such as Gottfredson (2004b) and Schmidt & Hunter (2004), have argued that many tasks in moderately complex jobs cannot be automated, and hence cognitive ability continues to be important because of the constant need for adaptation and improvisation. The key assumption that there is a dramatic decrease in the need for novel problem solving with increased age can also be questioned. Although it is true that a great deal of novel problem solving may be required when one is first starting a career, considerable problem solving may also be needed in many activities associated with middle age and late adulthood, such as when selecting among investment and retirement plans, making health care decisions, and adhering to medication regimens. The research on tasks designed to predict independent living in older adults is also relevant in this context because the results suggest that novel problem solving is a stronger predictor of measures related to independent living than measures of accumulated knowledge. The relative importance of novel problem solving versus accumulated knowledge almost certainly varies as a function of many factors, including type of activity and amount of experience, but there may be very few situations at any age in which there is no advantage of high levels of novel problem-solving ability.

(C) Cognition is not the only determinant of success in life. Several researchers have noted in the context of the relation between cognition and job performance that even a correlation of 0.5 leaves about 75% of the variance unexplained (e.g., Higgins et al. 2007, Matthews et al. 2002, Sternberg & Hedlund 2002). Numerous speculations have consequently been offered about what is responsible for the remaining variance in job performance not predicted by cognitive ability. For example, Moss & Tilly (2001) noted that job performance is not only affected by hard skills, which is their term for cognitive and technical skills, but also by soft skills, by which they mean personality and attitude. Posner (1995) mentioned the possibility that psychometric tests do not measure occupationally relevant aspects of application, focus, flexibility, and effort. Furthermore, Gottfredson (2002) suggested that there were three major determinants of job success, which she characterized as "can do" (ability), "will do" (motivation), and "have done" (experience), with only the first typically represented in most assessments.

KSAO: knowledge, skills, abilities, and others, presumed to be major dimensions of competency of an individual

The existence of factors beyond cognitive ability has been explicitly acknowledged in the field of industrial organizational psychology, in which determinants of job performance are frequently referred to as KSAOs, where K refers to general knowledge, S to task-specific skills, A to physical and cognitive ability, and O to miscellaneous Other factors. Because task-specific skills can be expected to be acquired with experience, it is possible that some relevant skills are greater at older ages and represent a form of experience-based compensation. One example of a positive relation of age on a task-specific skill is available in the domain of transcription typing. Salthouse (1984, 1987) examined various typing-related tasks in samples of adults selected such that there was no relation between age and net typing speed. Although increased age was associated with slower reaction time to individual letters, older typists were found to have larger eye-hand spans, or greater preview of forthcoming keystrokes, than younger typists had, and it is possible that this typing-related skill functioned to compensate for their slower perceptual motor speed. The typing research is only one example in which experienced older individuals perform at higher levels than one would expect based on their levels of basic abilities, but it is likely that many other situations exist in which increased age is associated with the acquisition of task-specific skills that contribute to high proficiency on the job.

Among the many candidates for Other factors in the KSAO framework are aspects of personality (Roberts et al. 2007, Schmidt & Hunter 2004), emotional intelligence (Matthews et al. 2002), practical intelligence (Sternberg & Hedlund 2002, Wagner & Sternberg 1985), decision-making competence or rationality (De Bruin et al. 2007, Parker & Fischoff 2005, Stanovich 2009, Stanovich & West 2008), process analytic ability (Zysberg 2009), and even chance (Gladwell 2008). Evidence for the contribution of other factors is most convincing when they are examined simultaneously with cognitive ability to determine whether the factors are associated with incremental prediction of the relevant criterion. For example, Schmidt & Hunter (1998, 2004; also see Judge et al. 2010) found that conscientiousness had incremental prediction of job performance and success in job training beyond general cognitive ability. Wagner & Sternberg (1990; also see Sternberg et al. 1995) have also reported incremental prediction from tacit knowledge over conventional measures of cognitive ability of performance in managerial simulations.

However, in addition to evidence of incremental prediction, in order to account for the discrepancy between the expected and observed patterns of real-world functioning with increased age there should also be evidence of an interaction, with greater incremental prediction of the relevant outcomes from other factors at older ages than at young ages. That is, if other factors are responsible for the discrepancy between the predicted and observed age-outcome relations, then the other factors either must have higher values at older ages, a stronger relation with the criterion at older ages, or a combination of higher values and stronger relations. In other words, it is not sufficient to demonstrate that factors other than cognitive ability are involved in the outcomes because it also needs to be established that these other factors are related to age and that they have different relations to the criterion as a function of age.

