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Memory Aging as a General Phenomenon: Episodic Recall of Older Adults is a Function of Episodic Recall of Young Adults

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The focus of this study was on the relationship between young and older adults' performance on tasks of deliberate recall from episodic memory. A meta-analysis on 91 relevant studies (comprising a total of 154 conditions) was conducted. It was found that 83% of the variance in older adults' recall probability was accounted for by a quadratic function using young adults' recall probabilities as predictors. No significant interaction with age of older adults was found. Interaction with task type was, however, significant, resulting in separate functions for list recall, prose recall, and paired-associate recall. The results point at the importance of the main effect of age in studies on memory aging.

It is a well-established fact that older adults perform less well than do young adults on episodic memory tasks involving deliberate recall. On the average, recall of elderly subjects on typical tasks such as list recall, prose recall, and recall of lists of paired associates is about one standard deviation below that of young adults (Verhaeghen, Marcoen, & Goossens, 1993; standard deviation is standard deviation of the pooled sample).

An important issue in current aging research is whether the observed age difference is mainly quantitative or qualitative in nature. On the one hand, if the decrease in episodic memory performance is due to a decrease in a general age-related factor, as is stated in many theories (e.g., Baddeley, 1986; Hasher & Zacks, 1988; Salthouse, 1985, 1988, 1991), one should expect "a systematic relation . . . between the performance levels of young and older adults regardless of the identity or composition of the processing components involved in the task" (Salthouse, 1991, p. 313). If, on the other hand. age differences are much more task specific, for instance, they are due to differences in strategy use (whether caused by deficient knowledge about memory functioning, by disuse, by a production deficiency, by lack of memory self-efficacy, or by monitoring problems; see Light, 1991, for an overview of these explanations), one should expect a less systematic, that is, a more qualitative, relation between the performance levels of both groups.

Unfortunately, very little is known about the relationship between performance levels of different age groups on tasks of deliberate recall from episodic memory. Extensive studies with latency data (Cerella, 1985, 1990; Cerella, Poon, & Williams, 1980; Hale, Myerson, & Wagstaff, 1987; Lima, Hale, & Myerson, 1991; Myerson, Hale, Wagstaff, Poon, & Smith, 1990; and Salthouse, 1991) have demonstrated that latency of the old is indeed a function of latency of the young. This conclusion holds for a wide variety of tasks for which latency data exist, and the proportion of variance accounted for is impressingly large (typically larger than 90%, often exceeding 95%). Linear, quadratic, and power functions, and Myerson et al.'s "information-loss" function all explain the data about equally well. Thus, mean speed of older adults on a wide variety of tasks can be very well predicted simply from knowing the mean speed of young adults on the same tasks; no additional information about the processes involved or the exact nature of the tasks is required. This suggests that speed loss is not task specific but that it is, to a great extent, a general phenomenon.

Very little is known, however. about the relation between young and older adults' episodic recall performance. In the few studies that have been conducted (Rubin, 1989; Stine & Wingfield, 1988; Verhaeghen & Marcoen. 1993), it was found that the Pearson correlation (after correcting for test unreliability) between the probability that an item is recalled by the young and the probability that the same item is recalled by the elderly ranges from .47 to .95, with a median of .86. Thus, about 74% of the variance in mean recall performance of the old can be explained from mean recall performance of the young in corresponding tasks. The fact that this proportion of the variance explained for is smaller than what is found for latency data may be due to differences in the method used. The studies on latency data mentioned earlier all adopt a meta-analytic perspective; that is, they consider studies or conditions within studies as a unit of measurement. whereas the studies on recall data all used individual items as units of analysis. It is quite possible that the within-item error variability in episodic memory tasks induces some additional scatter in the data. as compared with using conditions within studies, where error components associated with individual items are averaged out. In other words, the correlations between mean recall performance of young and older adults found in episodic memory research may well be an underestimation of the true correlation.

In the present study. we tried to provide a hetter estimation of

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the relationship between young and older adults' episodic recall performance. We conducted a meta-analysis, using conditions within studies as the unit of analysis rather than probability of recall of individual items. A large database on three typical tasks in the episodic memory literature, namely recall of word lists, recall of lists of paired associates, and recall of prose material, was compiled. In this analysis, recall probability of the young, $p(\mathrm{Re}|\mathrm{Y})$, was related to recall probability of the old, $p(\mathrm{Re}|\mathrm{O})$, performing identical tasks. Because this database is quite extensive, we trust that the function (if any) relating recall performance of the old to recall performance of the young will give a better estimation of the true relationship between recall performance of the old and recall performance of the young that exists in the population.

Method

The Sample of Studies

For the present analysis, we made use of a database on studies (published from 1975 and after) of adult age differences in episodic (and short-term) memory collected earlier (Verhaeghen, Marcoen, & Goossens, 1993). The database on episodic memory performance consists of 68 studies on list recall, 21 studies on paired-associate recall, and 39 studies on prose recall. These studies were collected through a systematic search of core developmental and gerontological journals (*Developmental Psychology, The Gerontologist, International Journal of Aging and Human Development, Journals of Gerontology*, and *Psychology and Aging*). We used references cited in the selected studies and some review papers to identify studies not contained in the original sample. In this database, studies were included that (a) compared a young group (central tendency of age between 16 and 30 years) with a group of older subjects (central tendency of age 60 years or over), both groups being free from cognitive problems caused by organic pathology; and (b) assessed performance on word list recall, prose recall, paired-associate recall (of verbal stimuli), or any combination of these. Selection of studies was concluded in November 1990. From this original data pool, all studies were selected from which probability of recall of word lists, lists of paired associates, and texts could be derived for both age groups. No studies were excluded from the final data pool for reasons other than those stated earlier.

