

MEMORY AGING
AND THE INCREASING DIVERSITY HYPOTHESIS:
EMPIRICAL EVIDENCE

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In the literature, it is generally asserted that diversity of performance increases with advancing age. Recent research by Hale, Myerson, Smith and Poon (1988), however, demonstrated that for reaction time measures, increasing diversity (*SD*) is a function of performance solely. The present meta-analytic research indicates that correlations between age and *SD*, with mean performance partialled out, are significant for STM span and for measures of episodic memory. Thus, aging includes both an effect on the mean of memory performance and on the interindividual diversity in at least some aspects of memory performance.

With increasing age, the performance of people on many tasks grows more diverse. For most gerontologists, this statement represents a truism, hardly worth investigating. The age-diversity relationship has become a central assumption, to the extent that some researchers finding smaller variability for the old as compared to the young consider it necessary to offer long and complex explanations for this divergence (e.g., Weinert, Schneider, & Knopf, 1988). Recently, however, Hale, Myerson, Smith and Poon (1988) challenged the increasing diversity hypothesis in an article presenting a meta-analysis of the literature on reaction time.

Hale and her colleagues remark that the increase in variability that is often observed coincides with a decrease in performance. This implies that it is quite possible that "the greater diversity among older adults' reaction-times may be a direct result of slowing, rather than an independent consequence of aging" (Hale et al., 1988, p. 407). By regressing the standard deviation (*SD*) on the mean reaction time performance as reported in a total of 23 conditions in 6 studies on manual reaction time and 30 conditions in 7 studies on vocal reaction time, Hale and her colleagues demonstrated that the relationship between diversity and mean performance is the same for young and old adults: Diversity in reaction time performance is simply a linear function of the mean ($r^2 > .82$). Moreover, they found that controlling the effect of age did not reduce the correlation between reaction time and *SD*, whereas control-

ling for reaction time eliminated the correlation between age and *SD*. Thus, these authors convincingly demonstrated that the increased diversity associated with aging is simply an effect of elevated reaction time.

In the present study, we investigated whether the results obtained on reaction time data could be replicated on data concerning performance on memory tasks. For that purpose, three meta-analyses were conducted, one on speed of search in Short-Term Memory (STM) (the so-called Sternberg task; Sternberg, 1966), one on STM span, and one on three measures of episodic memory (paired-associate recall, prose recall, and list recall).

METHOD

Data sets

We used part of a data set already collected for other purposes (Verhaeghen & Marcoen, in preparation). The PsycLit CD-ROM data base and some recent review papers were used in order to identify studies. References cited in the selected studies were used in order to identify studies not included in the original sample. Studies were included that (a) compared a young group (mean age 16 to 30) with a group of normal, healthy elderly subjects (mean age 60 or over); (b) assessed performance on STM search tasks, STM span tasks, paired-associate recall, prose recall or list recall, or any combination of these; (c) reported both group mean performance and *SD*; (d) were published after 1974; and (e) were available at the local university library. The latter two criteria were used solely in order to limit the amount of data (and thus the amount of time and other resources spent). No studies were excluded from the analysis for reasons other than not satisfying the criteria stated above.

Only three studies (yielding six age comparisons) on speed of STM search could be located. Ten studies (19 age comparisons) on STM span were included. Nine studies (19 age comparisons) on paired-associate recall, 11 (42 age comparisons) on prose recall, and 20 (38 age comparisons) on list recall were retrieved, combining to 99 age comparisons on episodic memory. Mean age for the young in the three data sets was 21.8, 21.8 and 21.4, respectively, and mean age for the old was 70.2, 71.1, and 70.7, respectively. Studies are listed in the Appendix (note that in some papers more than one relevant study may be reported).

Analyses

In order to make performance measures comparable across studies, means and *SDs* were scaled to those of the young age groups. For each reported age comparison, mean performance of the old was transformed into classical effect size (mean performance of the young was subtracted from that of the old and this result was divided by the *SD* of the young; Glass, McGaw, & Smith, 1981). Mean performance of the young was set at zero. For each condition, *SD* of the old was divided by *SD* of the young, and *SD* of the young was set at 1. Because Hale et al. (1988) conducted their analyses directly upon reported mean scores and *SDs*, we included a re-analysis of their data-set on manual reaction time, in order to check if procedural differences would alter the results.

Of course, the data-transformation renders the Hale et al. method of linear regression within samples impossible, but it has the advantage of presenting a common metric for the large diversity in performance measures.

For all analyses, the alpha level for statistical significance was set at .05.

RESULTS

It was indeed found that diversity was larger for the old groups as compared to the young (see Table 1). In our sample, mean *SD* of the older groups is 1.24 times as large as that of the younger groups.