Consider the case of conscientiousness as a candidate for the Other factor. In order for it to be responsible for maintained real-world functioning despite age-related declines in cognitive functioning, not only should it be positively related to age, but there should also be evidence of greater incremental prediction of relevant outcomes at older ages. There is evidence that values of conscientiousness are somewhat higher with increased age (e.g., Roberts & Mroczek 2008, Srivastava et al. 2003, Terracciano et al. 2005), but at the present time there is apparently no research establishing that the incremental contribution of conscientiousness in the prediction of job performance or other important outcomes is greater at older ages.

Cognitive ability is clearly not the only determinant of successful functioning in life, and it is certainly possible that some determinants increase with age and offset any age-related declines in cognitive ability. Although plausible, empirical evidence documenting the compensatory nature of these other determinants is currently quite limited.

(D) Accommodations. A fourth possible interpretation of why there are not greater consequences of age-related cognitive declines is that there might be real consequences of the declines, but they are not apparent because of accommodations of the individual. For example, accommodations could occur if people minimize the consequences of declines by restricting their exposure to deficit-revealing situations. Driving may be an example of this type of restricted exposure as, likely in part due to recognition of their declining levels of sensory and cognitive abilities, many older adults avoid driving in rush hour, at night, and on unfamiliar routes. There is also evidence that workers tend to shift jobs as they experience difficulty in the original job (e.g., Warr & Pennington 1994), which is apparent in different age distributions for different jobs (e.g., Hunt 1995, Kanfer & Ackerman 2004, Warr 1994, Welford 1958). Other possible types of accommodation include a reduction in the range of domains in which one maintains a high level of expertise ("selective optimization"; see Baltes & Baltes 1990) and greater reliance on others, including delegation of responsibility to junior associates, paid assistants, and children (e.g., Birren 1969).

Still another form of accommodation could occur at the societal level and involve adaptations of the environment in which the individual lives. That is, the nature of many jobs has changed over time as automation and technology have reduced cognitive demands. To illustrate, Hunt (1995) described the case of a cashier who now merely scans bar codes with little or no need to rely on memory and arithmetic. In the past, performance in a job such as this may have had strong relations to cognitive abilities, but that is no longer the case because of the altered requirements of the job.

Although empirical evidence on effects of environmental adaptations in people of different ages is currently limited, it seems likely that there could be differential impact of future technological innovations as a function of the worker's age. For example, if novel problem-solving requirements are reduced by new technology, older individuals will likely have the greatest benefit because they tend to have lower levels of novel problem-solving ability than young adults. In contrast, if technology leads to extraction of relevant knowledge that can be embodied in expert systems, young individuals may experience the greatest benefit because they have not yet acquired the relevant knowledge. (See Posner 1995, p. 69, for a similar argument.) Because at the current time it may be more feasible to build a knowledge base (and it may already exist in the form of Google and its competitors) than to automate novel problem solving, benefits of technology in the reduction of cognitive demands may currently be greater for young adults than for older adults.

Relatively little is known about how people adapt, either consciously or unconsciously, to diminishing cognitive abilities. Nevertheless, it seems likely that many people will tend to alter what they do, or how they do it, to try to maintain a high level of functioning in the face of declines in relevant abilities, and this may contribute to the often minimal consequences of declining abilities.

CONCLUSIONS

Cognitive ability is important in daily life, and there is currently little evidence that its importance declines with increasing age. In fact, there are some reasons to expect that the role of cognitive ability in late adulthood is even more important now than in the past because individuals of all ages are being asked to take more responsibility for financial (Banks & Oldfield 2007, McArdle et al. 2009) and medical (Reyna et al. 2009) decisions.

Negative relations of age to cognition are among the strongest individual difference relations in psychology, and thus it is reasonable to expect consequences of those declines in life outside the laboratory. Very robust inverted-U relations between age and different measures of achievement have been reported in many different domains. Although these trends are superficially consistent with the existence of age-related cognitive declines, the relation is weak because the declines may reflect quantity more than quality, there are many other possible determinants of the functions besides cognitive ability, and there are no direct linkages of cognitive ability and achievement in the same individuals.

At the current time, evidence of negative consequences of age-related decreases in cognitive ability is limited until the level of cognitive ability reaches pathological limits. Reasons for the lack of consequences are still not fully understood, but they probably reflect a combination of several factors, including few life situations in which one needs to perform at his or her maximum, greater reliance with increased age on acquired knowledge or on noncognitive factors that do not decline with age instead of novel problem solving, or because of a variety of different types of accommodations that minimize impact of the declines.

Despite the lack of definitive answers at the current time, it will ultimately be valuable to discover why the consequences of age-related cognitive declines are so small because the reasons may have implications in other areas. For example, understanding why there are few consequences may suggest possibilities for remediation of cognitive disabilities or for the design of interventions to prevent decline.

