What and When of Cognitive Aging

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Abstract

Adult age differences have been documented on a wide variety of cognitive variables, but the reasons for these differences are still poorly understood. In this article I describe several findings that will need to be incorporated into eventual explanations of the phenomenon of cognitive aging. These are that age-related declines in measures of cognitive functioning: (a) are relatively large; (b) begin in early adulthood; (c) are evident in several different types of cognitive abilities; and (d) are not always accompanied by increases in between-person variability.

What and When of Cognitive Aging

The phenomenon of cognitive aging has been noticed almost as long as the phenomenon of physical aging, but it is still not well understood. This is unfortunate because cognitive functioning can affect one's quality of life, and even the ability to live independently. Furthermore, cognitive functioning in early adulthood may be related to the development of pathologies such as Alzheimer's Disease in later adulthood.

One way to conceptualize understanding is that it is equivalent to knowing answers to the questions of what, when, why, where, and how. In the current article I summarize some of the progress that has been achieved in describing the phenomenon of cognitive aging in terms of the questions of what and when. Although not much is yet known about answers to the questions of why (what is ultimately responsible), where (in the nervous system), and how (via what mechanisms) age-related cognitive changes occur, a key assumption of my research is that answering these other questions will be easier as the characterization of what and when becomes more precise.

WHAT AND WHEN

It is often assumed that age-related effects on cognitive functioning are small, are limited to aspects of memory, begin relatively late in adulthood, and possibly only affect some people such that any age-related declines are accompanied by increases in between-person variability. However, recent research in my laboratory and elsewhere suggests that most of these assumptions are incorrect. Evidence relevant to these issues can be illustrated with data aggregated across several recent studies in my laboratory (Salthouse, 2001a; 2001b; Salthouse, Atkinson, & Berish, 2002; Salthouse & Ferrer-Caja, in press; Salthouse, Hambrick, & McGuthry, 1998; Salthouse, Toth, Daniels, Parks, Pak, Wolbrette, & Hocking, 2000). Participants in these studies were recruited from newspaper advertisements, appeals to community groups, and referrals from other participants. Nearly all of the participants reported themselves to be in good to excellent health, and they averaged approximately 16 years of education.

Four tests were common to most of these studies. A vocabulary test involved the examinee selecting the best synonym of target words from a set of five alternatives. A speed test required the participant to classify pairs of line patterns as the same or different as rapidly as possible. Reasoning was assessed with the Raven's Progressive Matrices, in which the test items consist of a matrix of geometric patterns with one missing cell, and the task for the participant is to select the best completion of the missing cell from a set of alternatives. Finally, a memory test involved three auditory presentations of the same list of unrelated words, with the participant instructed to recall

as many words as possible after each presentation. Data for the vocabulary, speed, and reasoning tests are based on 1,424 adults, and those for the memory test are based on 997 adults.

Because the variables are in different units, in order to allow the age trends on the variables to be directly compared all of the scores have been converted to z-scores (by subtracting each score from the mean and then dividing by the standard deviation). The means for the z-scores corresponding to the different variables are plotted as a function of age in Figure 1. The bars above and below each point are standard errors, which represent the precision of the estimate (i.e., the smaller the bars, the more precise the estimate). Six major points can be noted from the data in this figure.
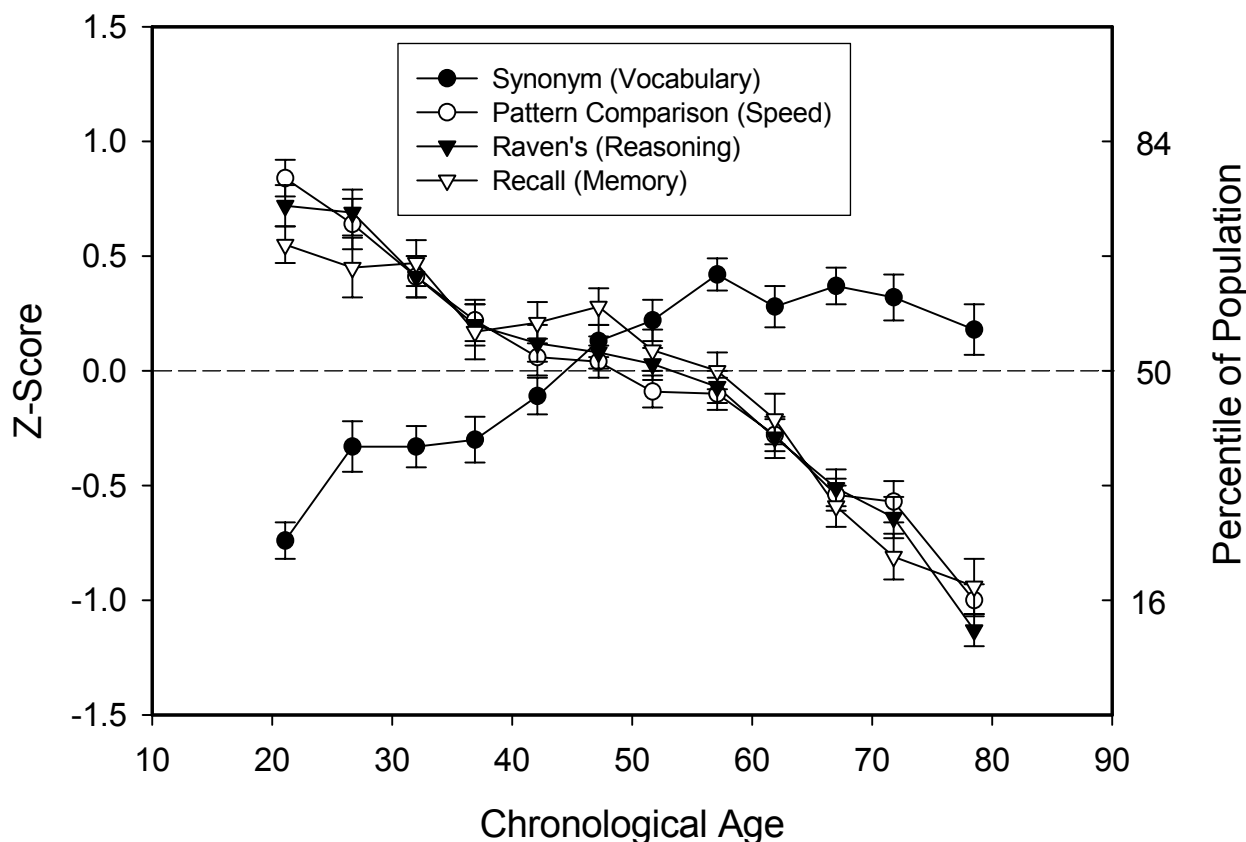