Eventually, we retained 91 studies, contained in 78 articles. These included 53 studies on list recall, 32 on prose recall, and 11 on paired-associate recall. These studies are listed in the Appendix. In total, the memory performance of 3,300 elderly subjects was compared with that of 3,177 young subjects. Mean age (estimated from central tendency measures) was 22.1 years (ranging from 16.9 to 29.6) for the young subgroup and 69.7 years (ranging from 61.4 to 79.8) for the older subgroup.

Statistical Analyses

Statistical analyses were done in two steps. First, data points in the $p(\mathrm{Re}|\mathrm{Y}) \times p(\mathrm{Re}|\mathrm{O})$ space were identified or calculated from available data, for as many between-subject conditions as could be detected in the original articles. To limit the degree of dependence among data points, data from within-subject comparisons within task type (i.e., list recall, prose recall, and paired-associate recall) were averaged. This yielded a fairly extensive database of 81 data points for list recall, 54 data points for prose recall, and 19 data points for paired-associate recall, summing to a total of 154 data points for episodic memory recall. Second, $p(\mathrm{Re}|\mathrm{O})$ was predicted from $p(\mathrm{Re}|\mathrm{Y})$, using weighted least squares analysis, weighting for sample size.

Results and Discussion

A plot of the data points in the $p(\mathrm{Re}|\mathrm{Y}) \times p(\mathrm{Re}|\mathrm{O})$ space for the three types of task can be found in Figures 1, 2, and 3. As can be seen in the figures, the young adults generally outperformed the older adults. The average performance of the elderly was significantly lower than that of the young: Probability of recall for list material was .57 for young adults and .43 for older adults, $t(80) = 12.67$, $p < .001$; for prose recall, probabilities were .41 and .31, respectively, $t(53) = 10.47$, $p < .001$; for paired-associate recall, probabilities were .61 and .41, respectively, $t(18) = 7.10$, $p < .001$. Overall, the young recalled 52% of items in the episodic memory tasks reported here: the elderly recalled 39%, $t(153) = 16.87$, $p < .001$. From the figures, it can also be gathered that recall probability of the elderly only rarely equaled or exceeded that of the young: that is, only 7 data points (9%) for list recall, 3 data points (6%) for prose recall, and 2 data points (11%) for paired-associate recall were situated on or above the diagonal in the $p(\mathrm{Re}|\mathrm{Y}) \times p(\mathrm{Re}|\mathrm{O})$ space. Thus, in the large majority of the conditions in the present sample (92%), the young outperformed the old on episodic memory recall.

Predicting Older Adults' Recall From Episodic Memory

First, a linear function between $p(\mathrm{Re}|\mathrm{Y})$ and $p(\mathrm{Re}|\mathrm{O})$ was estimated. This function fitted the data well, $R^2 = .813$, $p(\mathrm{Re}|\mathrm{O}) = 0.778p(\mathrm{Re}|\mathrm{Y}) - 0.019$. However, as can be seen in Figure 1, variance of the observations in the data set increased with $p(\mathrm{Re}|\mathrm{Y})$. To test for heteroscedasticity, we applied the method by Goldfield and Quant (1965). In this method, the data are reordered according to the values of the independent variable, and the middle 25% of the observations are deleted (in the present sample, the 39 middle observations were deleted). Two separate regression analyses (i.e., in the present case, least squares analysis, weighted for sample size) are then carried out on the remaining observations, one on the 37.5% observations ranked lowest and one on the 37.5% observations ranked highest. The ratio of the error sum of squares of these regression analyses is F distributed with the degrees of freedom for both nominator and denominator equal to the degrees of freedom for the error sum of squares in the separate analyses. This statistic should be equal to unity if the error variance is equal for both groups of observations. Another test statistid for heteroscedasticity appropriate when variance is proportional to the values of the independent variable is the rank correlation between the absolute values of the residuals and the values of the independent variable (Kleinbaum, Kupper, & Muller, 1988; for the sake of brevity, this statistic is referred to as rank r in the remainder of this text). Both of these statistics proved significant, $F_{\text{high-low}}(57, 57) = 2.01$, $p < .01$; rank $r = .39$, $p < .001$, indicating that the variance increased reliably with increases in values of the independent variable. There appears to be no problem with regard to normality of the data (Kolmogorov-Smirnov test on residuals has $Z = 0.72$, *ns*). The heteroscedasticity problem was not resolved after estimation of a quadratic function. This function fitted the data reliably better than did the linear function, $R^2 = .825$, incremental $F(1, 151) = 7.47$, $p < .01$; $p(\mathrm{Re}|\mathrm{O}) = 0.465p(\mathrm{Re}|\mathrm{Y})^2 + 0.339p(\mathrm{Re}|\mathrm{Y}) + 0.061$. Residuals were normally distributed (Kolmogorov-Smirnov $Z = 0.88$, *ns*). Hetero-