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LITERATURE CITED

Ackerman PL. 1994. Intelligence, attention and learning: maximal and typical performance. In *Current Topics in Human Intelligence*, ed. DK Detterman, pp. 1–27. Norwood, NJ: Ablex

Ackerman PL, Cianciolo AT. 2002. Ability and task constraint determinants of complex task performance. *J. Exp. Psychol. Appl.* 8:194–208

Agarwal S, Driscoll J, Gabaix X, Laibson D. 2008. The age of reason: financial decisions over the lifecycle. *Am. Law Econ. Assoc. Annu. Meet.* 97:1–5

An intriguing study examining relations of age to actual borrowing decisions in large samples of loan or credit applicants.

Allaire JC, Marsiske M. 1999. Everyday cognition: age and intellectual ability correlates. *Psychol. Aging* 14:627–44

Allaire JC, Marsiske M. 2002. Well- and ill-defined measures of everyday cognition: relationship to older adults' intellectual ability and functional status. *Psychol. Aging* 17:101–15

Avolio BJ, Waldman DA. 1990. An examination of age and cognitive test performance across job complexity and occupational types. *J. Appl. Psychol.* 75:43–50

Backman L, MacDonald SWS. 2006. Death and cognition: synthesis and outlook. *Eur. Psychol.* 11:224–35

Baker J, Deakin J, Horton S, Pearce GW. 2007. Maintenance of skilled performance with age: a descriptive examination of professional golfers. *J. Aging Phys. Act.* 15:300–17

Baltes PB, Baltes MM, eds. 1990. *Successful Aging: Perspectives from the Behavioral Sciences*. New York: Cambridge Univ. Press

Baltes PB, Staudinger UM, Lindenberger U. 1999. Lifespan psychology: theory and application to intellectual functioning. *Annu. Rev. Psychol.* 50:471–507

Banks J, Oldfield Z. 2007. Understanding pensions: cognitive function, numerical ability and retirement saving. *Fisc. Stud.* 28:143–70

Batty GD, Deary IJ. 2004. Early life intelligence and adult health. *Br. Med. J.* 329:585–86

Batty GD, Deary IJ, Gottfredson LS. 2007. Premorbid (early life) IQ and later mortality risk: systematic review. *Ann. Epidemiol.* 17:278–88

Batty GD, Gale CR, Tynelius P, Deary IJ, Rasmussen F. 2009a. IQ in early adulthood, socioeconomic position, and unintentional injury mortality by middle age: a cohort study of more than 1 million Swedish men. *Am. J. Epidemiol.* 169:606–15

Batty GD, Wennerstad KM, Smith GD, Gunnell D, Deary IJ, et al. 2009b. IQ in early adulthood and mortality by middle age: cohort study of 1 million Swedish men. *Epidemiology* 20:100–9

Beard GM. 1874. *Legal Responsibility in Old Age*. New York: Russells

Beard GM. 1881. *American Nervousness: Its Causes and Consequences. A Supplement to Nervous Exhaustion* (*Neurasthenia*). New York: Putnam

Becker JT, Milke RM. 1998. Cognition and aging in a complex work environment. *Aviat. Space Environ. Med.* 69:944–51

Birren JA. 1969. Age and decision strategies. In *Interdisciplinary Topics in Gerontology*, vol. 4, ed. AT Welford, JA Birren, pp. 23–36. New York: Karger

Bosworth HB, Siegler IC. 2002. Terminal change in cognitive function: an updated review of longitudinal studies. *Exp. Aging Res.* 28:299–315

Broach D, Schroeder DJ. 2006. Air traffic control specialist age and en route operational errors. *Int. J. Aviat. Psychol.* 16:363–73

Burks SV, Carpenter JP, Goette L, Rustichini A. 2009. Cognitive skills affect economic preferences, strategic behavior, and job attachment. *Proc. Natl. Acad. Sci. USA* 106:7745–50

Burton CL, Strauss E, Hultsch DF, Hunter MA. 2006. Cognitive functioning and everyday problem solving in older adults. *Clin. Neuropsychol.* 20:432–52

Carroll JB. 1993. *Human Cognitive Abilities: A Survey of Factor-Analytic Studies*. New York: Cambridge Univ. Press

Cobb BB. 1968. Relationships among chronological age, length of experience, and job performance ratings of air traffic control specialists. *Aerosp. Med.* 39:119–24

Cobb BB, Lay CD, Bourdet NM. 1971. The relationship between chronological age and aptitude test measures of advanced level air traffic control trainees. *Fed. Aviat. Rep.* Oklahoma City, OK: FAA Civil Aeromed. Inst.

