Memory Aging from 18 to 80

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Summary

Data from samples of adults selected to be representative of the U.S. population were examined to investigate issues related to the breadth and timing of age-related effects on memory and other cognitive functions. The results suggest that memory aging begins in early adulthood, that it overlaps with other aspects of cognitive aging, and that it can occur without accompanying increases in between-person variability. These findings imply that it is important to consider factors occurring early in life when attempting to understand the causes of memory and cognitive impairments apparent late in life.

My goal in this article is to summarize evidence for six assertions about aging and memory. The assertions are: (1) age-related differences are evident on many different types of memory variables; (2) these differences can occur in the absence of age-related increases in between-person variability; (3) the differences are apparent as early as the decade of the 20s in adults who report themselves to be in good health; (4) the age-related differences on different types of memory variables are not independent of one another; (5) similar age-related differences are evident on variables reflecting other types of cognitive abilities; and (6) the age-related effects on memory variables are not independent of age-related effects on variables reflecting other types of cognitive functioning. These assertions are potentially important because to the extent that they are valid, they are likely to have important implications for how late-life cognitive pathologies such as Alzheimer's Disease should be viewed relative to normal aging.

Much of the evidence I present will be in the form of figures because most of the data has been obtained from published sources. Furthermore, all of the evidence for the assertions is based on cross-sectional rather than longitudinal comparisons.   Although it is conceivable that a different pattern of results might be obtained with longitudinal research, relevant data are lacking. That is, there are apparently not yet any reports of longitudinal comparisons in which a broad variety of variables has been examined in moderately large samples of adults who were initially tested in early adulthood and then were followed for intervals of 30 or more years.

The best data to examine many of the issues are those from the samples used to establish norms in standardized tests because the samples are relatively large, and the individuals were selected to be representative of the U.S. population. Because the variables are typically reported in different units, to facilitate across-variable comparisons they have all been converted to standard deviations of a reference distribution comprised of adults between 20 and 34 years of age.

Evidence for the first assertion is presented in Figure 1 which is based on data from the normative sample for the Wechsler Memory Scale III (WMS III)[1]. This figure portrays the age relations for measures of immediate and delayed memory for stories, for arbitrary pairs of words, for faces, and for lists of unrelated words. Notice that a similar pattern is apparent with each type of memory variable. That is, in every case the average performance at age 80 is approximately 1 to 1.5 standard deviations below the mean of the reference group of young adults. There are obviously many more ways in which memory could be assessed, and measures of semantic memory or cumulative knowledge tend to increase rather than decrease with age. However, the results in Figure 1 clearly indicate that the memory aging phenomenon is not restricted to measures of only a few types of memory.

The between-person variance in the scores is also of interest because this type of information is relevant to whether the memory aging phenomenon should be viewed as a reflection of normal development, or as an indication of pathology. This point was recently articulated by Small[2] in his suggestion that "If memory decline is a normal occurrence with age, distribution curves of memory scores in old and young age groups should have similar variance, with a leftward shift in the mean for the older age group. However, if memory decline is not normal, the distribution curve should have increased variance, and might show bimodality, compared with the young age group (p. 361)."

Data relevant to this issue are portrayed in Figure 2, which contains means (in the top panel) and standard deviations (in the bottom panel) as a function of age for measures of immediate and delayed verbal and visual memory from the standardization sample in the WMS III. The data in the top panel indicate that increased age was associated with lower mean levels of performance in each of the variables, but the data

in the bottom panel reveal that there was little consistent age trend in the magnitude of between-person variability.

A very similar pattern is apparent in Figure 3 which contains the same type of information based on data from different standardization samples and different memory tests, namely, the Rey Complex Figure Test[3] and the Rey Auditory and Verbal Learning Test[4]. As in Figure 2, these results indicate that, with the possible exception of the Rey Figure Copy variable, there is an age-related decline in mean levels of performance without a systematic increase in between-person variability.

The results in Figures 2 and 3 support my second assertion that age-related declines in memory between 18 and 80 years of age are not necessarily accompanied by an increase in between-person variability. The absence of substantial age-related increases in variability suggests that the declines are not attributable to some individuals experiencing large declines and others maintaining the same level of performance. Instead, following the argument of Small[2], the pattern of nearly constant variability is consistent with a downward shift in the entire distribution that might be indicative of a normal aging phenomenon.