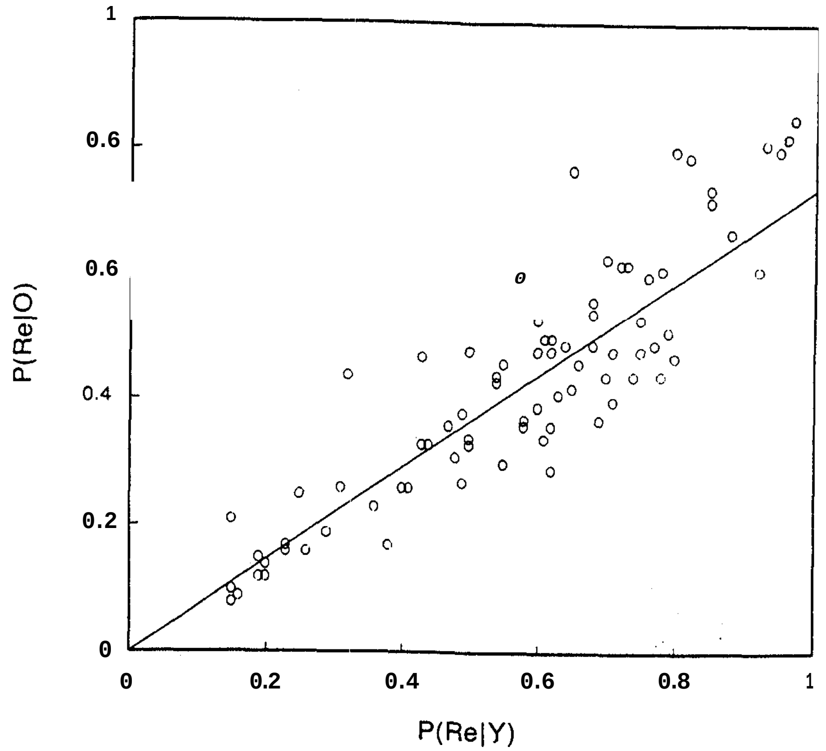

Figure 1. Proportion recalled from list recall tasks ($k = 81$) by older adults as a function of proportion recalled by young adults, along with the best-fitting curve through the origin ($R^2 = .79$). [$p(\text{Re|O})$ = recall probability of older adults; $p(\text{Re|Y})$ = recall probability of young adults.]

scedasticity, however, proved significant, $F_{\text{high-low}}(56, 56) = 1.86$, $p < .05$; rank $r = .28$, $p < .001$.

To solve the heteroscedasticity problem, we included interaction terms in the regression analysis, respectively for the interaction with age of older adults, split at median (69.5 years; note that in three studies, the age of the older subsample was not reported; these studies were omitted from the analysis with an interaction term for age) and with task type (list recall, prose recall, and paired-associate recall). The inclusion of an interaction term for age did not lead to a reliable increase in model fit: linear function with interaction term for age, $R^2 = .816$, incremental $F(1, 148) = 0.38$, *ns;* quadratic function with interaction term for age, $R^2 = .829$, incremental $F(2, 145) = 1.49$, *ns.* Interactions for task type, however, proved significant: linear function with interaction term for task type, $R^2 = .835$, incremental $F(2, 148) = 6.12$, $p < .01$; quadratic function with interaction term for task type, $R^2 = .847$, incremental $F(2, 145) = 4.11$, $p < .05$. The quadratic functions for the three task types were (a) for list recall: $p(\text{Re|O}) = 0.033 + 0.596p(\text{Re|Y}) + 0.125p(\text{Re|Y})^2$; $R^2 = .791$, $F_{\text{high-low}}(29, 28) = 1.37$, *ns;* rank $r = .35$, $p < .001$; Kolmogorov-Smirnov $Z = 0.65$, *ns;* (b) for prose recall: $p(\text{Re|O}) = 0.075 + 0.259p(\text{Re|Y}) + 0.646p(\text{Re|Y})^2$; $R^2 = .913$, $F_{\text{low-high}}(18, 19) = 3.03$, $p < .05$; rank $r = -.02$, *ns,* Kolmogorov-Smirnov $Z = 0.63$, *ns;* and (c) for paired-associate recall: $p(\text{Re|O}) = 0.214 - 0.535p(\text{Re|Y}) + 1.323p(\text{Re|Y})^2$; $R^2 = .837$, $F_{\text{high-low}}(5, 4) = 14.26$, $p < .05$; rank $r = .25$, *ns:* Kolmogorov-Smirnov $Z = 0.60$, *ns.* There were no problems with nonnormality of residuals, but there are possibly problems with heteroscedasticity: For each of the regression equations, one (but only one) of the two heteroscedasticity statistics was significant. So, probably, interactions with other variables within task type might prove significant. Note, however, that for text recall, heteroscedasticity as indicated by the Goldfield and Quant (1965) method was now significant in the opposite direction: Variability was larger at the lower end of the $p(\text{Re|Y})$ scale.

An interesting feature of the three quadratic equations presented in the previous paragraph was that the intercept terms in these models proved nonsignificant. This makes sense, because it is reasonable to assume that the regression lines run through the origin, implying that when recall performance of the young equals zero, the elderly will recall nothing as well, whereas the models presented earlier all imply that when recall performance of the young is zero, the elderly will still recall on average between 3% and 21% of the words. Forcing regression lines through the origin resulted in the following equations: (a) for list recall, $p(\text{Re|O}) = 0.729p(\text{Re|Y}) + 0.008p(\text{Re|Y})^2$; $R^2 = .790$, $F_{\text{low-high}}(28, 29) = 1.13$, *ns;* rank $r = .40$, $p < .001$; Kolmogorov-Smirnov $Z = 0.65$, *ns;* (b) for prose recall, $p(\text{Re|O}) = 0.570p(\text{Re|Y}) + 0.366p(\text{Re|Y})^2$; $R^2 = .907$, $F_{\text{high-low}}(19, 17) = 3.31$, $p < .01$; rank $r = .12$, *ns;* Kolmogorov-Smirnov $Z = 0.86$, *ns;* and (c) for paired-associate recall, $p(\text{Re|O}) = 0.154p(\text{Re|Y}) + 0.790p(\text{Re|Y})^2$; $R^2 = .830$, $F_{\text{high-low}}(6, 5) = 11.71$, $p < .05$; rank $r = -.05$, *ns;* Kolmogorov-Smirnov $Z = 0.77$, *ns.* These regression lines are drawn in Figures 1, 2, and 3. Goodness of fit was (of course) reduced somewhat when no intercept term was estimated, but the reduction was rather small, between 0.7% and 0.1% of the variance accounted for. (The reader may note that most computer programs use the total sum of squares un-

