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Groups Versus Individuals as the Comparison Unit in Cognitive Aging Research

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A database containing speed and memory data from 362 adults ranging from 20 to 79 years of age was analyzed (a) to determine the nature of the normative cross-sectional age trends for each variable and (b) to estimate the sensitivity of within-individual comparisons for detection of age differences. The cross-sectional results revealed largely monotonic, linear declines for each variable, a trend evident in each quartile of the sample of individuals from each decade. Because the consistency of scores from the same individual within the same measurement occasion was rather low, it was inferred that it may prove very difficult to detect the effects of aging within individual adults.

The typical comparison in studies of psychological aging involves a cross-sectional contrast of groups of adults of different ages assessed at the same point in time. There is still considerable controversy concerning the decade when aging effects first occur, whether the age functions are linear, and whether similar functions characterize all segments of the population, but there are many reports of statistically significant age differences in measures of cognitive functioning based on cross-sectional group comparisons (for reviews, see Kausler, 1982; Salthouse, 1982). Many fewer studies have been conducted in which aging effects have been investigated longitudinally, and there are apparently no studies in which age-related effects in cognitive functioning have been documented within a given individual.

It is not surprising that attempts to investigate aging effects within specific

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individuals are rare because within-individual investigations are considerably more difficult than between-group investigations. One source of difficulty is that the necessary longitudinal assessments are more time-consuming and expensive than cross-sectional measurements. Another more subtle problem is that in order to be confident that the differences observed across time periods are reliable they must be evaluated against the differences occurring within a given time period. However, this latter information is seldom available because there is typically only a single estimate of performance obtained from a given individual at a particular measurement occasion.

In the current article we report data relevant to both group and individual comparisons of aging effects. The study from which the data were obtained was cross-sectional rather than longitudinal, but because every research participant performed each task twice it was possible to obtain an index of within-subject variability at the same measurement occasion. The distribution of these variability indices across participants was then used to estimate the sensitivity of detecting an across-time (or across-age) difference of a given magnitude.

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METHOD

Participants

A total of 362 adults (196 females, 166 males) 20 to 79 years old participated in a single experimental session of approximately 2 hr. Although age was negatively correlated with years of formal education ($r = -.22$), 75% of the participants had at least 12 years of education. The correlation between age and self-reported health was only +.03, and 95% of the participants reported themselves to be in at least average health. Further characteristics of the samples are reported in Salthouse, Kausler, and Saults (1986).

Procedure

The data to be reported were derived from five tasks, each administered on a microcomputer. The Digit Symbol task consisted of the participant classifying digit-symbol pairs as correct or incorrect according to a displayed code table as accurately and rapidly as possible. The median number of seconds per pair served as the primary performance measure in this task. In the Number Comparison task, participants compared two strings of numbers as rapidly and accurately as possible, and indicated their decision by pressing one of two keys on the keyboard. Median time per problem again served as the principle index of performance. In the Verbal Memory and Spatial Memory tasks, participants viewed a matrix of 25 letters, with 7 highlighted as targets

by inverse coloring, and attempted to remember either the identities (Verbal) or the locations (Spatial) of the target items. The mean number of items correctly recalled across four trials with each type of informational instruction served as the measure of performance in each task. Two trials of a Paired Associates task involving eight pairs of unrelated words were also administered to each participant, with the percentage of correctly associated words on each test trial serving as the measure of performance. (See Salthouse, Kausler, & Saults, 1986, for further description of the tasks and additional measures of performance.)

Each task was administered to each participant twice, with the second administration of a given task occurring only after all tasks had been presented at least once.

RESULTS AND DISCUSSION

Group Differences

The initial step in the analysis of age group differences consisted of computing the average of the scores for each individual from the two administrations of each task to serve as the primary measure of performance in that task. Table 1 indicates that the age trends were quite comparable with the composite and single-administration scores, and that the two scores had moderate to high correlations with one another even after partialing out the effects of age.