Although the results in Figures 2 and 3 seem clear, it is important to be explicit about exactly how they should be interpreted. That is, even though the samples used to establish the norms were selected to be representative of the U.S. population, they almost certainly did not include many individuals in very poor health, and it is likely that between-person variability would have increased with age had it been possible to sample from the entire population at each age. However, the important point in the current context is that age-related memory declines can occur even in the absence of increases in between-person variability.

My third assertion concerns when memory aging effects are first apparent. The figures portraying the age trends from standardized tests suggest that some effects may begin early, but the estimates of the age relations in those data sets are not very precise because each age was represented by relatively few individuals. Fortunately several data sets have included large numbers of individuals under the age of 50, and they can be used to evaluate the magnitude of any age differences in memory occurring during the period of early adulthood. One set of data that is particularly valuable set of data for this purpose because it includes information from over 5000 healthy adults between 18 and 50 years of age was collected by David Schroeder and colleagues at the Johnson O'Connor Research Foundation[5]. Furthermore, because these data were collected in a vocational guidance center in which either the individuals or their employers paid for the assessment, the participants can be presumed to be highly motivated.

The Johnson O'Connor test battery included two measures of memory, immediate reproduction of line patterns (Designs), and immediate recall of a series of eight visually-presented 6-digit numbers (Numbers). Performance in these two tests as a function of age is portrayed in Figure 4. Notice that in both variables a negative relation between performance and age is apparent even among adults in their 20s. Age-related effects may accelerate and become even more pronounced at older ages, but these data indicate that age-related declines are clearly evident well before the age of 50.

My fourth assertion is that the age-related effects on different memory variables are not independent of one another. Because it is unlikely that the age-related effects on different variables could be completely independent if the variables are at least moderately correlated with one another, one type of evidence relevant to the independence of age-related influences on different memory variables simply consists of the magnitude of correlations among variables. A large body of research has found that when they are assessed reliably, most memory variables have moderate to large

correlations with one another. As just one example, in the standardization sample of 1250 adults for the WMS III, the correlation of the auditory immediate memory variable and the visual immediate memory variable was .42.

More direct evidence concerning the independence of age-related influences on different memory variables can be obtained by statistically controlling the variance in one variable when examining age-related effects on another variable. The rationale is that if the age-related influences on two variables are independent of one another, then statistical control of the variance in one variable should have little or no effect on the magnitude of the age relations on the other variable. However, if the age-related effects on one variable are substantially reduced when the variance in another variable is controlled, then one can infer that the age-related effects on the two variables are not independent of one another.

Typical results from this type of statistical control procedure can be illustrated with data from a recent study in my laboratory involving 204 healthy adults between 18 and 94 years of age[6]. Each individual performed a multiple trial free recall task, a logical memory task, and a paired associates task. Results of the statistical control analyses are summarized in Figure 5. The first bar represents the age-related variance (i.e., the square of the correlation with age) in the free recall variable (i.e., number of words correctly recalled across four trials of the same list of 12 words), the second bar represents age-related variance in the free recall variable after control of the variance in a logical memory variable (i.e., sum of idea units recalled from three stories in the WMS III), and the third bar represents the age-related variance in the free recall variable after control of the variance in a paired associates variable (i.e., average number of response terms reported correctly across two trials of six pairs of unrelated words). Because the unfilled bars are much smaller than the filled bar it can be inferred that the age-related effects on these variables are not independent of one another. Furthermore, an estimate of the degree of dependence, or overlap, in the age-related influences can be obtained from the proportional reduction in the age-related variance, which is approximately 51% for the logical memory variable and 78% for the paired associate variable.