Cronbach LJ. 1949. *Essentials of Psychological Testing*. New York: Harper

Davies DR, Sparrow PR. 1988. Effects of age, tenure, training, and job complexity on job performance. *Psychol. Aging* 3:307–14

Deary IJ. 2005. Intelligence, health and death. *Psychologist* 18:610–13

Deary IJ. 2008. Why do intelligent people live longer? *Nature* 456:175–76

Deary IJ. 2009. Introduction to the special edition on cognitive epidemiology. *Intelligence* 37:517–19

Deary IJ, Gale CR, Stewart MCW, Fowkes FGR, Murray GD, et al. 2009. Intelligence and persisting with medication for two years: analysis in a randomized control trial. *Intelligence* 37:607–12

Deary IJ, Penke L, Johnson W. 2010. The neuroscience of human intelligence differences. *Nat. Rev. Neurosci.* 11:201–11

de Bruin WB, Parker AM, Fischhoff B. 2007. Individual differences in adult decision-making competence. *J. Personal. Soc. Psychol.* 92:938–56

Demaree HA, Burns KJ, DeDonno MA. 2010. Intelligence, but not emotional intelligence, predicts Iowa Gambling Task performance. *Intelligence* 38:249–54

Dennis MJ, Sternberg RJ, Beatty P. 2000. The construction of "user-friendly" tests of cognitive functioning: a synthesis of maximal- and typical-performance measurement philosophies. *Intelligence* 28:193–211

Der G, Batty GD, Deary IJ. 2009. The association between IQ in adolescence and a range of health outcomes at 40 in the 1979 US National Longitudinal Study of Youth. *Intelligence* 37:573–80

Diehl M, Marsiske M, Horgas A, Rosenberg A, Saczynski JS, Willis SL. 2005. The revised observed tasks of daily living: a performance-based assessment of everyday problem solving in older adults. *J. Appl. Gerontol.* 24:211–30

Diehl M, Willis SL, Shaie KW. 1995. Everyday problem solving in older adults: observational assessment and cognitive correlates. *Psychol. Aging* 10:478–91

Droege RC. 1967. Effects of aptitude score adjustments by age curves on prediction of job performance. *J. Appl. Psychol.* 51:181–86

Droege RC, Crambert AC, Henkin JB. 1963. Relationship between G.A.T.B. aptitude scores and age for adults. *Pers. Guid. J.* 41:502–8

Fiske DW, Butler JM. 1963. Experimental conditions for measuring individual differences. *Educ. Psychol. Meas.* 23:249–66

Folstein MF, Folstein SE, McHugh PR. 1975. "Mini-mental state." A practical method for grading the cognitive state of patients for the clinician. *J. Psychiatr. Res.* 12:189–98

Fozard JL, Nuttall RL. 1971. General aptitude test battery scores for men differing in age and socioeconomic status. *J. Appl. Psychol.* 55:372–79

An early study examining implications of age differences in cognitive abilities in occupational selection.

Frey MC, Detterman DK. 2004. Scholastic assessment or *g*? The relationship between the Scholastic Achievement Test and general cognitive ability. *Psychol. Sci.* 15:373–78

Ghiselli EE. 1973. The validity of aptitude tests in personnel selection. *Pers. Psychol.* 26:461–77

Gladwell M. 2008. *Outliers: The Story of Success*. New York: Little Brown

Goff M, Ackerman PL. 1992. Personality-intelligence relations: assessment of typical intellectual engagement. *J. Educ. Psychol.* 84:537–52

Gonzalez C, Thomas RP, Vanyukov P. 2005. The relationships between cognitive ability and dynamic decision making. *Intelligence* 33:169–86

Goodwin TH, Sauer RD. 1995. Life-cycle productivity in academic research: evidence from cumulative publication histories of academic economists. *South. Econ. J.* 61:728–43

Gottfredson LS. 1998. The general intelligence factor. *Sci. Am. Presents* 9:24–30

Gottfredson LS. 2002. Where and why *g* matters: not a mystery. *Hum. Perform.* 15:25–46

Gottfredson LS. 2003. The challenge and promise of cognitive career assessment. *J. Career Assess.* 20:1–21

Gottfredson LS. 2004a. Intelligence: Is it the epidemiologists' elusive "fundamental cause" of social class inequalities in health? *J. Personal. Soc. Psychol.* 86:174–99

Gottfredson LS. 2004b. Life, death and intelligence. *J. Cogn. Educ. Psychol.* 4:23–46

Gottfredson LS, Deary IJ. 2004. Intelligence predicts health and longevity, but why? *Curr. Dir. Psychol. Sci.* 13:1–4

Gustafsson JE. 1988. Hierarchical models of individual differences in cognitive abilities. In *Advances in the Psychology of Human Intelligence*, ed. RJ Sternberg, vol. 4, pp. 35–71. Hillsdale, NJ: Erlbaum

Hartigan J, Wigdor A. 1989. *Fairness in Employment Testing*. Washington, DC: Natl. Acad. Sci. Press

Heil MC. 1999. Air traffic control specialist age and cognitive test performance. *Fed. Aviat. Rep. 99–23*. Oklahoma City, OK: FAA Civil Aeromed. Inst.