Figures 1 through 6 illustrate, for each variable, the performance associated with the 25th, 50th (median), and 75th percentiles of the distributions of

TABLE 1
Age Correlations for the Six Performance Measures

Performance Measure	*Correlation*				
	Age–Mean	*Age–Measure 1*	*Age–Measure 2*	*Measure 1–Measure 2*	*Measure 1–Measure 2, Partialing Age*
Digit Symbol	.55	.51	.56	.92	.89
Number Comparison	.36	.32	.38	.86	.84
Verbal Memory	−.38	−.31	−.38	.63	.59
Spatial Memory	−.43	−.42	−.33	.50	.42
Paired Associates Trial 1	−.30	−.23	−.29	.54	.51
Paired Associates Trial 2	−.38	−.35	−.34	.68	.63

Note. All correlations significant at $p < .01$.

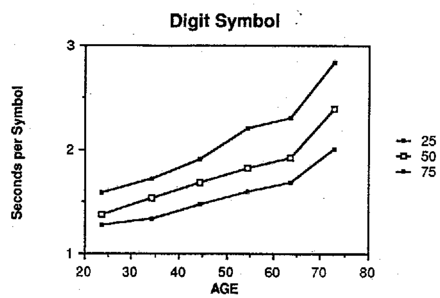

FIGURE 1 Digit Symbol performance as a function of age for the 25th, 50th, and 75th percentiles of the sample distribution at each decade.

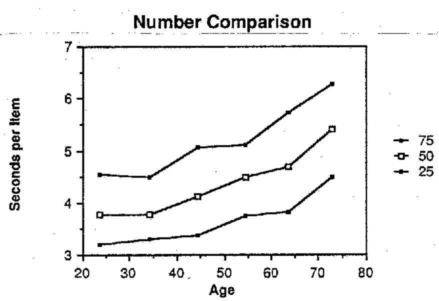

FIGURE 2 Number Comparison performance as a function of age for the 25th, 50th, and 75th percentiles of the sample distribution at each decade.

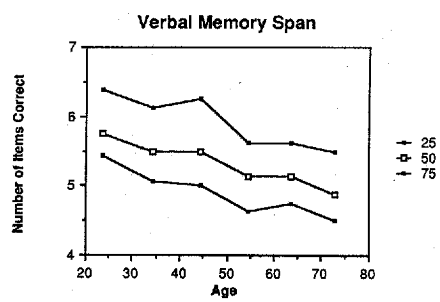

FIGURE 3 Verbal Memory performance as a function of age for the 25th, 50th, and 75th percentiles of the sample distribution at each decade.

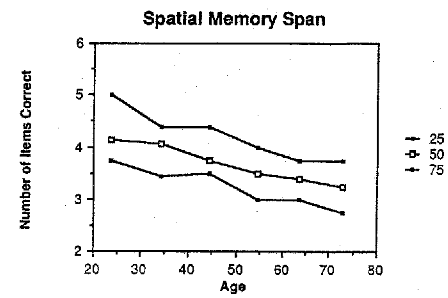

FIGURE 4 Spatial Memory performance as a function of age for the 25th, 50th, and 75th percentiles of the sample distribution at each decade.

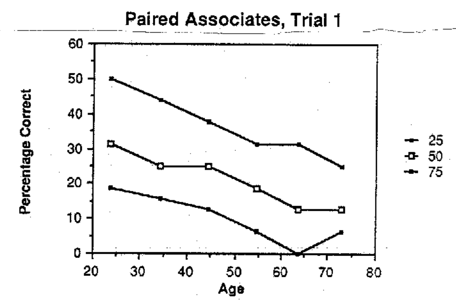

FIGURE 5 Paired Associate Trial 1 performance as a function of age for the 25th, 50th, and 75th percentiles of the sample distribution at each decade.

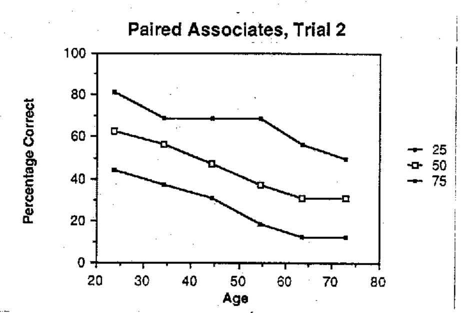

FIGURE 6 Paired Associate Trial 2 performance as a function of age for the 25th, 50th, and 75th percentiles of the sample distribution at each decade.

individuals in each decade. The number of adults in each decade grouping ranged from 54 (for the decade of the 70s) to 65 (for the decade of the 50s), and the percentage of females in each group ranged from 51 (for the decade of the 60s) to 57 (for the decade of the 30s).