My fifth assertion is that other cognitive abilities are also related to age in the range between 18 and 80 years of age. Evidence for this assertion is presented in Figure 6 which depicts the age trends in several variables from the Wechsler Adult Intelligence Scale III (WAIS III)[7]. Notice that there are similar age relations for four variables often assumed to represent different cognitive abilities, namely, working memory (Letter-Number Sequencing), perceptual speed (Digit Symbol Substitution), spatial visualization (Block Design), and inductive reasoning (Matrix Reasoning).   In each case the mean performance at age 50 is approximately 0.5 standard deviations below the reference group mean, and by age 80 the mean performance is about 1 to 2 standard deviations below the mean of the reference group.

My sixth assertion is that the age-related effects on these other types of cognitive variables are not independent of the age-related effects on memory variables. As with the fourth assertion, two types of data are relevant to this assertion. First, correlations between memory variables and other types of cognitive variables can be examined, and in the normative samples for the WMS III and WAIS III most of these correlations are in the moderate to large range. For example, the correlation between the WAIS full-scale IQ and the auditory immediate memory variable was .59, and the correlation between the WAIS full-scale IQ and the visual immediate memory variable was .36. It is worth noting that these correlations are approximately the same magnitude as the correlation of the latter two variables with one another (i.e., .42).

The second more direct type of evidence relevant to the independence of age-related influences comes from statistical control analyses. The same study described earlier[6] can be used to illustrate typical results because the participants performed several cognitive tasks in addition to the memory tasks.   Figure 7 summarizes the percentage of age-related variance in the free recall variable before and after statistical control of the variance in two cognitive variables, Block Design and Digit Symbol Substitution. The estimated proportion of shared age-related variance was 45% with the Block Design variable, and 87% with the Digit Symbol variable. These results not only indicate that the age-related effects on memory and cognitive variables are not independent of one another, but that there is nearly as much overlap between the free recall variable and the Block Design and Digit Symbol variables as that found when the variance in other memory variables was controlled.

Implications of the Assertions

Although each of the preceding assertions could be challenged, the available evidence suggests that they all have at least some plausibility. It is therefore useful to consider some of the possible implications of these claims.

The first assertion was that memory aging is evident in several different types of memory variables, and hence that age-related effects are not restricted to a particular type of memory. One possible implication of this assertion is that the phenomenon of memory aging is unlikely to be attributable to non-optimal strategies or to inefficient processes that are specific to particular types of tasks. Another potential implication is that to the extent that the memory aging phenomenon is relatively general, interventions designed to improve memory either must have broad consequences, or must include multiple aspects to target different types of memory.

The second assertion was that, at least in the samples used to establish the norms for recent standardized tests, there is a similar degree of variability at all ages, and thus age-related declines in memory are not necessarily associated with increased variability. As mentioned earlier, this pattern seems to imply that, at least in the periods of early and middle adulthood, the memory aging phenomenon is associated with a shift of the entire distribution, and is not simply attributable to a small proportion of individuals experiencing large declines with the remainder maintaining the same level of performance.

The third assertion was that the phenomenon of memory aging begins in the 20s among adults who report themselves to be in good health. An obvious implication of this assertion is that it is important to consider factors operating early in life to understand the cause of many late-life effects because some of them may simply be continuations of effects that start at much younger ages.

The fourth assertion was that age-related effects on different types of memory variables are not independent of one another. That is, it does not appear that there are completely distinct and independent age-related influences on tasks with verbal or visual material, on tasks with unrelated words or meaningful stories, or on immediate or delayed tests. Instead at least some of the influences of aging appear to be on what is common to several different types of variables. (Note that it is not being claimed that there are no variable-specific or task-specific age-related effects, but rather than there are also some age-related effects that are shared across different types of variables.) The primary implication of this assertion is theoretical in nature. That is, to the extent that some of the age-related influences are shared across different types of memory variables, explanations of the memory aging phenomenon will need to incorporate mechanisms that can account for relatively broad effects.

The fifth and sixth assertions were that age-related effects are also apparent on other types of cognitive variables, and that those effects are not independent of the age-

related effects on measures of episodic memory. These results imply that memory aging occurs in a broader context of cognitive aging, and that there appear to be some common determinants of the age-related effects on memory and cognitive variables. Comprehensive explanations of memory aging will therefore need to account for influences of aging on a variety of cognitive variables, and not just variables representing memory aging.

