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# Fact Retrieval in Younger and Older Adults: The Role of Mental Models

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Using a fan effect paradigm, three experiments tested whether younger and older adults differ in the retrieval of integrated and nonintegrated facts, where integration refers to the development of a mental model. Earlier work by G. A. Radvansky and R. T. Zacks (1991) had found that as long as facts can be integrated into a single mental model, young adults show no increase in retrieval time or error rates as the size of the subset of related facts increases (i.e., no fan effect). The present studies show a similar pattern for older adults. By contrast, and in confirmation of our previous findings on age differences and the fan effect (L. D. Gerard, R. T. Zacks, L. Hasher, & G. A. Radvansky, 1991), older adults show an exaggerated fan effect, at least in their error rates, on subsets of related facts not easily integrated into a single mental model.

The purpose of the present experiments is to assess how younger and older adults compare in the construction and use of mental models (e.g., Johnson-Laird, 1983, 1989). A *mental model* is a representation of a described situation rather than a representation of a text itself or the propositions conveyed by a text. The structure of a mental model corresponds to the functional relations among entities as they would exist in the world. As such, a mental model can be thought of as a simulation of events in the world, either real or imaginary.

The idea of a mental model can be conveyed by considering a study by Garnham (1982). In that study, people who originally heard the sentence "The hostess bought a mink coat *from* the furrier" were likely to mistakenly claim that the sentence "The hostess bought a mink coat *at* the furrier's" was heard before. In contrast, people who originally heard the sentence "The hostess received a telegram *from* the furrier" were not likely to mistakenly claim that the sentence "The hostess received a telegram *at* the furrier's" was heard before. The first two sentences potentially describe the same situation, and therefore correspond to a single mental model, whereas the second two sentences do not.

There is some evidence that young and older adults create and use mental models similarly (Morrow, Leirer, & Altieri, 1992; Radvansky, Gerard, Zacks, & Hasher, 1990). In a study modeled after the Garnham (1982) experiment described previously, Radvansky et al. found that young and older adults used mental model representations to identify previously heard statements on a later recognition test. The two groups showed the same pattern of confusion errors on the recognition test, suggesting that younger and older adults create similar types of mental models and then use these representations during recognition.

One specific aspect of mental models on which young and older adults seem not to differ is foregrounding. Foregrounding refers to keeping certain story elements, such as the protagonist, more available than other elements (e.g., Garrod & Sanford, 1983; Glenberg, Meyer, & Lindem, 1987). In a study by Morrow et al. (1992), people read a passage followed by a series of comprehension questions that referred back either to the protagonist or to minor characters. Although young adults outperformed older adults overall, both groups more accurately identified the foregrounded story protagonists than the minor characters. In fact, performance on questions referring to the protagonist was identical in the two age groups. These findings suggest that both age groups form similar mental models. The current experiments expand on this earlier research by comparing young and older adults' use of mental models with sets of facts presented outside of a connected discourse.

In previous studies with young adults, we (Radvansky, Spieler, & Zacks, 1993; Radvansky & Zacks, 1991) have demonstrated that the use of mental models to integrate potentially competing items of information results in the elimination of the negative impact of competitors at retrieval. This finding was observed in the context of a fan effect paradigm (Anderson, 1974). The fan effect is an increase in response time (RT) or error rate in recognizing learned facts with an increase in the number of other facts having a concept in common with the probed fact. Our research has shown that the fan effect is eliminated when facts having a concept in common can be readily integrated into a single mental model. In contrast, the standard fan effect is obtained when facts having a common concept can-

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not be integrated into a single mental model. Because of a possible elevated susceptibility to competition at retrieval, leading to poorer memory performance for older adults relative to younger adults (e.g., Winocur & Moscovitch, 1983), it is of interest to learn whether older adults can use mental models to reduce the influence of competing associations during retrieval.

The present experiments used a procedure developed by Radvansky et al. (1993) and Radvansky and Zacks (1991) to manipulate the ease of integrating facts having a common concept into a single mental model. As an example of one condition, suppose that the following facts were memorized: "The pay phone is in the barber shop," "The pay phone is in the city hall," and "The pay phone is in the laundromat." This corresponds to what we call a multiple locations (ML) condition. According to a standard (i.e., propositional) account (e.g., Anderson, 1983) of how such materials are stored in long-term memory, these facts should be interconnected in an associative network through their sharing of the concept "pay phone," and a fan effect should occur. Our mental model view also predicts a fan effect for ML conditions. Although all three facts share a common concept, these ideas are inconsistent with a single situation in the world. It is unlikely that an object such as a pay phone would travel from place to place as part of a single situation. Each location is likely to be interpreted as a different situation. As a result, a separate mental model is constructed for each location containing a pay phone. During retrieval, not only is the appropriate mental model activated from long-term memory but so are the other mental models that contain a pay phone. These other mental models interfere with the retrieval of the desired representation. The more of these irrelevant representations there are, the greater the amount of interference; retrieval time and errors increase accordingly, hence, the fan effect.