Higgins DM, Peterson JM, Pihl RO, Lee AGM. 2007. Prefrontal cognitive ability, intelligence, Big Five personality, and the prediction of advanced academic ability and workplace performance. *J. Personal. Soc. Psychol.* 93:298–319

Hulsheger UR, Maier GW, Stumpp T. 2007. Validity of general mental ability for the prediction of job performance and training success in Germany: a meta-analysis. *Int. J. Sel. Assess.* 15:3–18

Hunt E. 1995. *Will We Be Smart Enough?* New York: Sage Found.

A monograph examining the implications of cognitive ability, and age differences in cognitive ability, in the current and future workforce.

Hunter J. 1986. Cognitive ability, cognitive attitudes, job knowledge, and job performance. *J. Vocat. Behav.* 29:340–62

Hunter J, Hunter R. 1984. Validity and utility of alternate predictors of job performance. *Psychol. Bull.* 96:72–98
Hunter J, Schmidt FL. 1996. Intelligence and job performance: economic and social implications. *Psychol. Public Policy Law* 2:447–72
Hunter J, Schmidt FL. 1998. The validity and utility of selection methods in personnel psychology: practical and theoretical implications of 85 years of research findings. *Psychol. Bull.* 124:262–74
Jensen AR. 1998. *The* g *Factor: The Science of Mental Ability*. Westport, CT: Praeger
Jokela M, Batty GD, Gale CR, Kivimaki M. 2009. Low childhood IQ and early adult mortality: the role of explanatory factors in the 1958 British birth cohort. *Pediatrics* 124:e380–88
Jones HE, Conrad HS. 1933. The growth and decline of intelligence: a study of a homogenous group between the ages of ten and sixty. *Genet. Psychol. Monogr.* 13:223–98
Judge TA, Colbert AE, Ilies R. 2004. Intelligence and leadership: a quantitative review and test of theoretical propositions. *J. Appl. Psychol.* 89:542–52
Judge TA, Higgins CA, Thoresen CJ, Barrick MR. 1999. The big five personality traits, general mental ability, and career success across the life span. *Pers. Psychol.* 52:621–52
Judge TA, Hurst C, Simon LS. 2009. Does it pay to be smart, attractive, or confident (or all three)? Relationships among general mental ability, physical attractiveness, core self-evaluations, and income. *J. Appl. Psychol.* 94:742–55
Judge TA, Klinger RL, Simon LS. 2010. Time is on my side: time, general mental ability, human capital, and extrinsic career success. *J. Appl. Psychol.* 95:92–107
Kanfer R, Ackerman PL. 2004. Aging, adult development, and work motivation. *Acad. Manag. Rev.* 29:440–58
Koenig KA, Frey MC, Detterman DK. 2008. ACT and general cognitive ability. *Intelligence* 36:153–60
Kroner S, Plass JL, Leutner D. 2005. Intelligence assessment with computer simulations. *Intelligence* 33:347–68
Kuncel NR, Hezlett SA, Ones DS. 2004. Academic performance, career potential, creativity and job performance: Can one construct predict them all? *J. Personal. Soc. Psychol.* 86:148–61
Kuncel NR, Ones DS, Sackett PR. 2010. Individual differences as predictors of work, educational, and broad life outcomes. *Personal. Individ. Differ.* 49:331–36
Lachman ME. 2004. Development in midlife. *Annu. Rev. Psychol.* 55:305–31
Lavery LL, Dodge HH, Snitz B, Ganguli M. 2009. Cognitive decline and mortality in a community-based cohort: the Monongahela Valley Independent Elders Survey. *J. Am. Geriatr. Soc.* 57:94–100
Lehman HC. 1953. *Age and Achievement*. Princeton, NJ: Princeton Univ. Press

Classic study of the inverted-U functions relating age to achievement in many different domains.