Table 1. — *Standard Deviation and Mean Performance of the Old as Compared to the Young*

Sample	<i>n</i> ^a	Mean transformed <i>SD</i> ^b	Mean effect-size ^c
Speed of search in STM	12	2.03	-3.49
STM span	38	1.22	-0.79
Episodic memory	198	1.19	-0.67
Paired-associates	38	1.39	-0.66
Prose recall	84	1.06	-0.84
List recall	76	1.20	-0.48
Reaction time ^d	46	1.34	-1.32 ^e

Note. ^aYoung and old groups combined. ^b(*SD*_{old} / *SD*_{young}).

^c(*M*_{old} - *M*_{young})/*SD*_{young}; except where noted. ^dReanalysis of the data on manual reaction time reported by Hale et al. (1988).

^e(*M*_{young} - *M*_{old})/*SD*_{young}.

Unsurprisingly, we find that there is a rather marked age difference in memory performance between the young and the old: The mean effect-size is -0.82 , meaning that the average older person can be situated at the 21th percentile of the distribution of the young.

Combining the data on means and *SDs*, this indicates that the elderly, even those who are functioning at high level, generally perform less well than their younger contemporaries. The old who perform at $+1$ *SD* of their age distribution, perform at -1.46 *SD* of the distribution of the young for STM speed, 0.43 *SD* for STM span, and 0.52 *SD* for episodic memory.

In order to investigate the effects of age on diversity of memory performance, correlations between the three variables (age, mean performance, and *SD*) were calculated, and partial correlations were used as a simple form of path analysis. The results are shown in Table 2.

Table 2. — *Correlations and Partial Correlations Between Age, Memory Performance, and Diversity of Memory Performance*

Sample	<i>n</i> ^a	MA	M.A.S	MS	MS.A	SA	SA.M
Speed of search in STM	12	-.96*	-.94*	-.65*	.18	.71*	.41
STM span	38	-.56*	-.61*	.07	.30	.29	.40*
Episodic memory	198	-.46	-.51*	.21*	.33*	.17*	.30*
Paired-associates	38	-.43*	-.76*	.49*	.77*	.38*	.74*
Prose recall	84	-.74*	-.74*	-.24*	-.23*	.12	-.09
List recall	76	-.30*	-.34*	.24*	.29*	.12	.20
Reaction time ^b	46	-.88*	-.81*	-.77*	-.61*	.62*	-.22

Note. M = Mean performance; S = *SD* of performance; A = Age.

^aYoung and old groups combined. ^bReanalysis of the data on manual reaction time reported by Hale et al. (1988); higher reaction times were taken as lower performance.

* $p < .05$.

First, it is important to note that the results with the Hale et al. (1988) data-set replicate those obtained in the original research. So, our data transformation does not seem to have a major effect on the results obtained.

Secondly, in all of the samples, there is a reliably negative correlation between age and performance. With the influence of diversity controlled, this correlation is not altered to a great extent, with the exception of the correlation for paired-associate recall. This is what could be expected, since it is hard to assume that diversity brings about a decrease in performance. The fact that the Pearson correlations are

largely identical to the corresponding partial correlations can be taken as an indication of the stability of the derived models, with the exception of paired-associate recall. Removing paired-associate recall from the analysis results in high stability for the episodic memory sample ($r_{MA} = -.47$; $r_{MA.S} = -.49$; $p < .05$).

Thirdly, only in episodic memory (in general, and in its subsamples) a reliably positive correlation between performance and diversity is observed that remains reliable after age is partialled out. The partial correlation remains significant when paired-associate recall is excluded from the analysis ($r_{SA.M} = .20$; $p < .05$). The observed negative correlation for STM speed is transformed to a positive but not significant partial correlation.

Fourthly, in both STM span and episodic memory, there is a reliably positive partial correlation between age and diversity. For speed, this partial correlation is not significant, perhaps due to small sample size. The significant correlation for the episodic memory sample, however, is not evident in its subsamples, except for paired-associate recall. When paired-associate recall is excluded from the analysis, the partial correlation between age and diversity in episodic memory functioning remains significant ($r_{SA.M} = .19$; $p < .05$).

DISCUSSION

Our results are radically different from those obtained by Hale et al. (1988) on reaction time performance. These authors found no correlation between age and diversity when the influence of performance was partialled out. From our meta-analysis, it can be concluded that there is a relationship between age and diversity of performance on memory span tasks and episodic memory tasks. The observed correlation cannot be explained solely by performance factors, as is evidenced by partial correlations ranging from .30 to .40.

Note that Hale et al. found a negative correlation between mean performance and diversity. For most memory tasks, we found a positive correlation. The reaction time and prose recall data may be explained by a ceiling effect in the younger age groups. In that case, the data on paired-associate and list recall may reflect a true relationship between performance and *SD*, or they may be due to floor effects in the old age groups.

