Age and Storage Dynamics in Continuous Recognition Memory

WAYNE A. WICKELGREN
University of Oregon

Continuous recognition memory for English words was studied in three age groups, with mean age for the groups being 9.5, 21, and 68 years, respectively. Words were presented at a rate of 3 seconds/word in a 2.6-hour session, with subjects deciding whether or not each word had been presented earlier in the session. Young adults had substantially superior acquisition compared to elderly adults, who were in turn superior in acquisition to the children. However, the form and rate of the retention function was the same for all three age groups, and storage dynamics appear to be invariant with age.

On the average, children and elderly subjects perform less well in learning and memory tasks than do young adults. Are these deficiencies of young and old subjects due to differences in storage dynamics (retention) or to acquisition or retrieval? In addition to this distinction, it is important to distinguish between basic unconscious storage processes, on the one hand, and conscious rehearsal processes, on the other hand. The incidence of spontaneous rehearsal is known to increase from childhood to adulthood (Belmont & Butterfield, 1971; Flavell, Beach, & Chinsky, 1966), and it may be that this decreases in old age. To study the rate of forgetting as a function of age, it is important to exclude age differences in acquisition, rehearsal, and retrieval.

Some investigators have concluded that one should compare forgetting only for retention functions that have been equated for the strength of the memory trace at some point. One way to accomplish this has been to equate degree of learning by giving more study time to the slower learning group. To the extent that distributing practice over a longer period of time may produce slower forgetting or to the extent to which groups learning more slowly encode in less distinctive ways that may be associated with faster forgetting, such a procedure is prone to serious problems of its own. Another principal method has been to slide one retention function along the time axis until it coincides with the other retention function at some early point and then compare the subsequent form and rate of forgetting. Because of Jost's Second Law (see Wickelgren, 1972), this method is inappropriate since the rate of forgetting is continually decreasing with increasing trace age.

Belmont and Butterfield (1969), in a critical review, concluded that the forgetting rate for short-term memory in children was invariant with age for both verbal and nonverbal material. Berch and Evans (1973) studied continuous recognition memory for numbers over retention intervals ranging from seconds to minutes. In continuous recognition memory, subjects decide as each item is presented whether or not it was presented previously. Berch and Evans found no significant difference in the decay rate for 5.5-year-olds and 9-year-olds, though the initial level of acquisition was lower for the younger children. The use of recognition memory rather than recall minimizes differences in retrieval effectiveness as a function of age.

This work was supported by Grant 3-0097 from the National Institute of Education, by Grant MH 17958 from the National Institute of Mental Health, and by Contract F 44620-73-C-0056 from the Advanced Research Projects Agency, U. S. Department of Defense.

Requests for reprints should be sent to Wayne A. Wickelgren, Psychology Department, University of Oregon, Eugene, Oregon 97403.

Reprinted from and copyrighted as part of *Developmental Psychology*, Vol. 11, No. 2, 1975, American Psychological Association, Inc.

Nelson (1971) studied long-term picture recognition memory, employing two retention intervals, zero and 14 days. Nelson found no differences in either degree of learning or rate of decay over the age range from 7 to 13 years. This finding was obtained for a wide range of initial degrees of learning obtained by using three different types of pictures varying substantially in memorability and two different durations of presentation. Using pictures minimizes differences in rehearsal as a function of age. Brown and Scott (1971) also studied recognition memory for pictures in preschool children (ages 3 to 5) and found retention functions (from 1 to 28 days) that approximately paralleled those found by Nickerson (1965) for adults, though acquisition was lower in children. Finally, Fajnsztejn-Pollack studied picture recognition memory using retention intervals from 2 to 49 weeks, and found the form of the retention function and the forgetting rate for pictures to be invariant from 5 to 16 years of age. For a critical review of a number of earlier, less satisfactory studies of developmental changes in long-term retention, see Fajnsztejn-Pollack (1973).

There are fewer studies of retention in elderly subjects. A short-term recall study by Talland (1967) found no differences between elderly and young subjects in the rate of forgetting of a consonant trigram over a 3- to 18-second interval filled with backward counting. Even the degree of learning was comparable for older and younger subjects when there was no opportunity for differential rehearsal prior to beginning the backward counting. Craik (1971) studied the effects of aging on short-term retention for a list of seven two-digit numbers, using a probe recognition test. Craik compared the performance of groups of 23-, 47-, and 76-year-old subjects and found the young subjects to have a higher degree of learning than the middle subjects, who in turn showed a slightly higher degree than the old subjects, with no difference in the form or rate of the retention function from 3 to 9 seconds. Since there were five points on each retention function and substantial forgetting was obtained over this time interval, the conclusion of comparable forgetting rates was relatively well established.