To summarize, I have described several findings that I suggest should be considered when interpreting late-life memory aging in both normal and pathological populations. Several of these assertions may be inconsistent with commonly held assumptions, and thus they should be investigated in future research. However, even if some of the assertions will eventually need to be qualified, researchers would be well-advised to consider how to investigate possible relations between the timing or rate of decline in early adulthood and the memory and cognitive impairments that occur late in life.

References

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[6]Salthouse TA, Berish DE, Miles JD. The role of cognitive stimulation on the relations between age and cognitive functioning. *Psychology and Aging*, 2002, 17, 548-557.

[7]Wechsler D. Wechsler Adult Intelligence Scale – Third Edition (WAIS III): Administration and Scoring Manual. San Antonio, TX: The Psychological Corporation; 1997.

Figure Captions

Figure 1 – Mean performance in eight memory variables as a function of age. Data from Table D.1 in Wechsler[1].

Figure 2 – Means (top panel) and standard deviations (bottom panel) in eight memory variables as a function of age. Data from Table D.1 in Wechsler[1].

Figure 3 – Means (top panel) and standard deviations (bottom panel) in variables from the Rey Auditory Verbal Learning Test and the Rey Complex Figure Test as a function of age. Data from Table 5 in Schmidt[4] and Table 2 in Meyers and Meyers[3].

Figure 4 – Means and standard errors at each age on two memory tests. Data from Schroeder & Salthouse[5].

Figure 5 – Proportion of age-related variance in a free recall memory variable before and after statistical control of the variance in other memory variables. Data from Salthouse, Berish and Miles[6].

Figure 6 – Mean performance in four cognitive variables as a function of age. Data from Table A.1 in Wechsler[7].