Two aspects of the data in Figures 1 through 6 are worthy of comment—the linear nature of the age trends, and the parallel functions across the different quartiles of the distributions. Every dependent variable has a very pronounced linear trend between age and performance, and for many measures this trend is apparent as early as from the 20s to the 30s. These findings suggest that the aging effects on these variables are continuous and gradual, and not sudden and precipitous as might be expected if they were due to a discrete event such as late-life disease or retirement-associated disengagement.

The second interesting feature of Figures 1 through 6 is that the same general trends are evident in the lower and higher quartiles of the distribution as in the middle of the distribution. These data thus indicate that very similar age-related trends are apparent in individuals from different portions of the sample distribution and are not simply characteristic of adults from the bottom or middle of the distribution.

One of the simplest ways of summarizing the effects portrayed in Figures 1 through 6 involves reporting the parameters of the linear regression equations relating age to performance. These parameters are displayed in Table 2, where it can be seen that the linear trends were statistically significant with each variable. The data in Table 2 also reveal that comparable trends were evident for both males and females because the regression parameters for the two groups were quite similar.

Individual Differences

Because each individual contributed two scores for each task, the difference between the two scores can serve as an estimate of same-session consistency in that it indicates the dispersion of measures within the same individual in a single session. (All the correlations between age and this difference score were quite small, $r < .13$, suggesting that within-session consistency was relatively unaffected by age.)

There are two ways in which these difference scores can be used to evaluate the sensitivity of within-individual analyses of aging effects. One procedure involves determining the percentage of individuals for whom the observed difference between the two scores is greater than the difference predicted, from the slopes of the regression equations from the cross-sectional analyses, to occur over an interval of 10 years. This is an arbitrary interval, but to the extent that a large percentage of individuals exhibit a difference this large or greater within a single session, it will obviously prove difficult to detect within-individual aging effects over intervals of this magnitude.

TABLE 2
Linear Regression Parameters for the Six Mean Performance Measures

Measure	r^2	*Intercept*	*Slope*
Digit Symbol			
All	.297*	0.95	0.019
Males	.340*	0.84	0.021
Females	.260*	1.05	0.017
Number Comparison			
All	.128*	3.15	0.029
Males	.241*	2.96	0.037
Females	.069*	3.31	0.022
Verbal Memory			
All	.149*	6.26	−0.019
Males	.174*	6.35	−0.020
Females	.129*	6.17	−0.018
Spatial Memory			
All	.181*	4.74	−0.020
Males	.212*	4.94	−0.022
Females	.161*	4.56	−0.019
Paired Associates Trial 1			
All	.088*	43.27	−0.370
Males	.112*	44.32	−0.417
Females	.071*	42.42	−0.332
Paired Associates Trial 2			
All	.145*	76.19	−0.613
Males	.163*	74.69	−0.664
Females	.134*	76.78	−0.574

*$p < .01$.

A second means of evaluating the sensitivity of within-individual aging effects consists of computing the number of years needed to achieve an expected across-time difference that is greater than the observed within-session differences of 95% of the individuals. That is, the across-individuals distribution of same-session differences can be examined to determine the value exceeded by less than 5% of the individuals, and then this value can be divided by the regression slope to determine the number of years, at the predicted change per year, needed to achieve this magnitude of difference.

Summary results of these analyses are displayed in Table 3. Both analyses suggest that the prospects of detecting aging effects within a given individual are very slight. A large majority of the individuals exhibited differences between their two scores in the same session greater than that predicted to occur across an interval of 10 years, and the intervals needed to ensure that less than 5% of the individuals had within-session differences greater than the expected difference range from 43 to 135 years.

TABLE 3
Percentages of Individuals With Difference Scores Exceeding Predicted 10-Year Differences and Estimated Number of Years to Exceed 95% of Observed Differences

Variable	*Percentage of Individuals Greater Than Abs[a](10 × Slope)*	*Years to Exceed 95% of Across-Individuals Within-Session Differences*
Digit Symbol	61.9	43.16
Number Comparison	66.1	58.28
Verbal Memory	84.0	80.21
Spatial Memory	90.6	100.00
Paired Associates Trial 1	71.3	135.14
Paired Associates Trial 2	75.7	83.33

[a]Abs = absolute value.