Now suppose that the following facts were memorized: "The potted palm is in the hotel," "The waste basket is in the hotel," and "The ceiling fan is in the hotel." This corresponds to what we call a single location (SL) condition. According to a propositional network view, these facts should also be interconnected in the network through their sharing of the "hotel" concept and a fan effect should occur. In contrast, our mental model view predicts no fan effect for SL conditions. This is because all three of these facts are consistent with a single situation in the world. It is easy to conceive of a single situation in which a potted palm, a waste basket, and a ceiling fan are all in a hotel at the same time. As a result, a single mental model is constructed for that location. During fact retrieval, there are no related and irrelevant mental models to interfere with the retrieval of the appropriate one. Therefore, retrieval time and accuracy remain constant across different numbers of associations with a location.

Our previous research with younger adults (Radvansky et al., 1993; Radvansky & Zacks, 1991) has repeatedly upheld the predicted difference between SL and ML conditions and shown the effect to be insensitive to instructions to organize by other means, to the specific types of situations (e.g., location-based or person-based), to the use of definite versus indefinite articles, and to whether the location concepts serve as the sentence subject or predicate.

The current experiments tested whether older adults will create mental models from a randomly ordered list of facts in much the same way as younger adults. If older and younger adults are able to integrate the facts into mental models in a similar fashion, then similar differences between the ML and SL conditions should be found. In particular, there should be a fan effect for the ML condition but not the SL condition. If older adults are not able to integrate the facts into mental models as effectively as young adults, then older adults would show a fan effect in both the SL and ML conditions, whereas young adults would show a fan effect only in the ML condition.

Another issue addressed by this research is whether, under conditions involving retrieval interference (i.e., the ML conditions), older adults will show greater interference (fan) effects than young adults. Previous studies of the fan effect and aging have found that older adults do show a larger fan effect (Cohen, 1990; Gerard, Zacks, Hasher, & Radvansky, 1991). In the Gerard et al. study, participants memorized a list of sentences such as "The doctor cut the apple pie into six pieces." Across the entire list of study sentences, each sentence subject (e.g., "doctor") and predicate (e.g., "cut the apple pie into six pieces") had one to three associates. For example, the doctor could have been described as doing one to three things, such as cutting an apple pie into six pieces, taking a car for a test drive, and playing chess with a friend. Likewise, each activity could have been described as being performed by one to three people, such as the doctor, lawyer, and farmer. After memorizing a list of such sentences, participants were given a speeded recognition test. The results showed that both age groups produced a fan effect with the fan effect for the older adults being greater than that for the young adults. This was interpreted as showing that older adults have a greater difficulty ignoring non-goal path ideas. Generalizing to the current experiments, the fan effect in the ML condition should be larger for the older than the young adults. Furthermore, if older adults can and do form mental models, as the young adults have been shown to, neither age group should show a fan effect in the SL condition.

## Experiments 1 and 2

Three experiments tested whether older adults form and retrieve mental models in the same fashion as young adults and whether they experience greater interference during the retrieval of related facts represented in multiple mental models. The only difference between the first two experiments was that sentences that did not directly contribute to either the SL or ML conditions were not included in the recognition test of Experiment 1, whereas they were included in Experiment 2. Because this procedural difference did not produce any important differences in the pattern of data, the two experiments are presented together.

### *Method*

#### *Participants*

In Experiment 1, 28 native English-speaking participants were tested in each age group, whereas in Experiment 2, 32 people were tested in each age group. The younger adults were recruited from the Michigan State University subject pool and given partial class credit for their participation. The older adults were recruited from the greater Lansing community and provided their own transportation to the building. They were paid $8 for their participation. Normative data on participants' ages, years of education, and scores on the Wechsler Adult Intel-

Table 1
*Normative Data for the Participants in Experiments 1, 2, and 3*

| | Age | | Education | | WAIS-R[a] | | Shipley[b] | |
|---|---|---|---|---|---|---|---|---|
| Participants | Range | *M* | Range | *M* | Range | *M* | Range | *M* |
| | | | Experiment 1 | | | | | |
| Young adults | 18–21 | 19.0 | 12–15 | 12.9 | 35–64 | 46.8 | — | — |
| Older adults | 60–81 | 70.3 | 12–18 | 13.6 | 30–69 | 51.6 | — | — |
| | | | Experiment 2 | | | | | |
| Young adults | 18–28 | 19.8 | 12–15 | 13.3 | 31–64 | 46.5 | — | — |
| Older adults | 60–79 | 69.3 | 8–20 | 14.0 | 35–69 | 51.6 | — | — |
| | | | Experiment 3 | | | | | |
| Young adults | 18–23 | 20.2 | 12–15 | 13.5 | — | — | 25–36 | 31.3 |
| Older adults | 64–82 | 72.3 | 10–20 | 15.3 | — | — | 20–40 | 34.7 |