Harwood and Naylor (1969) tested long-term recognition memory in 45-year-olds and 68-year-olds for a set of 20 line drawings of familiar objects. Some attempt was made to equate degree of learning on the basis of an immediate recall measure. However, equating performance on a recall measure, which is subject to a variety of retrieval interference effects, does not necessarily equate for degree of learning as measured by a recognition test. Harwood and Naylor found that both recognition and recall were poorer after 4 weeks in the older group than in the younger group. Hulicka and Weiss (1965) found insignificantly less forgetting over a period from 20 minutes to 1 week in elderly as opposed to young subjects. Wimer and Wigdor (1958) found no age difference in retention over a 15-minute period, but Wimer (1960) did find significantly poorer retention for old subjects measured after a 24-hour retention interval. Neither study employed more than one retention interval, relying on learning to a common criterion to equate the degree of learning, with no attempt to assess differences in degree of learning achieved on the final study trial. Gladis and Braun (1958) found that an apparent inferiority in recall by older subjects after interfering learning could be entirely accounted for on the basis of differences in the rate of original and interpolated learning as well as the vocabulary levels of the different age groups.

Overall, previous studies suggest that rate of forgetting may be invariant with age in the elderly, but the evidence is not strong, especially for long-term retention. In the present study, retention functions are compared for children with those for young adults and elderly subjects in continuous recognition memory for words over retention intervals ranging from 2 minutes to 2 hours.

Method

Subjects

There were three groups of 10 subjects each. The youngest group ranged in age from 8 to 10, averaging 9.5 years of age; the middle group ranged in age from 19 to 24, with a mean age of 21 years; and the oldest group ranged in age from 60 to 82, averaging 68 years of age. The youngest group contained 4 males and 6 females obtained from families associated with the Psychology Department, University of Oregon. The middle group contained 5 males and 5 females obtained from the Student Employment Office. The elderly group was composed of 4 males and 6 females recruited using a newspaper ad. Because there was no attempt made to select comparable samples from different age groups, no significance should be attached to comparisons of overall level of memory performance but only to comparisons of the forms and rates of the forgetting functions.

Procedure

Subjects read a word and decided whether or not it had been presented previously, also giving their confidence on a 4-point scale. The rate of presentation was 3 seconds/word, and the entire session was run without a break in 2.6 hours for all three groups of subjects. Subjects were instructed not to rehearse (think of) previously presented words, concentrating only on the current item. Subjects were also instructed to base their decisions on the immediate familiarity of the presented word, without attempting to use any more complex retrieval strategies. The very limited period of 3 seconds in which to make each response reinforced this instruction.

Materials

Words were selected from a population of 9,915 most frequent nouns, verbs, adjectives, and adverbs, according to the Thorndike-Lorge (1944) word count. Proper nouns were excluded from the population and an attempt was made to include only one word-class variation of the same stem (e.g., *contribute, contribution,* etc.). Words were presented through the window of a Lafayette Instrument Company memory drum that uses computer output paper.

Design

All of the trials on which an item was presented for the first time in the session made up the "new" condition (to which the correct response is no). In addition to the new condition, there were 10 different "old" conditions (trials on which the item had appeared previously at one of 10 different delays). The delays were 2, 4, 6, 8, 12, 24, 48, 72, 96, and 120 minutes. Most words appeared on two trials of the session of 3,120 trials (once in the new condition and once in some old condition). Some words appeared only once as fillers necessary for achieving the proper retention intervals, but which could not themselves be tested. The assignment of a trial to a particular condition was accomplished by a computer using the following procedure. Starting at the beginning of a list, the computer program randomly picked a condition to which to assign Trial 1. There were 10 design conditions, one for each retention interval. On Trial 1, the computer randomly picked a design condition from the 10 and assigned it to that trial. This committed Trial 1 to be a new condition and committed some future trial, at the appropriate retention interval, to be a test of that same word. The computer then randomly selected some word out of the 9,915 possible to fill into those two trials. On Trial 2 the program randomly selected one of the remaining 9 design conditions and picked a new word to be inserted on Trial 2 and at the appropriate later trial. Sometimes the randomly selected design condition would commit a future trial that had already been committed by a previous trial. In this case, a new condition was randomly selected, and so on until one was found that would "fit." The program always attempted to achieve n replications of a given design condition before achieving $n + 1$ replications of any condition.