Figure 1 – Means (and standard errors) of performance in four cognitive tests as a function of age. Each data point is based on between 52 and 156 adults.

First, scores on the vocabulary test were higher with increased age until about the mid-50s, after which they either remained stable or declined slightly. Findings such as these have been interpreted as indicating that knowledge accumulates with increased age, but compelling explanations for the curvilinear nature of the age function are not yet available (Salthouse, in press).

Second, similar negative age trends are evident in the measures of speed, reasoning, and memory. Although not represented in the figure, the age correlations for the variables were also similar, as they were -.47, -.48, and -.43, respectively, for the speed, reasoning, and memory variables.

Third, the age-related effects on the speed, reasoning, and memory variables are fairly large. Not only are the age correlations greater than most correlations involving individual differences reported in the behavioral sciences, but the average performance for adults in their early 20s was near the 75th percentile in the population whereas the average for adults in their early 70s was near the 20th percentile.

Fourth, the relations between age and the speed, reasoning, and memory variables are primarily linear. This observation is relevant to potential interpretations of the effects because the absence of obvious discontinuities in the functions suggests that transitions such as retirement, or menopause for women, are probably not responsible for much, if any, of the effects.

Fifth, the data in the figure indicate that age-related effects are clearly apparent before age 50. For some variables there may be an acceleration of the influences at older ages, but age-related differences are evident in early adulthood for each variable.

And sixth, the age-related declines in these samples are not accompanied by increases in between-person variability.   One way to express the relation between age and between-person variability is in terms of the correlation between age and the between-person standard deviation for the individuals in each 5-year age group. For the data in Figure 1 these correlations were -.18 for vocabulary, -.80 for speed, -.74 for reasoning, and .13 for memory. If anything, therefore, the trend in these data is for increased age to be associated with a smaller range of scores. Instead of a pattern of increased variability that might be attributable to some people maintaining high levels of performance and others experiencing large declines, the nearly constant variability is more consistent with a downward shift of the entire distribution of scores with increased age.

Many of the results apparent in Figure 1 have been reported in a number of individual studies (see the earlier citations), and are also evident in data from nationally representative samples used to establish norms for standardized tests such as the WAIS III (Wechsler, 1997) and the Woodcock-Johnson III (Woodcock, McGrew & Mather, 2001). Results such as these suggest the following answers to the questions of what and when of cognitive aging. With respect to what, many different types of cognitive variables are affected by increased age, and with respect to when, age-related differences appear to begin in early adulthood, probably in the 20s.

WHY AREN'T THE EFFECTS MORE NOTICEABLE?
The research summarized above suggests that age-related cognitive declines are fairly broad, begin early in adulthood, and are cumulative across one's life. A question frequently raised when findings such as these are mentioned is why are there not greater negative consequences of the age-related cognitive declines? I suspect that there are at least four reasons.