These results also indicate that slowing of behavior as tapped by reaction time measures (including, in the Hale et al. study, simple

reaction time, choice reaction time, and time needed for lexical decision, mental rotation, pattern verification, verbal-pictorial recoding and category decision), appears to be different from slowing of search in STM. At least diversity on the Sternberg task seems to be influenced by some age covariate, whereas reaction time in general is not, even though mean performance on both these tasks is highly age related. Speed loss with advancing age may be a more diversified phenomenon than is generally assumed (Hertzog, Raskind & Cannon, 1986; Salthouse, 1985).

It is important to note that our analysis merely reveals that there are indeed age effects on diversity of memory performance. It does not indicate which age-related factors are responsible for this larger diversity in the old. Some likely candidates include physical and mental health, environmental conditions, and metamemorial knowledge (e.g. Perlmutter, 1988), but also rate of neurobiological change (e.g. Rabbitt, 1981).

Another important question which is not addressed by the present research, is the possible change in shape of performance distributions (as indicated by, e.g., skewness and kurtosis, which are rarely reported in published studies) with advancing age. This issue could shed some light on factors involved in the increase of diversity. For instance, when some mechanism of rapid deterioration (such as a higher prevalence of physical illness) in subsamples of the aged is an important factor, one would expect the performance distribution of the old to have a negative skewness, which would also be smaller than the (positive or negative) skewness of the distribution of the young.

The present study raises some important questions, which merit further investigation. First, the data suggest that the speed construct must be differentiated. Some aspects of speed (e.g., speed of search in STM) appear to age with much larger diversity than others (e.g., simple reaction time). So, it may be worthwhile to look also at data on interindividual differences, rather than solely at data on mean performance. Secondly, it may be worthwhile to try and identify some of the factors that contribute to an increasing differentiation with advancing age. Thirdly, our data suggest that the relationship between age, performance, and diversity may be different for different measures of episodic memory. It is not clear why this should be the case. Fourthly, it may be interesting to obtain data on diversity in other cognitive measures.

We may conclude, then, that the present research indicates that aging is indeed associated with larger interindividual differences in at least some aspects of memory task performance.

APPENDIX

Studies included in the present meta-analysis

Speed of search in STM

- Coyne, A. C., Allen, P. A., & Wickens, D. D. (1986). Influence of adult age on primary and secondary memory search. *Psychology and Aging, 3*, 187-194.
- Salthouse, T. A., & Somberg, B. L. (1982). Skilled performance: Effects of adult age and experience on elementary processes. *Journal of Experimental Psychology: General, 111*, 176-207.

STM span

- Burke, D. M., & Yee, P. L. (1984). Semantic priming during sentence processing by young and older adults. *Developmental Psychology, 20*, 903-910.
- Cohen, G., & Faulkner, D. (1981). Memory for discourse in old age. *Discourse processes, 4*, 253-265.
- Cohen, G., & Faulkner, D. (1982). Memory for text: Some age differences in the nature of the information that is retained after listening to texts. In H. Bouman & D. G. Bouwhuis (Eds.), *Attention and performance* (Vol.10, pp. 501-514). London: Erlbaum.
- Ferris, S. H., Crook, T., Clark, E., McCarthy, M., & Rae, D. (1980). Facial recognition memory deficits in normal aging and senile dementia. *Journal of Gerontology, 35*, 707-714.
- Kausler, D. H., Lichty, W., & Hakami, M. K. (1984). Frequency judgments for distractor items in a short-term memory task: Instructional variation and adult age differences. *Journal of Verbal Learning and Verbal Behavior, 23*, 660-668.
- Muhs, P. J., Hooper, F. E., & Papalia-Finlay, D. (1980). Cross-sectional analysis of cognitive functioning across the life-span. *International Journal of Aging and Human Development, 10*, 311-333.
- Salthouse, T. A. (1988). The role of processing resources in cognitive aging. In M. L. Howe & C. J. Brainerd (Eds.), *Cognitive development in adulthood: Progress in cognitive development research* (pp. 185-239). New York: Springer.
- Stine, E. L., & Wingfield, A. (1987). Process and strategy in memory for speech among younger and older adults. *Psychology and Aging, 2*, 272-279.
- Wright, R. E. (1981). Aging, divided attention, and processing capacity. *Journal of Gerontology, 36*, 605-614.

Paired-associate recall

- Ferris, S. H., Crook, T., Clark, E., McCarthy, M., & Rae, D. (1980). Facial recognition memory deficits in normal aging and senile dementia. *Journal of Gerontology, 35*, 707-714.