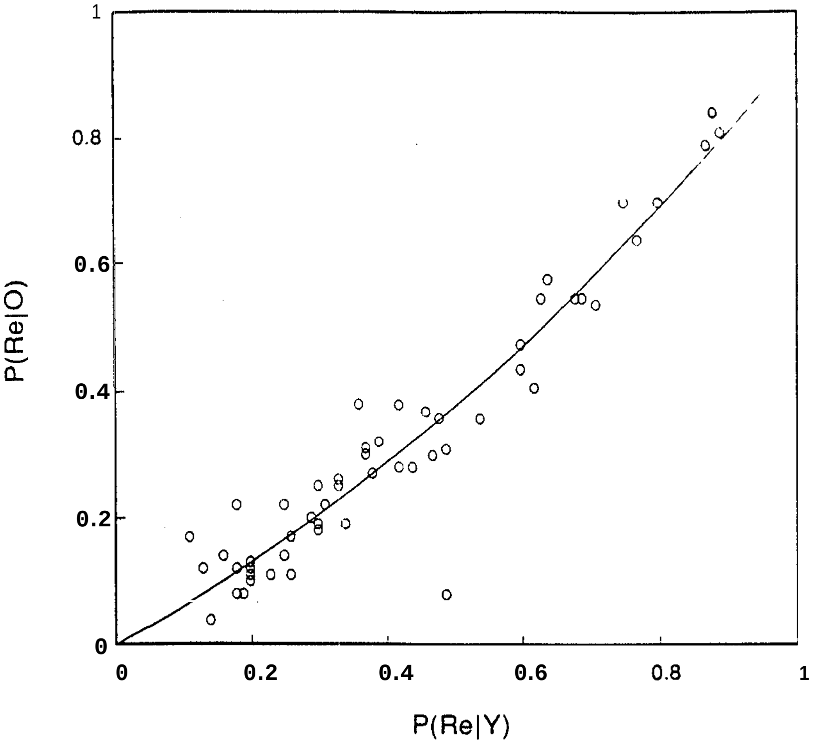

Figure 2. Proportion recalled from Prose recall tasks ($k = 54$) by older adults as a function of proportion recalled by young adults, along with the best-fitting curve through the origin ($R^2 = .91$). [$p(\text{Re}|\text{O})$ = recall probability of older adults; $p(\text{Re}|\text{Y})$ = recall probability of young adults.]

corrected for the mean for the calculation of R^2 in regression analysis without an intercept term. This results in inflated R^2s. To make the present analysis comparable to the analyses where an intercept term was estimated, we used the total sum of squares corrected for the mean for the calculation of R^2 values.) Again, there were possibly problems with heteroscedasticity: For each of the regression equations, one (but only one) of the two heteroscedasticity statistics was significant.

An alternative way to solve the heteroscedasticity problem would be to transform the data. Reciprocal and log transformations overcorrected the problem: reciprocal transformation, $F_{\text{low-high}}(57, 57) = 55.35$, $p < .001$, rank $r = -.31$, $p < .001$; log transformation, $F_{\text{low-high}}(57, 57) = 3.27$, $p < .001$, rank $r = -.26$, $p < .01$. A square root transformation, however, resulted in a well-fitted function without heteroscedasticity or nonnormality problems: $R^2 = .817$, $[p(\text{Re}|\text{O})]^{0.5} = 0.658p(\text{Re}|\text{Y}) + 0.258$; $F_{\text{low-high}}(57, 57) = 1.10$, *ns;* rank $r = .01$, *ns;* Kolmogorov-Smirnov $Z = 0.94$, *ns.* Retransformed, this resulted in a quadratic function: $p(\text{Re}|\text{O}) = 0.433p(\text{Re}|\text{Y})^2 + 0.340p(\text{Re}|\text{Y}) + 0.067$. The interaction with age was not significant on the transformed data, $R^2 = .822$; incremental $F(1, 148) = 0.03$, *ns.* However, the function with interaction terms for task type proved significant in transformed data also, $R^2 = .832$; incremental $F(2, 148) = 3.45$, $p < .05$. When equations were computed for each task type, it was found that model fit was larger for the linear function after square root transformation as compared with a quadratic function on raw data only for the list recall task ($R^2 = .807$). For prose recall and paired-associate recall, quadratic functions on raw scores fitted the data better (for transformed data: $R^2 = .858$ and $.789$, respectively). On the average, quadratic functions with an intercept term (on raw data) explained an extra 2.8% of the variance, and quadratic functions through the origin (on raw data) explained an extra 2.4% of the variance when compared with the transformed data. Moreover, some of the heteroscedasticity statistics signaled possible problems after square root transformation when functions were estimated per task type: for prose recall, rank $r = -.31$, $p < .01$; for paired-associate recall, $F_{\text{low-high}}(6, 5) = 8.75$, $p < .05$. Thus, data transformation did not result in increased model fit, it did not result in nonsignificance of the interaction with task type, nor did it take away the possible heteroscedasticity problems when regressing within task type.

As a conclusion, it can be stated that mean recall probability of older adults, within task type, can be reasonably well predicted from mean recall probability of younger adults. A quadratic function predicted 83% of the adult age differences in various types of episodic memory functioning. When fitting functions per task type, quadratic functions through the origin explained between 79% and 91% of the variance. However, because of the possible remaining heteroscedasticity, it is likely that there exist further interactions between adult age and characteristics of task and persons (other than age within older subsample) within each task type. In the present study, we have refrained from further investigating possible interactions, first because this was not the focus of the present research and second because in the present state of gerontological science we