First, cognitive ability is only one factor contributing to successful functioning in most activities. Other factors such as motivation, persistence, and various personality characteristics are also important, and they either may be unrelated to age, or may follow different age trajectories than measures of cognitive functioning.

Second, very few situations require individuals to perform at their maximum levels because humans tend to modify their environments to reduce the physical and cognitive demands. An analogy to physical ability and physical demands may be relevant here because there are well-documented age-related declines in strength, stamina, and speed, but these declines are seldom noticed in everyday life because of the relatively low physical requirements of most situations.

Third, many people may adapt to age-related changes by altering the nature and pattern of their activities. Examples of this type of adaptation are apparent in driving because as they grow older many adults make adjustments such as driving at different times and under different conditions, and possibly avoiding certain maneuvers such as left turns. Accommodations such as these do not eliminate the declines, but they may serve to minimize their detrimental consequences.

And fourth, the greater experience and knowledge associated with increased age probably reduces the need for the type of novel problem solving that declines with age. Continuous age-related increases in knowledge may not be apparent in standardized tests because the tests are designed to be applicable to the general population, and much of one's knowledge may be increasingly idiosyncratic as people pursue progressively more specialized vocational and avocational interests. Nevertheless, very high levels of performance might be apparent among older adults given the right combination of individuals and tasks. Research in my laboratory suggests that adults who regularly work crossword puzzles, and the task of solving crossword puzzles, may represent one such combination. In four recent studies, adults recruited because of their crossword puzzle experience were asked to perform a number of activities, including spending 15 minutes attempting to solve a

crossword puzzle taken from the New York Times. As can be seen in Figure 2, the highest average level of crossword performance in every sample was achieved by adults in their 60s and 70s.
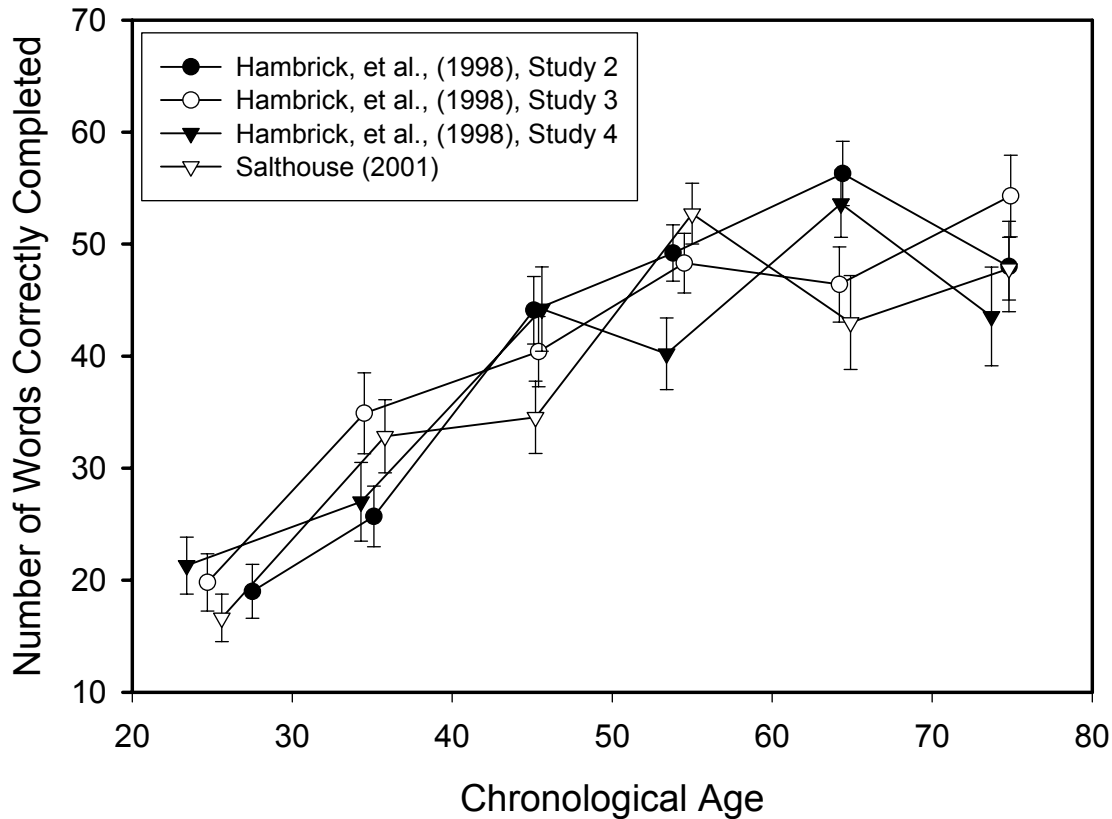

Figure 2 – Means (and standard errors) for the number of words in a New York Times crossword puzzle correctly answered in 15 minutes as a function of age. Between 195 and 218 adults participated in each study. The crossword puzzles required either 76 or 78 words for their solutions.