Analysis

Using the statistical decision theory methods described in Green and Swets (1966), Wickelgren and Norman (1966), and Wickelgren (1968), memory strength discriminability values (d' values) were obtained from memory operating characteristics that plotted each old-item condition against the new-item condition. Operating characteristics were fitted by least squares on the perpendicular distance of the points to the operating characteristic line. Actually, the d_s value was determined for each operating characteristic by the intersection of the operating characteristic with the negative diagonal. This d_s value has lower variance than d' (the x intercept of the operating characteristic), but is a biased estimate of d', when the slope of the operating characteristic differs from unity. To achieve an estimate of d' that had the low variance of the d_s estimate and was also unbiased, a linear regression of log slope (log m) on d_s was determined under the assumption that log slope was zero at $d_s = 0$. In other words, the parameter k was estimated in the equation: $\log m = kd_s$, ($m = e^{kd_s}$). This estimate of k was used to correct all d_s values (to get an estimate, d_a, of d' that was unbiased as well as having low variance) using the following equation: $d_a = \frac{1}{2}d_s(1 + e^{-kd_s})$.

The d_a value for each retention interval is the mean difference in memory strength for an old item tested at that delay and a new item (whose mean strength can be assumed to be zero since this is an interval scale). Thus, the retention function consists of a plot of some function of d_a as the dependent variable against some function of retention interval (time) as the independent variable. The choices of the appropriate functions of the dependent and independent variable depend on what theoretical function best describes long-term retention. The decision concerning the correct form of a retention function should be based on results for a wide variety of studies rather than that of a single study and each new study provides an additional test of the adequacy of that function. The theoretical retention function used to fit the current data was derived from the single-trace fragility theory (Wickelgren, 1974), and arguments favoring that theory are presented in that paper. In this case, the form of the retention function is as follows:

$$d_a = \lambda(1 + .022t)^{-\psi} \qquad (1)$$

In the above function, t is measured in seconds, and thus all values of t in the current experiment are sufficiently large that log d_a is approximately linear with log t. Thus, a plot of log d_a against log t should yield a straight line with the λ parameter (namely, the d_a value at $t = 0$) representing the degree of learning and the ψ parameter representing the rate of decay (slope of the straight line, when log d_a is plotted against log t). In this way, acquisition and decay rate parameters are separated and estimated from the data. The d_a values were calculated for each individual subject and averaged logarithmically to obtain an average function for young, middle, and old subjects.

Results and Discussion

The average retention functions for young, middle, and old subjects are shown in Figure 1 along with the best fitting straight lines derived from Equation 1 of single-trace fragility theory (Wickelgren, 1974). Table 1 presents the acquisition (λ) and decay rate (ψ) parameters for young, middle, and old subjects according to Equation 1.

Although there are substantial differences in degree of learning such that the young adults have a significantly higher degree of learning than elderly subjects ($p < .05$, Mann-Whitney U test), who are, in turn, superior to the children ($p < .05$, Mann-Whitney U test), there are no significant differences in the decay rate across the three age groups (by a Mann-Whitney U test on rates for individual subjects and by a t test for slope differences for average retention functions). Moreover, note that what slight differences there are would be eliminated or reversed if d_a were chosen as the dependent variable, instead of log d_a.

The present study has several advantages over previous studies of long-term retention, especially those concerned with elderly subjects. First, recognition memory was tested rather than recall. This minimizes differences in retrieval interference and retrieval strategies that might confound a comparison of storage dynamics. Second, a wide variety of retention intervals was used both to increase the power of the comparison of forgetting rates and also to permit comparison of the forms of the retention functions for different age groups. Third, a measure of the dependent memory trace (namely, log d') was used which has some possibility of being theoretically appropriate. Fourth, a large population of items was presented at a fast rate so as to minimize opportunities for rehearsal of the material by any age group.

Thus, some confidence can be placed in the conclusion that memory storage dynamics are equivalent over different ages, especially since the conclusion of this study coincides with the conclusion reached by many prior studies. However, in view of the substantial problems regarding the comparision of storage dynamics for different age groups, it should be apparent that this conclusion has to remain tentative until the basic theory of storage dynamics can be determined.