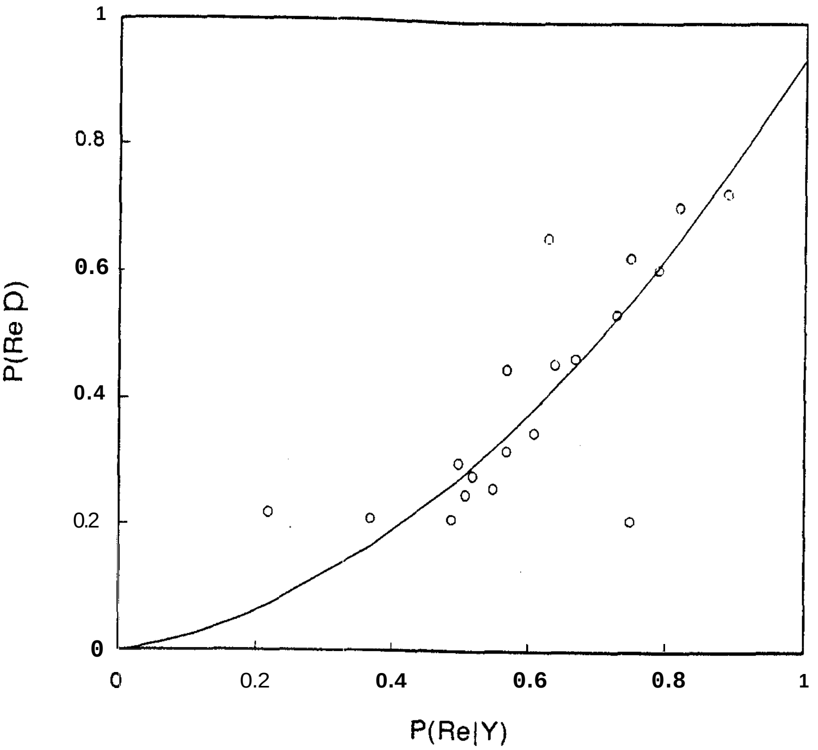

Figure 3. Proportion recalled from paired-associate recall tasks (k = 19) by older adults as a function of proportion recalled by young adults, along with the best-fitting curve through the origin (R^2 = .83). [p(Re|O) = recall probability of older adults; p(Re|Y) = recall probability of young adults.]

have no strong theory that would predict which further interactions might be interesting to investigate.

The fact that the proportion of the variance accounted for is larger in the present analysis as compared with the results from the studies by Rubin (1989), Stine and Wingfield (1988), and Verhaeghen and Marcoen (1993) indicates that some of the scatter in the earlier studies is indeed caused by error components associated with individual items. The proportion of the variance accounted for is, however, smaller than what is typically found in studies on latency differences. At least three reasons might be advanced for this. First, reliability of recall measures may well be smaller than reliability of latency measures. Recall is always measured in a binary way, whereas latency is measured in a continuous way; the binary form of scoring may induce additional scatter. This effect will, however, be rather small with the units of measurement (conditions within studies) used here, compared with the larger unreliability when considering items as units of measurement. Second and more important. recall is an off-line measure; it presupposes encoding, storage, and retrieval of the item. A problem in any of these memory stages may cause a recall failure, and this can, once again. induce additional scatter in the data as compared with on-line measures. There is some evidence that both encoding and retrieval are hampered in old age (e.g., Bayen & Erdfelder. 1992; Howe, 1988). A third reason. of course. is that there may indeed be some qualitative difference; that is. the true relationship may be somewhat weaker than for latency data. A major reason for this may be that there are indeed some differences in strategy use on episodic memory tasks between Young and older adults that influence performance.

Even though the relation between young and older adults' performance on episodic memory recall may be somewhat weaker than the relationship for latency data, it is still surprisingly strong, considering the diversity in tasks and procedures adopted in the primary studies. For list recall, for instance. some lists involved abstract and others involved concrete nouns; there were conditions of intentional and conditions of incidental learning; there were studies in which recall was tapped immediately or after some delay: there were learning conditions involving mere instruction, or semantic or nonsemantic orienting tasks; recall could be cued or free; and so on. Despite this wide variety of manipulations, presumably involving many different kinds of cognitive processes, 79% of the mean recall performance of the old could be reliably predicted from mean recall performance of the young. The result for mean prose recall performance is even more impressing: 91% of the adult age difference in prose recall performance could be predicted, without any reference to specific characteristics of task or subjects. So, these data offer a very strong case for the hypothesis of a quantitative effect of aging on episodic memory performance. The relationship between recall probability in the young and recall probability in the old appears to be quadratic (somewhat boomerang shaped) rather than linear (note that for list recall. the deviation from linearity is unnoticeable in the figure and in fact not significant). It might be possible that measurement limits (floor and ceiling effects) distort the true nature of the relationship, which might then be linear. This remains difficult to test, however (omitting data points below and above specified ranges would also imply that we artificially increase the scatter in the remaining data points. leading to less stable estimates of the function and less statistical power for detecting deviations from linearity).

The Age Main Effect and Consequences for Interactions

When interpreting the data presented here, one mistake should not be made. Strong predictability (between 79% and 91% of the variance accounted for) does not imply that there is no variability or scatter in the data points. There is, quite literally. room for deviations from the regression line. For instance, interactions between adult age and some other variable might still prove significant in primary analyses or meta-analyses. In fact, Fisk. Fisher, and Rogers (1992) recently demonstrated that such interaction effects need not account for large proportions of the variance to become significant. We found an interaction with task type and indications (in our heteroscedasticity analyses) that interactions with other variables might be needed to explain the young–old relationship completely This is important to note, because much of the research going on in cognitive gerontology is precisely aimed at identifying interactions: Researchers manipulate some variable arid look whether age differences are larger in one condition than in another. This research tradition is very valuable and has proven very fruitful. Yet, we think it is important to make two points with regard to this quest for interactions.