It could be argued that successful performance in crossword puzzle solving is primarily dependent on accumulated knowledge rather than on novel problem solving or abstract reasoning. This may be the case, but I suspect that the same is also true in many real-world activities. That is, much of what we typically do may be more dependent on successful access and retrieval of what we already know, instead of on our ability to solve novel problems or reason with unfamiliar material.

INVESTIGATING THE WHY, WHERE, AND HOW OF COGNITIVE AGING
Although the phenomenon of cognitive aging is fairly well documented in terms of the questions of what and when, there is much less consensus with respect to the answers to, or even the best methods of investigating, the questions of the why, where, and how of cognitive aging. In fact, it can be argued that much of the current theoretical debate in the field of cognitive aging is not focused on distinguishing among alternative explanations, but rather is concerned with which approach is likely to be most productive in investigating causes of age-related differences in cognitive functioning. Several of the major issues can be described in terms of the following dichotomies, although it should be recognized that these are simplifications, and that this list is by no means exhaustive.
    Micro vs. Macro   One theoretical issue is whether the primary focus should be on determining which specific aspects (e.g., theoretical processes or components) are most (or least) affected by aging, or whether several variables should be examined simultaneously to determine the extent to which the age-related effects on a particular variable are unique to that variable or are shared with other variables. Advocates of the former, micro, perspective point out that most

cognitive tasks can be assumed to involve multiple processes, and thus an overall measure of performance in a task is likely to represent an unknown mixture of theoretically distinct processes that may be difficult to interpret. Advocates of the latter, macro, perspective emphasize that a large number of cognitive variables have been found to be related to age, and that analyses have revealed that age-related influences on different types of cognitive variables are not statistically independent of one another. Researchers favoring the macro perspective have therefore argued that the age-related effects on particular cognitive tasks may be symptoms of a broader phenomenon, and consequently that it may not be very meaningful to attempt to provide a distinct explanation for the age differences in each variable.

Proximal vs. Distal A second theoretical issue is whether researchers should concentrate on specifying characteristics (such as strategy, efficiency of specific hypothesized processes, adherence to particular sets of beliefs, etc.) associated with the performance of adults of different ages at the time of assessment, or whether they should try to identify factors occurring earlier in life that may have contributed to any differences observed at the current time. The key question in this connection is whether it is more important to specify precisely how the performance of people of different ages differs at the current time, or to investigate the role of earlier life experiences in producing those differences.

Moderation vs. Manipulation A third issue relevant to the investigation of causes of cognitive aging phenomena is whether the focus should be on determining if people who share particular characteristics differ from people without these characteristics with respect to the age-related trends on various cognitive variables, or on attempting to alter the current level of performance by some type of intervention. Researchers on both sides of this issue acknowledge that true experiments are not possible in developmental research because the critical variable of age cannot be randomly assigned, but they differ in terms of which of two approximations is considered most desirable. Some tend to focus on identifying moderators by comparing pre-existing groups with respect to their age trends on target variables, whereas others prefer to investigate manipulations that might alter the relation between age and the level of performance on a particular variable.

Difference vs. Change One of the perennial issues in developmental research is whether the results of cross-sectional comparisons can be considered informative about age-related changes, or whether all inferences about aging must be based on directly observed longitudinal changes. There is little dispute that at the level of an individual, aging is manifested in terms of changes occurring in the person as he or she grows older. There is also considerable agreement that there are several possible influences on longitudinal changes, including endogenous maturational influences, effects related to practice or learning, and effects associated with changes in the society or culture in which the individual lives. However, there is much less consensus about the best method of distinguishing among these influences. On one hand, researchers favoring cross-sectional methods feel that it is plausible to assume that people of different ages and observed at the same point in time were similar in most important respects when they were at the same age, such that it is reasonable to make inferences about maturational changes on the basis of cross-sectional differences. On the other hand, researchers favoring longitudinal methods frequently assume that the maturational component of change can be distinguished from other components of change, such as practice effects and secular change effects, either because the latter are small relative to maturational effects, or because they can be separated by statistical or other means.

It is probably healthy for a field to pursue different approaches to explanation when the level of understanding is relatively limited. However, it is probably also the case that agreement on answers to the why, where, and how of cognitive aging will not be reached until there is some integration of the different theoretical perspectives on the best methods of addressing those questions.

CONCLUSION

To summarize, recent research in my laboratory and elsewhere has provided considerable information about the what and when of cognitive aging. We are also beginning to learn about the implications of this phenomenon for functioning outside of the research laboratory, but, perhaps

because of different perspectives on the best methods of investigation, much less is currently known about the why, where, and how of this phenomenon.

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