- Kausler, D. H., & Puckett, J. M. (1980). Frequency judgments and correlated cognitive abilities in young and elderly adults. *Journal of Gerontology*, *35*, 376-382.
- Lovelace, E. A., & Marsh, G. R. (1985). Prediction and evaluation of memory performance by young and old adults. *Journal of Gerontology*, *40*, 192-197.
- Margolis, R. B., & Scialfa, C. T. (1983). Age differences in Wechsler Memory Scale performance. *Journal of Clinical Psychology*, *40*, 1442-1449.
- Parks, C. W., Mitchell, D. B., & Perlmutter, M. (1986). Cognition and social functioning across adulthood: Age or student status differences? *Psychology and Aging*, *1*, 248-254.
- Puglisi, J. T., Park, D. C., Smith, A. D., & Dudley, W. N. (1988). Age differences in encoding specificity. *Journal of Gerontology*, *43*, 145-150.
- Rabinowitz, J. C. (1984). Aging and recognition failure. *Journal of Gerontology*, *39*, 65-71.
- Salthouse, T. A., Kausler, D., & Saults, J. S. (1988). Investigation of student status, background variables, and feasibility of standard tasks in cognitive aging research. *Psychology and Aging*, *3*, 29-37.

Prose recall

- Adams, C., Labouvie-Vief, G., Hobart, C. J., & Dorosz, M. (1990). Adult age differences in story recall style. *Journals of Gerontology: Psychological Sciences*, *45*, 17-27.
- Cohen, G., & Faulkner, D. (1982). Memory for text: Some age differences in the nature of the information that is retained after listening to texts. In H. Bouman & D. G. Bouwhuis (Eds.), *Attention and performance* (Vol. 10, pp. 501-514). London: Erlbaum.
- Cavanaugh, J. C., & Murphy, N. Z. (1986). Personality and metamemory performance in younger and older adults. *Educational Gerontology*, *12*, 385-394.
- Ferris, S. H., Crook, T., Clark, E., McCarthy, M., & Rae, D. (1980). Facial recognition memory deficits in normal aging and senile dementia. *Journal of Gerontology*, *35*, 707-714.
- Margolis, R. B., & Scialfa, C. T. (1983). Age differences in Wechsler Memory Scale performance. *Journal of Clinical Psychology*, *40*, 1442-1449.
- Meyer, B. J. K., Young, C. J., & Bartlett, B. J. (1989). *Memory improved: Reading and memory enhancement across the lifespan through strategic text structures*. Hillsdale, NJ: Erlbaum.
- Petros, T. V., Norgaard, L., Olson, K., & Tabor, L. (1989). Effects of text genre and verbal ability on adult age differences in sensitivity to text structure. *Psychology and Aging*, *4*, 247-250.
- Rice, G. E., & Meyer, B. J. F. (1986). Prose recall: Effects of aging, verbal ability and reading behavior. *Journal of Gerontology*, *41*, 469-480.
- Tun, P. A. (1989). Age differences in processing expository and narrative text. *Journals of Gerontology: Psychological Sciences*, *44*, 9-15.
- Zelinski, E. M., & Miura, S. A. (1988). Effects of thematic information on script memory in young and old adults. *Psychology and Aging*, *3*, 292-299.

List recall

- Barrett, T. R., & Watkins, S. K. (1986). Word frequency and cardiovascular health as determinants of age-related recall differences. *Journal of Gerontology, 41*, 222-224.
- Barret, T. R., & Wright, M. (1981). Age-related facilitation in recall following semantic processing. *Journal of Gerontology, 36*, 194-199.
- Bruning, R. H., Holzbauer, I., & Kimberlin, C. (1975). Age, word imagery, and delay interval: Effects on short-term and long-term retention. *Journal of Gerontology, 30*, 312-318.
- Cavanaugh, J. C., & Murphy, N. Z. (1986). Personality and metamemory performance in younger and older adults. *Educational Gerontology, 12*, 385-394.
- Coyne, A. C., Allen, P. A., & Wickens, D. D. (1986). Influence of adult age on primary and secondary memory search. *Psychology and Aging, 3*, 187-194.
- Howe, M. L. (1988). Measuring memory development in adulthood: A model-based approach to disentangling storage-retrieval contributions. In M. L. Howe & C. J. Brainerd (Eds.), *Cognitive development in adulthood: Progress in cognitive development research* (pp. 39-64). New York: Springer.
- Howe, M. L., & Hunter, M. A. (1985). Adult age differences in storage-retrieval processes: A stages-of-learning analysis of developmental interactions in concreteness effects. *Canadian Journal of Psychology, 39*, 130-150.
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- Rabinowitz, J. C. (1989). Age deficits in recall under optimal study conditions. *Psychology and Aging, 4*, 378-380.
- Rissenberg, M., & Glanzer, M. (1986). Picture superiority in free recall: The effects of normal aging and primary degenerative dementia. *Journal of Gerontology, 41*, 64-71.
- Zivian, M. T., & Darjes, R. W. (1983). Free recall by in-school and out-of-school adults: Performance and metamemory. *Developmental Psychology, 19*, 513-520.

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