Lehman HC. 1962. More about age and achievement. *Gerontologist* 2:141–48
Lehman HC. 1966. Psychologist's most creative years. *Am. Psychol.* 21:363–69
Leon DA, Lawlor DA, Clark H, Batty GD, Macintyre S. 2009. The association of childhood intelligence with mortality risk from adolescence to middle age: findings from the Aberdeen Children of the 1950s cohort study. *Intelligence* 37:520–28
Lubinski D. 2009. Cognitive epidemiology: with emphasis on untangling cognitive ability and socioeconomic status. *Intelligence* 37:625–33
Mata R, Schooler LJ, Rieskamp J. 2007. The aging decision maker: cognitive aging and the adaptive selection of decision strategies. *Psychol. Aging* 22:796–810
Matthews G, Zeidner M, Roberts RD. 2002. *Emotional Intelligence: Science and Myth*. Cambridge, MA: MIT Press
McArdle JJ, Smith JP, Willis R. 2009. *Cognition and economic outcomes in the health and retirement survey*. NBER Work. Pap. Ser., w15266. Cambridge, MA: Natl. Bur. Econ.
McDowell JM. 1982. Obsolescence of knowledge and career publication profiles: Some evidence of differences among fields in costs of interrupted careers. *Am. Econ. Rev.* 72:752–68
McEvoy GM, Cascio WF. 1989. Cumulative evidence of the relationship between employee age and job performance. *J. Appl. Psychol.* 74:11–17
Moss PI, Tilly C. 2001. *Stories Employers Tell: Race, Skill and Hiring in America*. New York: Russell Sage Found.
Murphy KR. 1989. Is the relationship between cognitive ability and job performance stable over time? *Hum. Perform.* 2:183–200
Neisser U, Boodoo G, Bouchard TJ Jr, Boykin AW, Brody N, et al. 1996. Intelligence: knowns and unknowns. *Am. Psychol.* 51:77–101

Ng TWH, Feldman DC. 2008. The relationship of age to ten dimensions of job performance. *J. Appl. Psychol.* 93:392–423

Nunes A, Kramer AF. 2009. Experience-based mitigation of age-related performance declines: evidence from air traffic control. *J. Exp. Psychol. Appl.* 15:12–24

Nyborg H, Jensen AR. 2001. Occupation and income related to psychometric *g*. *Intelligence* 29:45–55

Oster SM, Hamermesh DS. 1998. Aging and productivity among economists. *Rev. Econ. Stat.* 80:154–56

O'Toole BI, Stankov L. 1992. Ultimate validity of psychological tests. *Personal. Individ. Differ.* 13:699–716

Pachur T, Mata R, Schooler LJ. 2009. Cognitive aging and the adaptive use of recognition in decision making. *Psychol. Aging* 24:901–15

Park DC, Reuter-Lorenz P. 2009. The adaptive brain: aging and neurocognitive scaffolding. *Annu. Rev. Psychol.* 60:173–96

Parker AM, Fischoff B. 2005. Decision-making competence: external validation through an individual-differences approach. *J. Behav. Decis. Mak.* 18:1–27

Peters E, Vastfjall D, Slovic P, Mertz CK, Mazzocco K, Dickert S. 2006. Numeracy and decision making. *Psychol. Sci.* 17:407–13

Posner RA. 1995. *Aging and Old Age*. Chicago, IL: Univ. Chicago Press

Quetelet A. 1935/1842. *Facts, Laws and Phenomena of Natural Philosophy: Summary of a Course of General Physics*. Glasgow, UK: Sinclair

Ree MJ, Earles JA. 1991. Predicting training success: not much more than *g*. *Pers. Psychol.* 44:321–32

Ree MJ, Earles JA, Teachout MS. 1994. Predicting job performance: not much more than *g*. *J. Appl. Psychol.* 79:518–24

Reyna VF, Nelson WL, Han PK, Dieckmann NF. 2009. How numeracy influences risk comprehension and medical decision making. *Psychol. Bull.* 135:943–73

Rhodes SR. 1983. Age-related differences in work attitudes and behavior: a review and conceptual analysis. *Psychol. Bull.* 93:328–67

Roberts BW, Kuncel NR, Shiner R, Caspi A, Goldberg LR. 2007. The power of personality: the comparative validity of personality traits, socioeconomic status, and cognitive ability for predicting life outcomes. *Perspect. Psychol. Sci.* 2:313–45

Roberts BW, Mroczek D. 2008. Personality trait change in adulthood. *Curr. Dir. Psychol. Sci.* 17:31–35

Sabia S, Gueguen A, Marmot MG, Shipley MJ, Ankri J, Singh-Manoux A. 2010. Does cognition predict mortality in midlife? Results from the Whitehall II cohort study. *Neurobiol. Aging* 31:688–95

Salgado JF, Anderson N. 2002. Cognitive and GMA testing in the European Community: issues and evidence. *Hum. Perform.* 15:75–96

Salgado JF, Anderson N, Moscoso S, Bertua C, de Fruyt F. 2003. International validity generalization of GMA and cognitive abilities: a European Community meta-analysis. *Pers. Psychol.* 56:573–605

Salthouse TA. 1984. Effects of age and skill in typing. *J. Exp. Psychol. Gen.* 113:345–71

Salthouse TA. 1987. Age, experience, and compensation. In *Cognitive Functioning and Social Structures over the Life Course*, ed. C Schooler, KW Schaie, pp. 142–57. Norwood, NJ: Ablex

Salthouse TA. 1990. Cognitive competence and expertise in aging. In *Handbook of the Psychology of Aging*, ed. JE Birren, KW Schaie, pp. 310–19. Orlando, FL: Academic. 3rd ed.