*Note.* WAIS-R = Wechsler Adult Intelligence Scale—Revised.
[a] Out of a maximum of 70. [b] Out of a maximum of 40.

ligence Scale—Revised (WAIS-R; Wechsler, 1981) vocabulary test are presented in Table 1. While the two age groups did not significantly differ in terms of the number of years of education, as is frequently the case in cognitive aging studies, the older adults scored significantly higher than the younger adults on the WAIS-R vocabulary test, $t_1(54) = 2.40$, $SE_1 = 2.01$, and $t_2(62) = 2.26$, $SE_2 = 2.27$ (subscript 1 refers to Experiment 1, whereas subscript 2 refers to Experiment 2). Eight additional older adults were replaced for failing to finish, 5 in Experiment 1 and 3 in Experiment 2. This was usually a result of either the experimenter or the participant having an appointment, and the experimental session running over the allotted time. More older adults had this difficulty because of the slower rate at which they proceeded through the experiment and their busier schedules.

## Materials

There were 18 study sentences of the form "The *object* is in the *location*." The creation of the study lists followed Radvansky et al. (1993). Although the object was always mentioned first and the location concept second in the present experiments, previous studies have shown that the order of the concepts does not change the obtained data (Radvansky et al., 1993; Radvansky & Zacks, 1991). In particular, SL–ML differences in RT and error rates are unaffected by whether the object or the location concept is mentioned first in the study sentences.

Each participant's study list sentences were generated through random pairings of objects (e.g., potted palm, waste basket, or cola machine) and locations (e.g., city hall, hotel, or barber shop) so that there were one to three associations with each object and location concept (thus defining Fan Levels 1 to 3). For details, see Radvansky et al. (1993). The conditions of interest are those in which either a single object is associated with several locations (ML) or a single location is associated with several objects (SL). However, to provide the appropriate number of associations for those critical items and to keep the number of memorized sentences to a minimum, the study lists included six sentences in which multiple objects were associated with multiple locations. These were in the 2-3, 3-2, and 3-3 fan cells of the design ($X$–$Y$ refers to $X$ number of associations with the object concept and $Y$ number of associations with the location concept). These filler sentences were not included in the recognition test of Experiment 1 but were included in the recognition test of Experiment 2. There were four sentences in which both the object and location concept had only one association each (1-1 fan). Two of these sentences were arbitrarily assigned to the SL condition and two to the ML condition so that the same data would not be used for Fan Level 1 in both conditions. Finally, there were two study sentences in each of the 1-2, 1-3, 2-1, and 3-1 cells that composed the ML and SL conditions, respectively.

## Procedure

Participants were tested individually in a single session lasting approximately 1 h. Participants were first administered the WAIS-R vocabulary test. After this, they went through a study-test procedure to memorize the sentences. For the study portion, the study-list sentences were presented one at a time in a random order. Sentences were displayed on an Apple IIe computer with a monochrome (green) monitor set in 40 column mode. Each sentence was viewed for 7 s. At the end of the study portion, participants were given a series of questions of the form "What is in the *location*?" and "Where is the *object*?" for each of the locations and objects, respectively. Participants reported their answers to the experimenter. If there was more than one answer to a question, they were told to provide all of the answers. Correct answers were given if any errors were made. After all of the test questions had been answered, participants returned to the study portion. This study-test procedure continued until all of the test questions could be answered correctly twice in a row. In Experiment 1, the younger adults required 4.8 study-test cycles, whereas the older adults required 5.8 cycles, $t_1(54) = 2.89$, $SE_1 = 0.35$. In Experiment 2, the younger adults required 3.9 cycles compared with 5.5 cycles for the older adults, $t_2(62) = 4.33$, $SE_2 = 0.35$. (Unless otherwise mentioned, $p < .05$ is assumed.)

After the study lists had been memorized, a speeded recognition test was given. The task was to indicate whether a probe sentence was studied or not. Studied sentences were items from the study list, whereas nonstudied sentences were generated by repairing objects and locations from sentences having the same fan sizes (e.g., the objects and locations of the two 1-2 fan sentences would be exchanged). In both experiments, there were 16 trials at each fan size for each probe type (studied or nonstudied). Participants indicated that a sentence was studied by pushing a button held in the right hand and indicated that a sentence was not studied by pushing a button held in the left hand. An 18 trial practice period was given before the actual recognition test to familiarize the participants with using the buttons in this way. During the practice session, the computer displayed a line that read either "SENTENCE STUDIED" or "SENTENCE NOT STUDIED" and the participant responded accordingly. If an error was made, either during practice or the actual test, feedback was given in terms of a line presented for 500 ms that read either "**ERROR** SENTENCE STUDIED" or "**ERROR** SENTENCE NOT STUDIED," whichever was appropriate.