Table 1: Acquisition and Decay Rate for Children, Young Adults, and Elderly Subjects

Subjects	λ	ψ	r^2
Children	1.0	.26	.68
Adults	3.0	.26	.91
Elderly	1.8	.24	.81

Note. $d_a = \lambda(1 + .022t)^{-\psi}$. λ = Acquisition; ψ = decay rate. r^2 is the percentage of variance in the data for which the theory accounts.

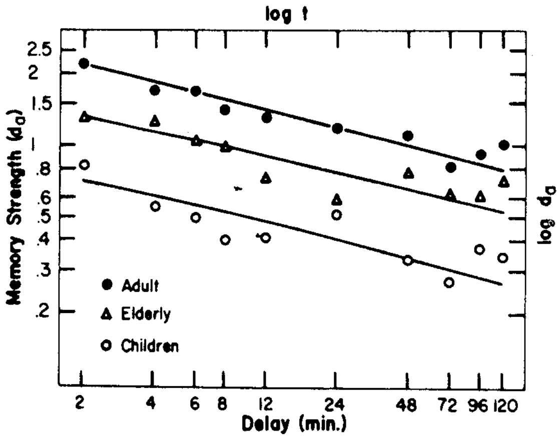

Figure 1 Memory strength retention functions for children, young adults, and elderly subjects with best-fitting theoretical lines derived from single-trace fragility theory.

REFERENCES

Belmont, J. M., & Butterfield, E. C. The relations of short-term memory to development and intelligence. In L. P. Litsitt & H. W. Reese (Eds.), *Advances in child development and behavior* (Vol. 4). New York: Academic Press, 1969.

Belmont, J. M., & Butterfield, E. C. What the development of short-term memory is. *Human Development*, 1971, **14**, 236-248.

Berch, D. B., & Evans, R. C. Decision processes in children's recognition memory. *Journal of Experimental Child Psychology*, 1973, **16**, 148-164.

Brown, A. L., & Scott, M. S. Recognition memory for pictures in preschool children. *Journal of Experimental Child Psychology*, 1971, **11**, 401-412.

Craik, F. I. M. Age differences in recognition memory. *Quarterly Journal of Experimental Psychology*, 1971, **23**, 316-323.

Fajnsztejn-Pollack, G. A developmental study of decay rate in long-term memory. *Journal of Experimental Child Psychology*, 1973, **16**, 225-235.

Flavell, J. H., Beach, D. R., & Chinsky, J. M. Spontaneous verbal rehearsal in a memory task as a function of age. *Child Development,* 1966, **37,** 283-299.

Gladis, M., & Braun, H. W. Age differences in transfer and retroaction as a function of intertask response similarity. *Journal of Experimental Psychology,* 1958, **55,** 25-29.

Green, D. M., & Swets, J. A. *Signal detection theory and psychophysics.* New York: Wiley, 1966.

Harwood, E., & Naylor, G. F. K. Recall and recognition in elderly and young subjects. *Australian Journal of Psychology,* 1969, **21,** 251-257.

Hulicka, I. M., & Weiss, R. L. Age differences in retention as a function of learning. *Journal of Consulting Psychology,* 1965, **29,** 125-129.

Nelson, K. E. Memory development in children: Evidence from nonverbal tasks. *Psychonomic Science,* 1971, **25,** 346-348.

Nickerson, R. S. A note on long-term recognition memory for pictoral material. *Psychonomic Science,* 1965, **11,** 58.

Talland, G. Age and the immediate memory span. *Gerontologist,* 1967, **7,** 4-9.

Thorndike, E. L., & Lorge, I. *The teacher's word book of 30,000 words,* New York: Bureau of Publications, Teachers College, 1944.

Wickelgren, W. A. Unidimensional strength theory and component analysis of noise in absolute and comparative judgments. *Journal of Mathematical Psychology,* 1968, **5,** 102-122.

Wickelgren, W. A. Trace resistance and the decay of long-term memory, *Journal of Mathematical Psychology,* 1972, **9,** 418-455.

Wickelgren, W. A. Single-trace fragility theory of memory dynamics. *Memory & Cognition,* 1974, **2,** 775-780.

Wickelgren, W. A., & Norman, D. A. Strength models and serial position in short-term recognition memory. *Journal of Mathematical Psychology,* 1966, **3,** 316-347.

Wimer, R. E. A supplementary report on age differences in retention over a twenty-four hour period. *Journal of Gerontology,* 1960, **15,** 417-418.

Wimer, R. E., & Wigdor, B. T. Age differences in retention of learning. *Journal of Gerontology,* 1958, **13,** 291-295.

(Received May 6, 1974)