DISCUSSION

Two sets of results have been reported, one rather surprising and one not. The group results indicated that there was a substantial cross-sectional decline in all measures, a trend that was noticeable in some measures by the decade of the 30s. These findings are consistent with many other large-scale cross-sectional studies involving similar types of measures (e.g., Botwinick & Storandt, 1974; Dirken, 1972; Heron & Chown, 1967; Horn, 1982; Schaie, 1958), and clearly indicate that the normative trend is for slower performance and less reliable memory with increased age. The observation that similar trends were evident in each quartile of the distribution of samples within each decade further suggests that the decline phenomenon is not simply attributable to profound losses among only the low-ability members of the population.

The results relevant to within-individual aging effects were quite surprising because they suggest that even though substantial age effects were evident in the group comparisons, those effects may be extremely difficult to detect with exactly the same measures of performance within individuals. The difference between two scores is a crude measure of within-session variability, but the results strongly suggest that the variation among measures obtained within the same session is large relative to the changes expected across temporally spaced sessions as a function of age. Furthermore, this is not simply true for measures with low reliability because the analyses indicate that within-individual differences would also be difficult to detect even with the Digit Symbol and Number Comparison measures, which had quite high reliabilities (i.e., test–retest coefficients corrected for age of .84 and .89, respectively).

It seems likely that traditional longitudinal studies would exhibit sensitivity to age differences intermediate between that of cross-sectional studies and that estimated for within-individual studies. As in the cross-sectional studies, longitudinal comparisons are based on scores from a group of individuals, but those scores are differences between measurements from the same individual as in the within-individual studies. Because the precision of the difference scores depends upon the within-individual variability of the measurements within each occasion, longitudinal studies will be influenced by inconsistency of performance by the same individual in the same session in a manner similar to within-individual studies. Discrepancies in age trends inferred from cross-sectional and longitudinal studies may therefore be partially attributable to longitudinal studies underestimating age differences because the considerable within-session variability reduces sensitivity to detect between-session (across-age) differences.

Although we believe that it is much more difficult than most researchers would probably have suspected to detect age-related effects within specific individuals, it is important to consider three issues relevant to the arguments outlined above. One issue is that the difference score may provide an inflated index of within-session variability because it incorporates the systematic effects of practice in addition to (presumably) unsystematic error. Therefore, if the across-session practice effects are small relative to the within-session practice effects, which may be quite possible with a lengthy intersession interval, then both the within-session variability and the insensitivity to aging effects may be overestimated with the present computations.

A second factor that may qualify the present conclusions is that the across-individual distribution of within-session differences scores may be more variable than the corresponding distribution within a given individual. To the extent that this is the case, the sensitivity to detect age-related effects within an individual will be greater than that estimated above by an amount proportional to the relative variabilities of the across-individual and within-individual difference score distributions.

Still a third issue that should be considered when interpreting the present results is that greater sensitivity for detecting within-individual effects could also result from increasing the number of separate measurement occasions. That is, the function relating age to performance is better defined the greater the number of measurement points available to represent the function, and therefore measurement imprecision at a single occasion may be partially compensated for by obtaining measurements across many temporally sequenced occasions.

These considerations suggest that the ability to detect within-individual age-related performance differences may be somewhat greater than that implied by the data summarized in Table 3. Nevertheless, researchers interested in investigating age-related effects within specific individuals should be sensitive to the problem of variability in performance at the same measurement occasion when attempting to draw inferences about possible changes (or lack thereof) occurring as a function of age.

In conclusion, the present analyses serve to add to the literature suggesting that nearly linear progressive age-related performance declines are the rule for many cognitive variables, but they also point out that detection of these effects within specific individuals may be very difficult. Within-individual comparisons could be made more powerful by increasing the precision of measurement within each occasion or increasing the number of separate measurement occasions, but caution should be exercised in attempting to interpret the results of such comparisons because real effects may be obscured by considerable, but heretofore unrecognized, within-individual, within-occasion variability.

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