Sentences in which there were multiple objects associated with multiple locations (non-SL and non-ML condition sentences) were not presented during the recognition test for Experiment 1 but were presented for Experiment 2, although they were not included in the main analysis. All of the studied and nonstudied sentences were presented in a random order within each of eight blocks, yielding a recognition test that was 192 trials long in Experiment 1 and 288 trials long in Experiment 2.

For the purpose of analysis, errors were trials in which the participant responded incorrectly. These trials were not included in the RT analysis. In addition, trials with responses faster than 500 ms and slower than 10 s, as well as those trials on which RTs were greater than 2.5 *SD* from the mean of a given cell for a participant, were excluded from the analysis, although they were not counted as errors. This trimming procedure eliminated 2.2% of the data in Experiment 1 and 2.3% in Experiment 2. At the end of the recognition test, a posttest was given composed of the questions from the list learning period. In Experiment 1, the younger adults made an average of 0.3 errors on the posttest compared with 2.1 errors for the older adults, $t_1(54) = 4.13$, $SE_1 = 0.43$; whereas, in Experiment 2, the younger adults made an average of 0.1 errors compared with 1.5 errors for the older adults, $t_2(62) = 5.61$, $SE_2 = 0.25$.

## Results

The results of both experiments showed that, although the older adults were slower and more error prone overall, both age groups produced the same patterns of data. In particular, there was a fan effect for conditions in which an object was in several locations (the ML condition) but not when several objects were all in the same location (the SL condition).[1] This pattern is present for both the studied and nonstudied probes and for both the RT and error rate data, supporting the notion the older and younger adults build and use similarly structured mental models. As such, the current results confirm the earlier findings of Morrow et al. (1992) and Radvansky et al. (1990) indicating age invariance in mental model use. We had also expected that the older adults would show larger fan effects in the ML condition than the younger adults (cf. Gerard et al., 1991). As will be seen, the error data, but not the RT data, confirmed this expectation as well. These data support the notion that aging is associated with increased difficulty ignoring sources of related, but irrelevant, information.

In the next sections, we first present the statistical analyses of the RT data followed by the analyses of the error rate data. Within each of these sections, those effects that collapse across age are presented first to provide a general perspective on the data. Following this, those analyses pertaining to the effects of age are presented. A final section compares the younger and older adults on the difference between the fan 1-1 and fan 3-3 conditions from Experiment 2 (the 3-3 cell was not present in the recognition test of Experiment 1). This compares the condition involving the fewest number of associations with the condition involving the greatest number of associations. This comparison is not included in the main analysis because the items from the 3-3 condition cannot be easily classified as belonging to either the SL or ML conditions. If there is a difference in the retrieval performance of the older and younger adults, it should be most prominent in the 1-1 versus 3-3 comparison.

### *Response Times*

The data from each experiment were submitted to a 2 (age) × 2 (studied–nonstudied) × 2 (SL–ML) × 3 (fan) mixed analysis of variance (ANOVA). The first variable was between subjects and the rest were within. The main effects and interactions that do not involve the SL–ML difference are not central to the predictions made here and so are simply reported in Table 2. In general, these show typical effects of age, fan level, and studied–nonstudied items.

*General mental model organization.* The relevant data collapsed over age are presented in Table 3. In both experiments, the SL–ML × Fan interaction was significant, $F_1(2, 108) = 16.4$, $MSE = 143{,}991$, and $F_2(2, 124) = 22.5$, $MSE = 97{,}744$ (as a reminder, Subscript 1 refers to Experiment 1, whereas Subscript 2 refers to Experiment 2). Simple effects tests showed that the fan effect was significant for the ML conditions, $F_1(2, 108) = 21.0$, $MSE = 203{,}961$, and $F_2(2, 124) = 50.8$, $MSE = 106{,}184$, but not the SL conditions, both $Fs < 1$. Thus, collapsed across age, these data are consistent with earlier findings (Radvansky et al., 1993; Radvansky & Zacks, 1991) showing that the utilization of mental models eliminates the fan effect.

In addition, it was observed that SL probes were responded to faster than ML probes, $F_1(1, 54) = 72.6$, $MSE = 152{,}655$, and $F_2(1, 62) = 64.3$, $MSE = 128{,}674$. The Studied–Nonstudied × SL–ML interactions were also significant, $F_1(1, 54) = 15.7$, $MSE = 86{,}778$, and $F_2(1, 62) = 19.5$, $MSE = 41{,}525$. The SL–ML differences were larger for nonstudied probes (Experiment 1 = 347; Experiment 2 = 273 ms) than for studied probes (Exp. 1 = 167; Exp. 2 = 143 ms). Simple effects tests showed that the effects of SL–ML were significant for both studied probes, $F_1(1, 54) = 38.6$, $MSE = 60{,}747$, and $F_2(1, 62) = 31.4$, $MSE = 62{,}191$, and nonstudied probes, $F_1(1, 54) = 56.5$, $MSE = 178{,}678$, and $F_2(1, 62) = 66.0$, $MSE = 108{,}008$.