Figure 7 - Proportion of age-related variance in a free recall memory variable before and after statistical control of the variance in other cognitive variables. Data from Salthouse, Berish and Miles[6].
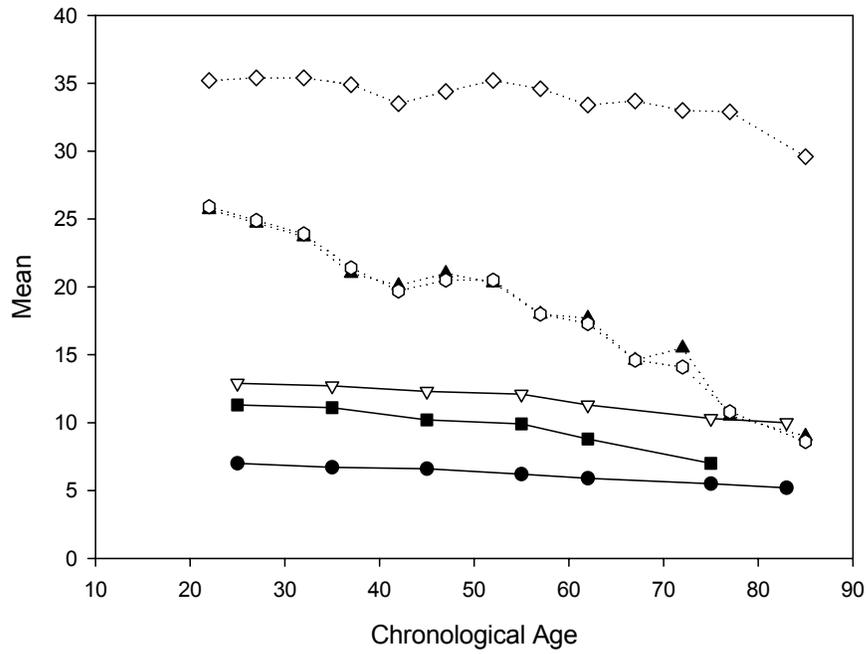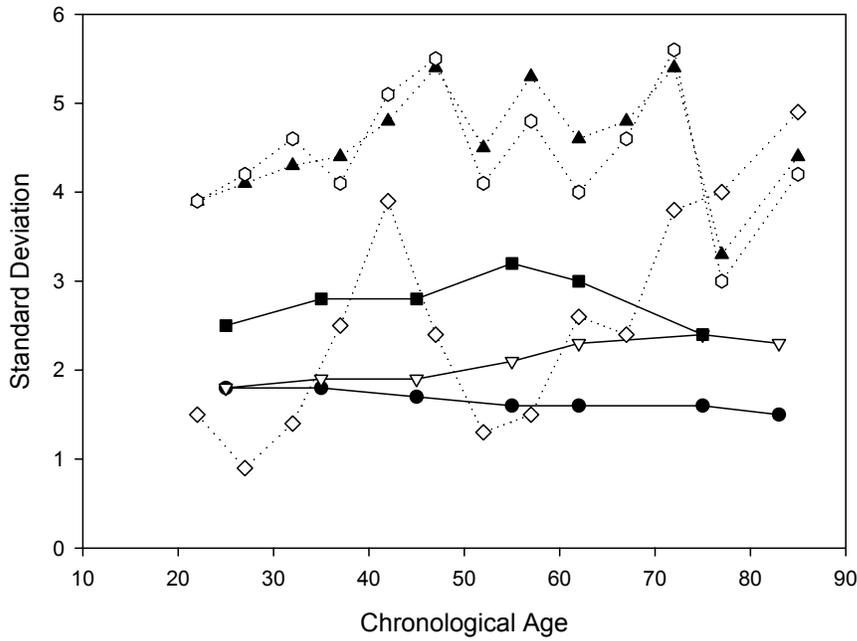
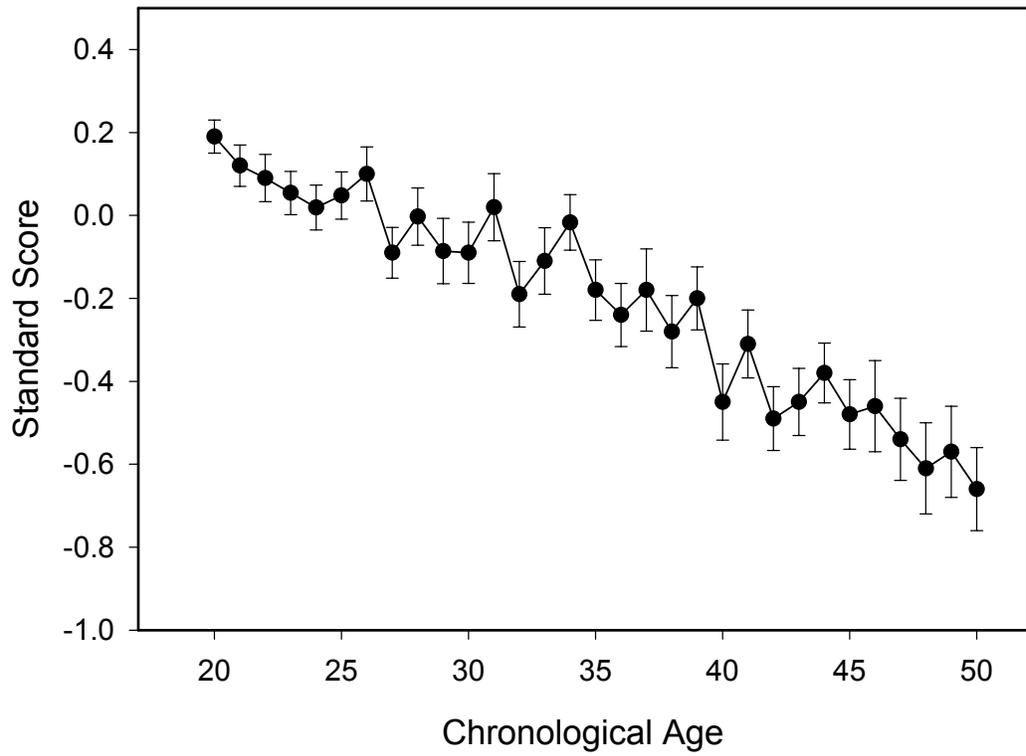Wechsler Memory Scale III (N = 1,250)
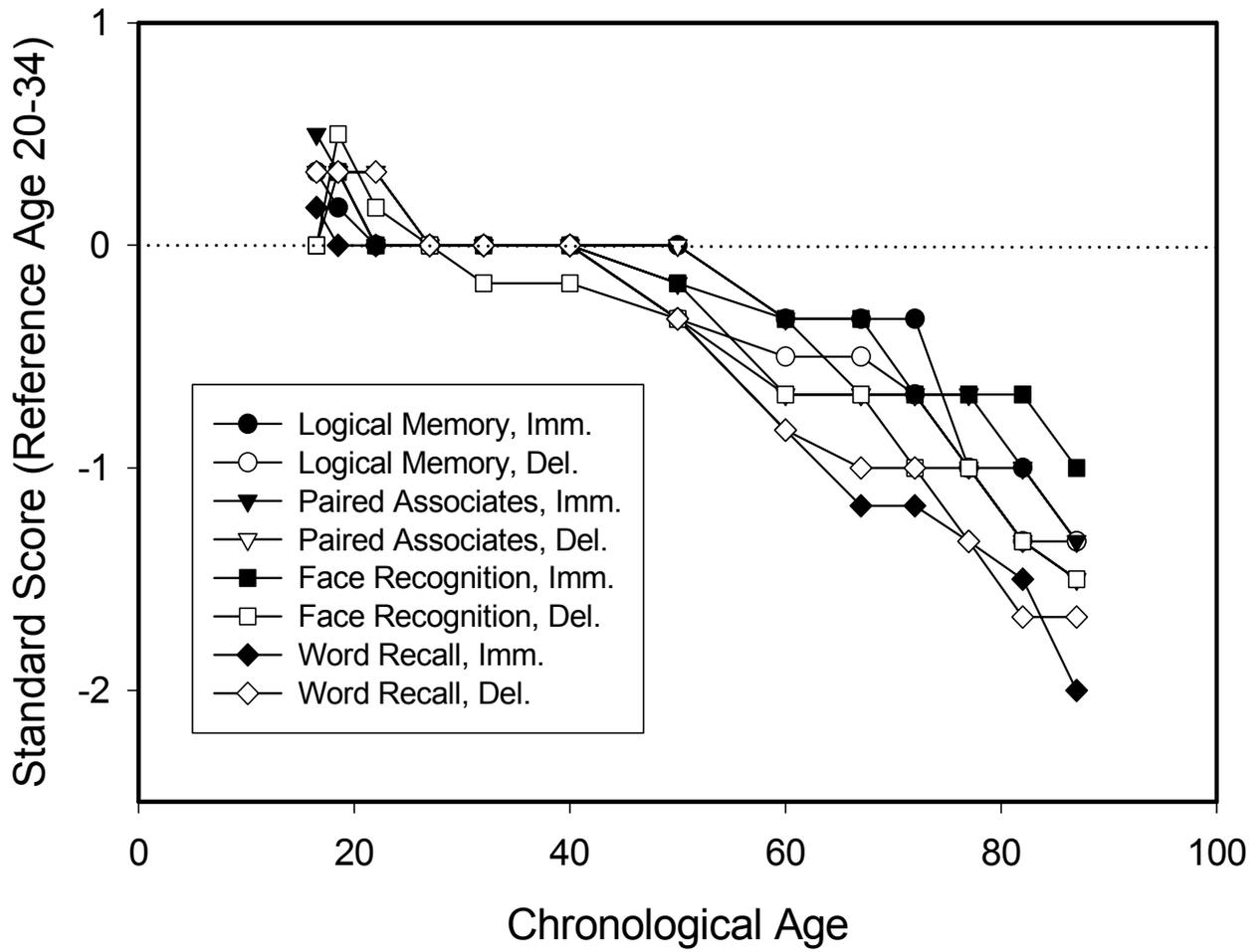
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(N=1250)