Salthouse TA. 1994. Age-related differences in basic cognitive processes: implications for work. *Exp. Aging Res.* 20:249–55

Salthouse TA. 2006. Mental exercise and mental aging: evaluating the validity of the "use it or lose it" hypothesis. *Perspect. Psychol. Sci.* 1:68–87

Salthouse TA. 2009a. Decomposing age correlations on neuropsychological and cognitive variables. *J. Int. Neuropsychol. Soc.* 15:650–61

Salthouse TA. 2009b. When does age-related cognitive decline begin? *Neurobiol. Aging* 30:507–14

Salthouse TA. 2010. *Major Issues in Cognitive Aging*. New York: Oxford Univ. Press

Recent monograph summarizing some of the most replicated results concerned with aging and cognition.

Salthouse TA, Maurer. 1996. Aging, job performance and career development. In *Handbook of the Psychology of Aging*, ed. JE Birren, KW Schaie, pp. 353–64. San Francisco, CA: Academic

Schaie KW. 2005. *Developmental Influences on Adult Intelligence: The Seattle Longitudinal Study*. New York: Oxford Univ. Press

Schaie KW, Willis S. 1986. Practical intelligence in later adulthood. In *Practical Intelligence*, ed. RJ Sternberg, RK Wagner, pp. 236–68. New York: Cambridge Univ. Press
Schmidt FL, Hunter J. 1998. The validity and utility of selection methods in personnel psychology: practical and theoretical implications of 85 years of research findings. *Psychol. Bull.* 124:262–74
Schmidt FL, Hunter J. 2004. General mental ability in the world of work: occupational attainment and job performance. *J. Personal. Soc. Psychol.* 86:162–73
Schmidt FL, Hunter JE, Outerbridge AN. 1986. Impact of job experience and ability on job knowledge, work sample performance, and supervisory ratings of job performance. *J. Appl. Psychol.* 71:432–39
Schmidt FL, Hunter JE, Outerbridge AN, Goff S. 1988. Joint relation of experience and ability with job performance: test of three hypotheses. *J. Appl. Psychol.* 73:46–57
Schroeder DH, Salthouse TA. 2004. Age-related effects on cognition between 20 and 50 years of age. *Personal. Individ. Differ.* 36:393–404
Schulz R, Curnow C. 1988. Peak performance and age among superathletes: track and field, swimming, baseball, tennis, and golf. *J. Gerontol.* 43:113–20
Schulz R, Musaa D, Staszewski J, Siegler RS. 1994. The relationship between age and major league baseball performance: implications for development. *Psychol. Aging* 9:274–86
Shamosh NA, Gray JR. 2008. Delay discounting and intelligence: a meta-analysis. *Intelligence* 36:289–305
Shipley BA, Der G, Taylor MD, Deary IJ. 2005. Cognition and all-cause mortality across the entire adult age range: Health and Lifestyle Survey. *Psychosom. Med.* 68:17–24
Simonton DK. 1988. Presidential style: personality, biography, and performance. *J. Personal. Soc. Psychol.* 55:928–36
Simonton DK. 1997. Creative productivity: a predictive and explanatory model of career trajectories and landmarks. *Psychol. Rev.* 104:66–89

Theoretical analysis of age-achievement functions and discussion of the "constant probability of success" proposal.

Small BJ, Fratiglioni L, von Strauss E, Backman L. 2003. Terminal decline and cognitive performance in very old age: Does cause of death matter? *Psychol. Aging* 18:193–202
Srivastava S, John OP, Gosling SD, Potter J. 2003. Development of personality in early and middle adulthood: set like plaster or persistent change? *J. Personal. Soc. Psychol.* 84:1041–53
Stanovich KE. 2009. *What Intelligence Tests Miss: The Psychology of Rational Thought*. New Haven, CT: Yale Univ. Press
Stanovich KE, West RF. 2008. On the relative independence of thinking biases and cognitive ability. *J. Personal. Soc. Psychol.* 94:672–95
Stein CI. 1962. The G.A.T.B.: the effect of age on intersample variations. *Pers. Guid. J.* 60:779–85
Stephan PE, Levin SG. 1993. Age and the Nobel Prize revisited. *Scientometrics* 28:387–99
Sternberg RJ, Wagner RK, Williams WM, Horvath JA. 1995. Testing common sense. *Am. Psychol.* 50:912–27
Sternberg RJ, Hedlund J. 2002. Practical intelligence, *g*, and work psychology. *Hum. Perform.* 15:143–60
Stilley CS, Bender CM, Dunbar-Jacob J, Sereika S, Ryan CM. 2010. The impact of cognitive function on medication management: three studies. *Health Psychol.* 29:50–55
Stilley CS, Sereika S, Muldoon MF, Ryan CM, Dunbar-Jacob J. 2004. Psychological and cognitive function: predictors of adherence with cholesterol lowering treatment. *Ann. Behav. Med.* 27:117–24
Strenze T. 2007. Intelligence and economic success: a meta-analytic review of longitudinal research. *Intelligence* 35:401–26
Sturman MC. 2003. Searching for the inverted U-shaped relationship between time and performance: meta-analyses of the experience/performance, tenure/performance, and age/performance relationships. *J. Manage.* 29:609–40
Terracciano A, McCrae RR, Brant LJ, Costa PT. 2005. Hierarchical linear modeling analyses of the NEO-PI-R scales in the Baltimore Longitudinal Study of Aging. *Psychol. Aging* 20:493–506
Trites DK, Cobb BB. 1963. Problems in air traffic management IV: comparison of pre-employment, job-related experience, with aptitude tests as predictors of training and job performance as air traffic control specialists. *Fed. Aviat. Rep. 63-31*. Oklahoma City, OK: FAA Civil Aeromed. Inst.
Trites DK, Cobb BB. 1964. CARI research on air traffic control specialists: age, aptitude and experience as predictors of performance. *Fed. Aviat. Rep.* Oklahoma City, OK: FAA Civil Aeromed. Inst.
Verhaeghen P, Salthouse TA. 1997. Meta-analyses of age-cognition relations in adulthood: estimates of linear and nonlinear age effects and structural models. *Psychol. Bull.* 122:231–49