Finally, in Experiment 2, the Studied–Nonstudied × SL–ML × Fan interaction was significant, $F_2(2, 124) = 8.2$, $MSE = 64{,}857$. The SL–ML × Fan interaction was significant for both the studied, $F_2(2, 124) = 5.5$, $MSE = 56{,}726$, and nonstudied probes, $F_2(2, 124) = 22.9$, $MSE = 105{,}875$. There was no SL fan effect for either the studied or nonstudied probes. In contrast, there was a fan effect for the ML probes, which was much larger for nonstudied probes than for studied probes. The larger SL–ML difference for nonstudied probes is consistent with the notion that there are more mental models involved in memory retrieval for these probes than for the studied probes. On a nonstudied probe trial, the number of mental models activated would include all of those associated with both the object and location concepts.

*Aging effects.* The data on age differences in RT for Experiments 1 and 2 are summarized in Figures 1 and 2, respectively. The Age × SL–ML and Age × SL–ML × Fan interactions were

[1] The absence of a fan effect in the SL condition could be seen as similar to the *min* effect described by Anderson (1976). Specifically, the *min* effect is the finding that fan effects are sometimes reduced or absent when one of the concepts in a recognition probe has only a single association. This is the case with respect to the object concept in our SL condition. However, it should be noted that it is also true that there is only a single association with the location concept in the ML condition. As such, the *min* effect cannot be used to explain the current difference in the SL and ML fans.

Table 2
*Analysis of Variance Results and Means for the Response Time Data (in Milliseconds)*
*Effects Not Involving the SL–ML Factor*

| Effect | *F* | *df* | *MSE* | | *M* |
|---|---|---|---|---|---|
| | | | Experiment 1 | | |
| Age | 8.1* | 1, 54 | 3,059,550 | Young | 1,712; |
| | | | | Old | 2,096 |
| S–NS | 96.4* | 1, 54 | 111,138 | S | 1,778; |
| | | | | NS | 2,030 |
| Age × S–NS | 9.4* | 1, 54 | 111,138 | Young | |
| | | | | S | 1,625; |
| | | | | NS | 1,799 |
| | | | | Old | |
| | | | | S | 1,930; |
| | | | | NS | 2,262 |
| Fan | 13.9* | 2, 108 | 142,889 | Fan level | |
| | | | | 1 | 1,815 |
| | | | | 2 | 1,894 |
| | | | | 3 | 2,003 |
| Age × Fan | 2.2 | 2, 108 | 142,889 | Young | 1,616; 1,743; 1,777 |
| | | | | Old | 2,014; 2,045; 2,228 |
| S–NS × Fan | 6.9* | 2, 108 | 91,084 | S | 1,734; 1,781; 1,818 |
| | | | | NS | 1,896; 2,008; 2,187 |
| Age × S–NS × Fan | 2.3 | | | Young | |
| | | | | S | 1,549; 1,660; 1,666 |
| | | | | NS | 1,683; 1,826; 1,888 |
| | | | | Old | |
| | | | | S | 1,919; 1,901; 1,970 |
| | | | | NS | 2,110; 2,189; 2,486 |
| | | | Experiment 2 | | |
| Age | 20.4* | 1, 62 | 1,415,405 | Young | 1,527 |
| | | | | Old | 1,915 |
| S–NS | 95.7* | 1, 62 | 81,954 | S | 1,620 |
| | | | | NS | 1,822 |
| Age × S–NS | 4.2* | 1, 62 | 81,954 | Young | |
| | | | | S | 1,447 |
| | | | | NS | 1,607 |
| | | | | Old | |
| | | | | S | 1,793 |
| | | | | NS | 2,037 |
| Fan | 29.8* | 2, 124 | 108,692 | Fan level | |
| | | | | 1 | 1,620 |
| | | | | 2 | 1,702 |
| | | | | 3 | 1,842 |
| Age × Fan | 1.0 | 2, 124 | 108,692 | Young | 1,417; 1,531; 1,634 |
| | | | | Old | 1,822; 1,873; 2,051 |
| S–NS × Fan | 6.9* | 2, 124 | 75,776 | S | 1,567; 1,595; 1,699 |
| | | | | NS | 1,673; 1,810; 1,985 |
| Age × S–NS × Fan | 1.1 | 2, 124 | 75,776 | Young | |
| | | | | S | 1,366; 1,460; 1,516 |
| | | | | NS | 1,468; 1,602; 1,751 |
| | | | | Old | |
| | | | | S | 1,767; 1,729; 1,883 |
| | | | | NS | 1,877; 2,017; 2,218 |
| | | | Experiment 3 | | |
| Age | 10.4* | 1, 54 | 3,359,441 | Young | 1,633 |
| | | | | Old | 2,088 |
| S–NS | 31.0* | 1, 54 | 81,308 | S | 1,800 |
| | | | | NS | 1,922 |
| Age × S–NS | 3.4 | 1, 54 | 81,308 | Young | |
| | | | | S | 1,592 |
| | | | | NS | 1,674 |
| | | | | Old | |
| | | | | S | 2,007 |
| | | | | NS | 2,170 |