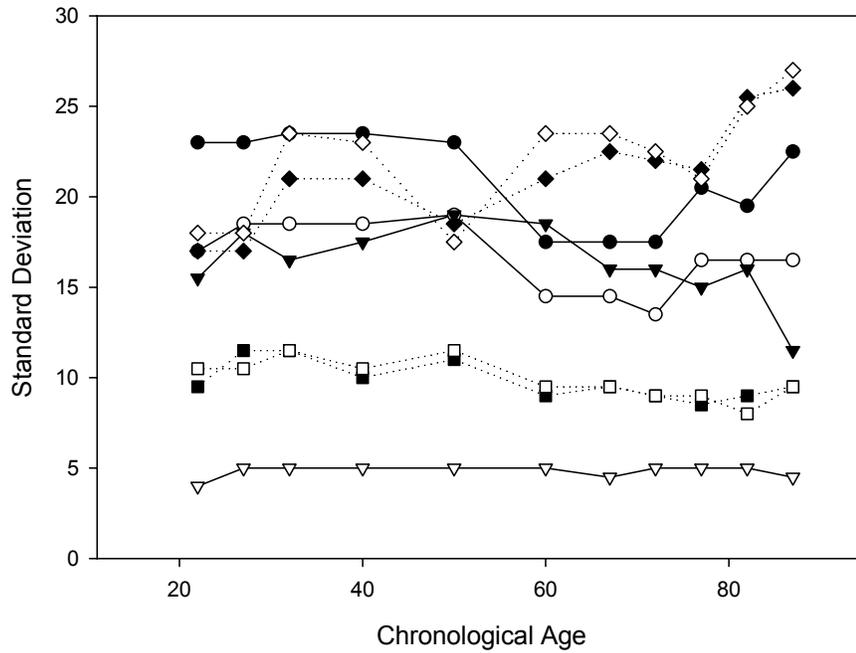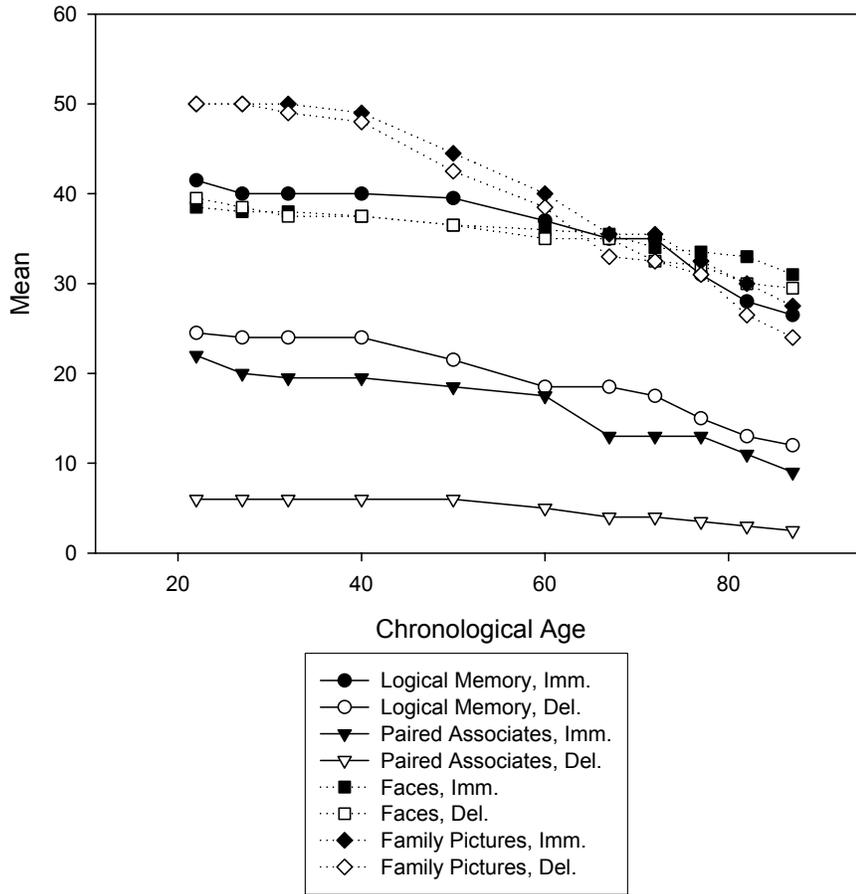
Rey AVLT & Rey Complex Figure Test
(N = 1,989 & N = 513)

Memory for Designs

Number Memory

WAIS III (N=2,450)