First, just as main effects are to be qualified when interactions are present, interaction effects (pointing at specific task-related influences on aging) need to be interpreted in the light of the main effect of age (pointing at a general age-related factor). There are large differences in episodic memory performance between young and older adults; in 92% of the conditions included in the present research, there were age differences favoring the young, and the recall performance from the old can be predicted quite accurately merely from knowing the recall performance of the young on the same task, without making any reference to the type of task or the kind of processes involved. Similar findings for data on young and older adults' performance in latency data have been taken as an indication of a general slowing factor (e.g., Cerella, 1990, 1991; Salthouse, 1991). Likewise, it can be suspected that in episodic recall data a general episodic memory aging factor a is at work. This general factor absorbed 83% of the variance, indicating that it is a major determinant of performance. Allowing specific factors for each task type (list recall, prose recall, and Paired-associate recall) through the inclusion of interaction terms resulted in a significant increase of 2.2% of the variance accounted for. So, evidently, a is not the whole picture, but it is an extremely important part of it. It is also crucial to note that this factor a is not an explanation of age differences but merely a "descriptive generalization" (Salthouse, 1991, p. 315). It denotes a regularity in a large pool of data, which still needs to be explained by an underlying theory For instance, for episodic memory recall, explanations relating the decline in older adults to slowing down of cognitive processes have become fashionable, with Salthouse (1985, 1988, 1991; see Light, 1991, for a critique) as the main advocate of this theory.

Of course, focusing on the age main effect, as we do here, does not imply that the quest for specific factors through investigation of interactions is not interesting. worthwhile, or necessary for a better understanding of memory aging. We strongly feel that in theories of memory aging both concepts need to be incorporated, but that perhaps the main effect needs to be explained first, before we can fully understand the nature of interaction effects. Also, precise estimates of the extent of the influence of specific factors can only be made when the general age-related influence has been removed first, to make sure that we are not simply rediscovering a different manifestation of the global factor. As stated most ardently by Salthouse (1992), this "general-plus-specific approach (p. 340) is necessary to achieve a real cumulation of knowledge about causes of adult age differences in cognition.

A second note with regard to interaction effects is a call for caution. The finding that age effects are altered after some experimental manipulation does not always necessarily imply that a local factor is responsible. The shape of the curves computed here implies that age differences will vary with varying task difficulty, regardless of the precise nature of the task involved. Clearly, the relationship between young and older adults' mean recall performance is not additive. so traditional analysis of variance techniques must not be applied to such data (for a related argument concerning latency data, see Nebes & Brady, 1992). For instance, when task difficulty for list recall of young adults is 35% in one experimental condition and 65% in another condition, older adults' recall performance can be expected to be 26% and 48%, respectively In a classical plot relating condition to recall performance with separate curves for each age group, a divergent interaction. along with a main effect for age and manipulation, can be noted. Conversely, when some manipulation increases recall probability from 65% to 75% in young adults for a paired-associate task. the average recall of the old will increase from 43% to 56%. which would amount to a convergent interaction. These observed interactions are not to be explained by a true interaction between age and the nature of the manipulation involved, but merely by the consequences of change in task difficulty. One possible way to counter this problem might be to adopt the method advocated by Cerella (1991), which is to include many conditions. and then estimate both a regression model with main effects only and a regression model with interaction terms, testing for the difference between these two models, or the Fisk et al. (1992) method.

As a general conclusion, it can be stated that probabilities of deliberate recall of verbal material from episodic memory in the old can be predicted to a large extent from recall probabilities of the young. The data suggest that a general aging factor a is at work. This factor seems to be a very powerful contributor to the decline of episodic memory functioning in old age, because it accounts for 83% of the variance in data on older adults' recall. Allowing for specific factors for task types within episodic memory recall increases the proportion of variance accounted for slightly but significantly.

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Appendix

Studies Included in the Meta-Analysis

(Inclusion in specific subsamples is indicated by the information between brackets after each reference. LR = list recall; PA = paired-associate recall; PR = 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. (PR)

Bäckman, L., & Karlsson, T. (1986). Episodic remembering in young adults, 73-year-olds, and 82-year-olds. *Scandinavian Journal of Psychology,* 27, 320–325. (LR)

Bäckman, L., & Mäntylä, T. (1988). Effectiveness of self-generated cues in younger and older adults: The role of retention interval. *International Journal of Aging and Human Development, 26,* 241–248. (LR)

Bäckman, L., Mäntylä, T., & Erngrund, K. (1984). Optimal recall in early and late adulthood. *Scandinavian Journal of Psychology, 25,* 306–314. (LR)

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. (LR)

Barrett, T. R., & Wright, M. (1981). Age-related facilitation in recall following semantic processing. *Journal of Gerontology,* 36, 194–199. (LR)

Bruce, P. R., Coyne, A. C., & Botwinick, J. (1982). Adult age differences in metamemory. *Journal of Gerontology, 37,* 354–356. (LR)

Byrd, M. (1986). The use of organizational strategies to improve memory for prose passages. *International Journal of Aging and Human Development,* 23, 257–265. (PR)

Cavanaugh, J. C., & Murphy, N. Z. (1986). Personality and metamemory performance in younger and older adults. *Educational Gerontology, 12,* 385–394. (LR, PR)

Cavanaugh, J. C., & Poon, L. W. (1989). Metamemorial predictors of memory performance in young and older adults. *Psychology and Aging, 4,* 365–368. (LR, PR)

Cerella, J., Paulshock, D., & Poon, L. W. (1982). The effects of semantic processing on memory of subjects differing in age. *Educational Gerontology,* 8, 1–7. (LR, PR)

Cohen, G. (1979). Language comprehension in old age. *Cognitive Psychology, 11,* 412–429. (PR)

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. Control of language processes* (pp. 501–514). Hillsdale, NJ: Erlbaum. (PR)

Cohen, R. L., Sandler, S. P., & Schroeder, K. (1987). Aging and memory for words and action events: Effects of item repetition and list length. *Psychology and Aging, 2,* 280–285. (Study I: LR, Study II: LR)