(*table continues*)

Table 2 (*continued*)

| Effect | *F* | *df* | *MSE* | | *M* |
|---|---|---|---|---|---|
| | | | Experiment 3 | | |
| Fan | 7.1* | 2, 108 | 150,648 | Fan level | |
| | | | | 1 | 1,784 |
| | | | | 2 | 1,880 |
| | | | | 3 | 1,918 |
| Age × Fan | 1.7 | 2, 108 | 150,648 | Young | 1,585; 1,662; 1,654 |
| | | | | Old | 1,984; 2,099; 2,183 |
| S–NS × Fan | 9.7* | 2, 108 | 35,739 | S | 1,760; 1,822; 1,816 |
| | | | | NS | 1,808; 1,938; 2,020 |
| Age × S–NS × Fan | 1.41 | 2, 108 | 35,739 | Young | |
| | | | | S | 1,564; 1,630; 1,583 |
| | | | | NS | 1,605; 1,694; 1,724 |
| | | | | Old | |
| | | | | S | 1,956; 2,015; 2,049 |
| | | | | NS | 2,010; 2,183; 2,317 |

*Note.* SL–ML = single location–multiple locations; S = studied; NS = nonstudied.
* $p < .05$.

Table 3
*Response Time Means (in Milliseconds) for Experiments 1 and 2 Collapsed Across Age*

| Effect | Level of fan 1 | 2 | 3 | *M* |
|---|---|---|---|---|
| | Experiment 1 | | | |
| Single location | | | | |
| S | 1,754 | 1,652 | 1,676 | 1,694 |
| NS | 1,839 | 1,847 | 1,884 | 1,857 |
| *M* | 1,797 | 1,749 | 1,781 | 1,776 |
| Multiple locations | | | | |
| S | 1,714 | 1,909 | 1,960 | 1,861 |
| NS | 1,954 | 2,169 | 2,489 | 2,203 |
| *M* | 1,834 | 2,039 | 2,224 | 2,032 |
| | Experiment 2 | | | |
| Single location | | | | |
| S | 1,547 | 1,518 | 1,582 | 1,549 |
| NS | 1,658 | 1,701 | 1,699 | 1,686 |
| *M* | 1,602 | 1,610 | 1,641 | 1,618 |
| Multiple locations | | | | |
| S | 1,586 | 1,672 | 1,817 | 1,692 |
| NS | 1,688 | 1,918 | 2,270 | 1,959 |
| *M* | 1,637 | 1,795 | 2,044 | 1,825 |
| | Experiment 3 | | | |
| Single location | | | | |
| S | 1,780 | 1,778 | 1,753 | 1,770 |
| NS | 1,841 | 1,803 | 1,858 | 1,834 |
| *M* | 1,810 | 1,790 | 1,806 | 1,802 |
| Multiple locations | | | | |
| S | 1,741 | 1,867 | 1,879 | 1,829 |
| NS | 1,775 | 2,073 | 2,183 | 2,011 |
| *M* | 1,758 | 1,970 | 2,031 | 1,920 |

*Note.* S = studied; NS = nonstudied.

not significant: Experiment 1, Age × SL–ML interaction; $F_1(1, 54) = 2.7$, $MSE = 152{,}655$, $p > .10$, all other *F*s < 1. So, there is no difference between the young and older adults' retrieval patterns other than the fact that the older adults are slower overall (see Table 2).

Because the experiments were so similar, the RT data were analyzed together in an additional analysis as though it were a single experiment to increase statistical power. The Age × Fan interaction was significant in the combined analysis, $F(2, 236) = 3.1$, $MSE = 123{,}227$. While the fan effect pattern differed between the older (Fan Level 1 = 1,912 ms; 2 = 1,954 ms; 3 = 2,134 ms) and younger adults (Fan Level 1 = 1,510 ms; 2 = 1,630 ms; 3 = 1,700 ms), in that the greatest difference is from Fan Level 2 to 3 for the older adults and Fan Level 1 to 2 for the younger adults, the overall size of the effect was similar in the two age groups. However, the Age × SL–ML and Age × SL–ML × Fan interactions remained nonsignificant, *F*s < 1. Thus, even with this increased statistical power, there is still no suggestion that there is a difference in the retrieval patterns of the older and younger adults. What is consistently present, for both older and younger adults, is that there is a fan effect for the ML condition but not the SL condition.