Von Stumm S, Macintrye S, Batty DG, Clark H, Deary IJ. 2010. Intelligence, social class of origin, childhood behavior disturbance and education as predictors of status attainment in midlife in men: the Aberdeen Children of the 1950s study. *Intelligence* 38:202–11

Wagner RK, Sternberg RJ. 1985. Practical intelligence in real-world pursuits: the role of tacit knowledge. *J. Personal. Soc. Psychol.* 49:436–58

Wagner RK, Sternberg RJ. 1990. Street smarts: In *Measures of Leadership*, ed. KE Clark, MB Clark, pp. 493–504. West Orange, NJ: Leadership Library Am.

Waldman DA, Avolio BJ. 1986. A meta-analysis of age differences in job performance. *J. Appl. Psychol.* 71:33–38

Walker NP, McConville PM, Hunter D, Deary IJ, Whalley LJ. 2002. Childhood mental ability and lifetime psychiatric contact: a 66-year follow-up study of the Scottish Mental Ability Survey. *Intelligence* 30:233–45

Warr P. 1994. Age and employment. In *Handbook of Industrial and Organizational Psychology*, vol. 4, ed. HC Triandis, MD Dunnette, LM Hough, pp. 485–550. Palo Alto, Consult. Psychol. Press

Warr P, Pennington J. 1994. Occupational age grading: jobs for older and younger non-managerial employees. *J. Vocat. Behav.* 45:328–46

Weatherbee SR, Allaire JC. 2008. Everyday cognition and mortality: performance differences and predictive utility of the everyday cognition battery. *Psychol. Aging* 23:216–21

Welford AT. 1958. *Aging and Human Skill*. London: Oxford Univ. Press

Whalley LJ, Deary IJ. 2001. Longitudinal cohort study of childhood IQ and survival up to age 76. *Br. Med. J.* 322:1–5

Wilk SL, Sackett PR. 1996. Longitudinal analysis of ability-job complexity fit and job change. *Pers. Psychol.* 49:937–67

Willis SL. 1991. Cognition and everyday competence. In *Annual Review of Gerontology and Geriatrics*, vol. 11, ed. KW Schaie, MP Lawton, pp. 80–109. New York: Springer

Willis SL. 1996. Everyday cognitive competence issues in elderly persons: conceptual issues and empirical findings. *Gerontologist* 36:595–601

Willis SL, Jay GM, Diehl M, Marsiske M. 1992. Longitudinal change and prediction of everyday task competence in the elderly. *Res. Aging* 14:68–91

Willis SL, Schaie KW. 1986. Practical intelligence in later adulthood. In *Practical Intelligence*, ed. RJ Sternberg, RK Wagner, pp. 236–68. New York: Cambridge Univ. Press

Wilson RS, Barnes LL, Mendes de Leon CF, Evans DA. 2009. Cognition and survival in a biracial urban population of old people. *Intelligence* 37:545–50

Wittmann WW, Hattrup K. 2004. The relationship between performance in dynamic systems and intelligence. *Syst. Res. Behav. Sci.* 21:393–409

Zagorsky JL. 2007. Do you have to be smart to be rich? The impact of IQ on wealth, income and financial distress. *Intelligence* 35:489–501

Zysberg L. 2009. An emerging new component of cognitive abilities in human resources selection: preliminary evidence to the existence of a "process-analytic" factor in selection batteries. *Int. J. Sel. Assess.* 17:69–75

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