Corgiat, M. D., Templer, D. I., & Newell, T. C. (1989). The effects of Presentation modality, task demand, and content structure on age-related memory differences for prose. *International Journal of Aging and Human Development. 29,* 53–65. (PR)

Craik, F. I. M., & Rabinowitz, J. C. (1985). The effects of presentation rate and encoding task on age-related memory deficits. *Journal of Gerontology, 40,* 309–315. (LR)

Dixon, R. A., Simon, E. W., Nowak, C. A., & Hultsch, D. F. (1982). Text recall in adulthood as a function of level of information, input modality, and delay interval. *Journal of Gerontology, 37,* 358–364. (PR)

Duchek, J. M. (1984). Encoding and retrieval differences between young and old: The impact of attentional capacity usage. *Developmental Psychology,* 20, 1173–1180. (LR)

Hanley-Dunn, P., & McIntosh, J. L. (1984). Meaningfulness and recall of names by young and old adults. *Journal of Gerontology, 39,* 583–585. (LR)

Hartley, J. T. (1986). Reader and text variables as determinants of discourse memory in adulthood. *Psychology and Aging, 1,* 150–158. (PR)

Hartley, J. T. (1988). Aging and individual differences in memory for written discourse. In L. L. Light & D. M. Burke (Eds.), *Language, memory, and aging* (pp. 36–57). Cambridge, England: Cambridge University Press. (PR)

Hartley, J. T., & Walsh, D. A. (1980). The effect of monetary incentive on amount and rate of free recall in older and younger adults. *Journal of Gerontology, 35,* 899–905. (LR)

Howard, D. V., McAndrews, M. P., & Lasaga, M. I. (1981). Semantic priming of lexical decisions in young and old adults. *Journal of Gerontology,* 36, 707–714. (LR)

Hulicka, I. M. (1982). Memory functioning in late adulthood. In F. I. M. Craik & S. E. Trehub (Eds.), *Aging and cognitive processes* (pp. 331–351). New York: Plenum Press. (LR)

Hultsch, D. F. (1975). Adult age differences in retrieval: Trace-dependent and cue-dependent forgetting. *Developmental Psychology, 11,* 197–201. (LR)

Jackson, D. K., & Schneider, H. G. (1985). Age, organization and memory: Effects of presentation rate and rehearsal strategy. *Psychological Reports,* 56, 471–479. (LR)

Kausler, D. H., & Puckett, J. M. (1980). Frequency judgments and correlated cognitive abilities in young and elderly adults. *Journal of Gerontology,* 35, 376–382. (PA)

Lehman, E. B., & Mellinger, J. C. (1984). Effects of aging on memory for presentation modality. *Developmental Psychology,* 20, 1210–1217. (Study I: LR)

Light, L. L., & Anderson, P. A. (1983). Memory for scripts in young and older adults. *Memory & Cognition, 11,* 435–444. (PR)

Light, L. L., & Anderson, P. A. (1985). Working-memory capacity, age, and memory for discourse. *Journal of Gerontology,* 40, 737–747. (Study I: PR, Study II: PR)

Lovelace, E. A., & Marsh, G. R. (1985). Prediction and evaluation of memory performance by young and old adults. *Journal of Gerontology,* 40, 192–197. (PA)

Macht, M. L., & Buschke, H. (1983). Age differences in cognitive effort in recall. *Journal of Gerontology,* 38, 695–700. (LR)

Mandel, R. G., & Johnson, N. S. (1984). A developmental analysis of story recall and comprehension in adulthood. *Journal of Verbal Learning and Verbal Behavior,* 23, 643–659. (PR)

Mason, S. E. (1979). Effects of orienting tasks on the recall and recognition performance of subjects differing in age. *Developmental Psychology, 15,* 467–469. (LR)

Mason, S. E., & Smith, A. D. (1977). Imagery in the aged. *Experimental Aging Research,* 3, 17–32. (Study II: LR)

McFarland, C. E., Warren, L. E., & Crockard, J. (1985). Memory for self-generated stimuli in young and old adults. *Journal of Gerontology, 40,* 205–207. (LR)

Meyer, B. J. F., & Rice, G. E. (1989). Prose processing in adulthood: The text, the reader and the task. In L. W. Poon, D. C. Rubin, & B. A. Wilson (Eds.), *Everyday cognition in adulthood and late life* (pp. 157–194). Cambridge, England: Cambridge University Press. (PR)

Mueller, J. H., Rankin, J. L., & Carlomusto, M. (1979). Adult age differences in free recall as a function of basis of organization and method of presentation. *Journal of Gerontology,* 34, 375–380. (LR)

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Parkinson, S. R., Lindholm, J. M., & Inman, V. W. (1982). An analysis of age differences in immediate recall. *Journal of Gerontology, 37,* 425–431. (LR)

Perlmutter, M. (1978). What is memory aging the aging of? *Developmental Psychology, 14,* 330–345. (LR)

Perlmutter, M. (1979). Age differences in adults' free recall, cued recall and recognition. *Journal of Gerontology, 34,* 533–539. (Study I: LR, Study II: LR)

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. (PR)

Petros, T. V., Tabor, L., Cooney, T., & Chabot, R. J. (1983). Adult age differences in sensitivity to semantic structure of prose. *Developmental Psychology, 19,* 907–914. (Study I: PR, Study II: PR)

Puglisi, J. T., Park, D. C., Smith, A. D., & Dudley, W. N. (1988). Age differences in encoding specificity. *Journal of Gerontology, 43,* 145–150. (Study I: PA)

Rabinowitz, J. C. (1984). Aging and recognition failure. *Journal of Gerontology, 39,* 65–71. (PA)

Rabinowitz, J. C. (1989). Age deficits in recall under optimal study conditions. *Psychology and Aging, 4,* 378–380. (LR)