*Analysis of 1-1 versus 3-3 fan.* The study reported by Gerard et al. (1991) compared performance across Fan Levels 1-1, 2-2, and 3-3. Because of the multiple associations for both sentence subjects and predicates in the 2-2 and 3-3 conditions, this comparison allows for a greater potential for observing interference than those reported above. The inclusions of the 1-1 and 3-3 cells in the recognition test in Experiment 2 (although the 3-3 cell was considered filler for the SL–ML analysis) permits a partial replication of the Gerard et al. analysis. Accordingly, the RT data from Experiment 2 were submitted to a 2 (age) × 2 (studied–nonstudied) × 2 (Fan 1-1 versus Fan 3-3) mixed ANOVA. There were significant main effects of age, $F(1, 62) = 25.5$, $MSE = 472{,}545$ (younger adults = 1,660 ms; older adults = 2,094 ms) and studied–nonstudied probes, $F(1, 62) = 19.1$, $MSE = 86{,}574$ (studied = 1,797 ms; nonstudied = 1,957 ms), as well as a significant Age × Studied–Nonstudied interac-

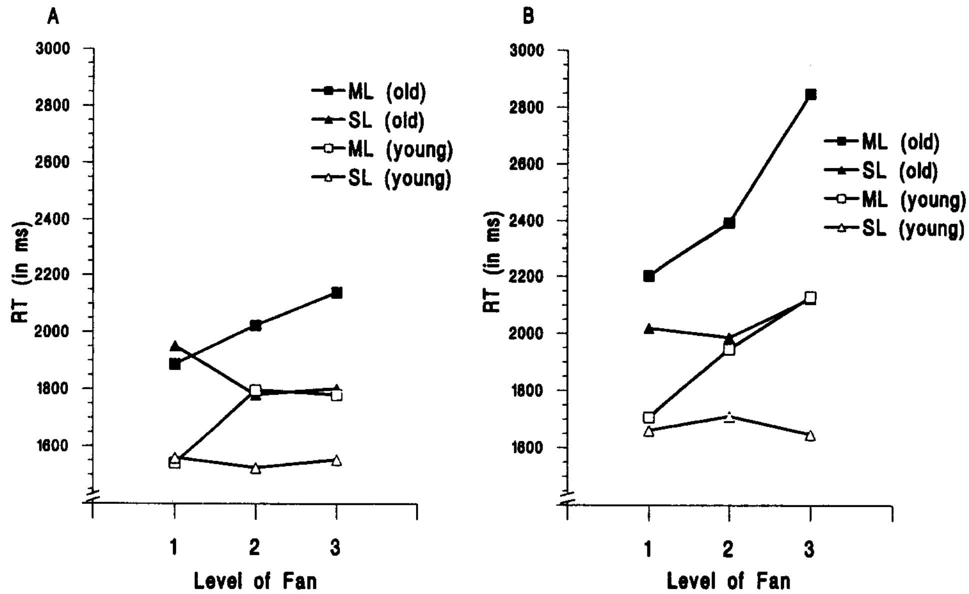


*Figure 1.* Response times (RTs) for single location (SL) and multiple locations (ML) conditions in Experiment 1 for both older and young adults. A = data from the studied trials; B = data from the nonstudied trials.

tion, $F(1, 62) = 4.9$, $MSE = 86{,}574$. In particular, the difference between the studied and nonstudied probes was larger for the older adults (studied = 1,973 ms; nonstudied = 2,215 ms) than for the younger adults (studied = 1,620 ms; nonstudied = 1,700 ms). In addition, there was a significant main effect of fan, $F(1, 62) = 118.7$, $MSE = 142{,}796$ (Fan Level 1 = 1,620 ms; 3 = 2,134 ms).

Although the Age × Fan interaction failed to reach significance, $F < 1$, the Age × Studied–Nonstudied × Fan interaction was significant, $F(1, 62) = 4.9$, $MSE = 78{,}709$. The size of the fan effect in the studied and nonstudied probe conditions differed for the older adults, $F(1, 31) = 5.2$, $MSE = 106{,}673$, but not for the young adults, $F < 1$. In particular, for the older adults, there was a larger fan effect for the nonstudied probes (Fan 1-1 = 1,877 ms; 3-3 = 2,553 ms) than for studied probes (Fan 1-1 = 1,767 ms; 3-3 = 2,179 ms).