Rabinowitz, J. C., Ackerman, B. P., Craik, F. I. M., & Hinchley, J. L. (1982). Aging and metamemory: The roles of relatedness and imagery. *Journal of Gerontology, 37,* 688–695. (PA)

Rabinowitz, J. C., & Craik, F. I. M. (1986). Prior retrieval effects in young and old adults. *Journal of Gerontology, 41,* 368–375. (Study I: LR, Study II: LR)

Rabinowitz, J. C., Craik, F. I. M., & Ackerman, B. P. (1982). A processing resource account of age differences in recall. *Canadian Journal of Psychology, 36,* 325–344. (Study I: LR, Study II: PA)

Rankin, J., & Hinrichs, J. (1983). Age, presentation rate and the effectiveness of structural and semantic recall cues. *Journal of Gerontology, 38,* 593–596. (LR)

Rankin, J., Karol, R., & Tuten, C. (1984). Strategy use, recall, and recall organization in young, middle-aged, and elderly adults. *Experimental Aging Research, 10,* 193–196. (LR)

Rebok, G. W., & Balcerak, L. J. (1989). Memory self-efficacy and performance differences in young and old adults: The effect of mnemonic training. *Developmental Psychology, 25,* 714–721. (LR)

Rice, G. E., & Meyer, B. J. F. (1986). Prose recall: Effects of aging, verbal ability and reading behavior. *Journal of Gerontology, 41,* 469–480. (PR)

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. (Study I: LR, Study II: LR)

Rose, T. L., & Yesavage, J. A. (1983). Differential effects of a list-learning mnemonic in three age groups. *Gerontology, 29,* 293–298. (LR)

Salthouse, T. A., Kausler, D., & Saults, J. S. (1988). Investigation of student status, background variables, and feasability of standard tasks in cognitive aging research. *Psychology and Aging, 3,* 29–37. (Study I: PA, Study II: PA)

Sanders, R. E., Murphy, M. D., Schmitt, F. A., & Walsh, K. K. (1980). Age differences in free recall rehearsal strategies. *Journal of Gerontology, 35,* 550–558. (LR)

Shaps, L. P., & Nilsson, L.-G. (1980). Encoding and retrieval operations in relation to age. *Developmental Psychology, 16,* 636–643. (Study I: PA, Study II: PA)

Shaw, R. J., & Craik, F. I. M. (1989). Age differences in predictions and performance on a cued recall task. *Psychology and Aging, 4,* 131–135. (LR)

Simon, E. (1979). Depth and elaboration of processing in relation to age. *Journal of Experimental Psychology: Human Learning and Memory, 5,* 115–124. (Study I: LR)

Simon, E. W., Dixon, R. A., Nowak, C. A., & Hultsch, D. F. (1982). Orienting task effects on text recall in adulthood. *Journal of Gerontology, 37,* 575–580. (PR)

Stine, E. A. L., Wingfield, A., & Myers, S. D. (1990). Adult age differences in processing information from television news: The effects of bisensory augmentation. *Journals of Gerontology: Psychological Sciences, 45,* 1–8. (PR)

Taub, H. A. (1975). Mode of presentation, age, and short-term memory. *Journal of Gerontology, 30,* 56–59. (PR)

Taub, H. A., & Kline, G. E. (1978). Recall of prose as a function of age and input modality. *Journal of Gerontology, 33,* 725–730. (PR)

Treat, N. J., & Reese, H. W. (1976). Age, pacing, and imagery in paired-associate learning. *Developmental Psychology, 12,* 119–124. (PA)

Tun, P. A. (1989). Age differences in processing expository and narrative text. *Journal of Gerontology: Psychological Sciences, 44,* 9–15. (PR)

Winograd, E., & Simon, E. W. (1980). Visual memory and imagery in the aged. In L. W. Poon, L. S. Cermak, D. Arenberg, & L. W. Thompson (Eds.), *New directions in memory and aging* (pp. 485–506). Hillsdale, NJ: Erlbaum. (LR)

Winograd, E., Smith, A. D., & Simon, E. W. (1982). Aging and the picture superiority effect in recall. *Journal of Gerontology, 37,* 70–75. (Studies I–III: LR)

Worden, P. E., & Meggison, D. L. (1984). Aging and the category-recall relationship. *Journal of Gerontology, 39,* 322–324. (LR)

Worden, P. E., & Sherman-Brown, S. (1983). A word-frequency cohort effect in young versus elderly adults' memory for words. *Developmental Psychology, 19,* 521–530. (Study I: LR, Study II: LR)

Wright, R. E. (1982). Adult age similarities in free recall output order and strategies. *Journal of Gerontology, 37,* 76–79. (LR)

Zacks, R. T., Hasher, L., Doren, B., Hamm, V., & Attig, M. S. (1987). Encoding and memory of explicit and implicit information. *Journal of Gerontology, 42,* 418–422. (PR)

Zelinski, E. M., Gilewski, M. J., & Thompson, L. W. (1980). Do laboratory tests relate to self-assessment of memory ability in the young and old? In L. W. Poon, F. L. Fozard, L. S. Cermak, D. Arenberg, & L. W. Thompson (Eds.), *New directions in memory and aging* (pp. 519–544). Hillsdale, NJ: Erlbaum. (LR, PR)

Zelinski, E. M., Light, L. L., & Gilewski, M. J. (1984). Adult age differences in memory for prose: The question of sensitivity to passage structure. *Developmental Psychology, 20,* 1181–1192. (Studies I–III: PR)

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. (Study I: PR, Study II: PR)

Zelinski, E. M., Walsh, D. A., & Thompson, L. W. (1978). Orienting task effects on EDR and free recall in three age groups. *Journal of Gerontology, 33,* 239–245. (LR)

Zivian, M. T., & Darjes, R. W. (1983). Free recall by in-school and out-school adults: Performance and metamemory. *Developmental Psychology, 19,* 513–520. (LR)

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