### *Error Rates*

The error rate data for each experiment were submitted to an ANOVA similar to the one for the RTs. Those main effects and

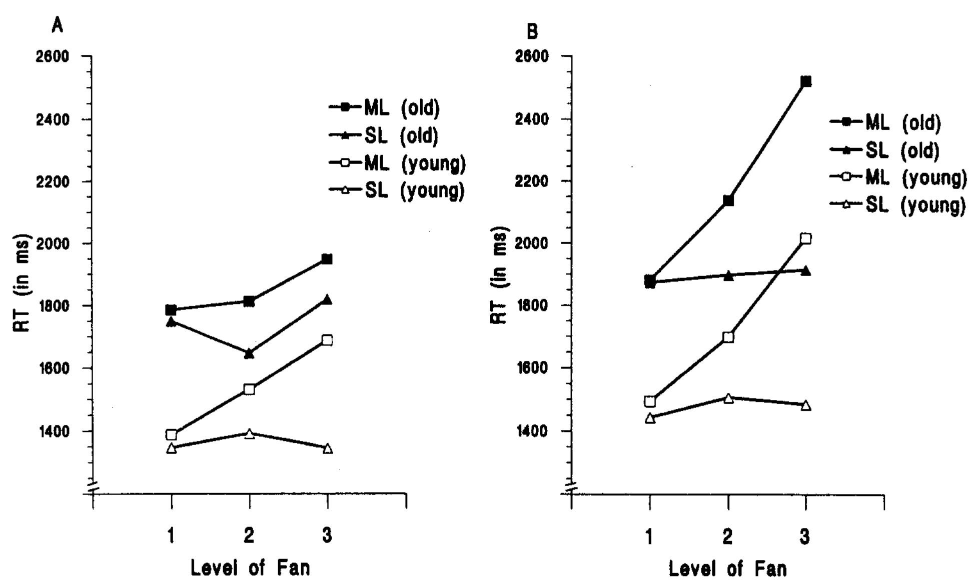


*Figure 2.* Response times (RTs) for single location (SL) and multiple locations (ML) conditions in Experiment 2 for both older and young adults. A = data from the studied trials; B = data from the nonstudied trials.

Table 4
*Analysis of Variance Results and Means for the Error Rates (in Percentages) for Effects Not Involving the SL–ML Factor*

| Effect | *F* | *df* | *MSE* | *M* | |
|---|---|---|---|---|---|
| Experiment 1 | | | | | |
| Age | 27.6* | 1, 54 | 180 | Young | 3.0 |
| | | | | Old | 8.4 |
| S–NS | 8.6* | 1, 54 | 114 | S | 4.5 |
| | | | | NS | 6.9 |
| Age × S–NS | 3.8** | 1, 54 | 114 | Young | |
| | | | | S | 2.6 |
| | | | | NS | 3.4 |
| | | | | Old | |
| | | | | S | 6.4 |
| | | | | NS | 10.5 |
| Fan | 12.1* | 2, 108 | 92 | Fan level | |
| | | | | 1 | 3.5 |
| | | | | 2 | 5.8 |
| | | | | 3 | 7.9 |
| Age × Fan | 5.2* | 2, 108 | 92 | Young | 2.1; 3.3; 3.6 |
| | | | | Old | 4.9; 8.3; 12.2 |
| S–NS × Fan | 6.1* | 2, 108 | 101 | S | 3.3; 5.5; 4.8 |
| | | | | NS | 3.6; 6.1; 11.0 |
| Age × S–NS × Fan | 3.6* | 2, 108 | 101 | Young | |
| | | | | S | 2.5; 2.7; 2.7 |
| | | | | NS | 1.7; 4.0; 4.6 |
| | | | | Old | |
| | | | | S | 4.1; 8.3; 6.9 |
| | | | | NS | 5.6; 8.3; 17.5 |
| Experiment 2 | | | | | |
| Age | 22.5* | 1, 62 | 195 | Young | 2.6 |
| | | | | Old | 7.4 |
| S–NS | 17.6* | 1, 62 | 109 | S | 3.5 |
| | | | | NS | 6.6 |
| Age × S–NS | 10.0* | 1, 62 | 109 | Young | |
| | | | | S | 2.2 |
| | | | | NS | 3.0 |
| | | | | Old | |
| | | | | S | 4.7 |
| | | | | NS | 10.2 |
| Fan | 22.4* | 2,124 | 90 | Fan level | |
| | | | | 1 | 2.7 |
| | | | | 2 | 4.3 |
| | | | | 3 | 8.1 |
| Experiment 2 (cont'd) | | | | | |
| Age × Fan | 15.8* | 2, 124 | 90 | Young | 1.9; 3.0; 3.0 |
| | | | | Old | 3.5; 5.6; 13.2 |
| S–NS × Fan | 11.9* | 2, 124 | 60 | S | 2.7; 2.8; 4.8 |
| | | | | NS | 2.6; 5.8; 11.4 |
| Age × S–NS × Fan | 7.0* | 2, 124 | 60 | Young | |
| | | | | S | 1.9; 2.6; 2.2 |
| | | | | NS | 1.9; 3.4; 3.8 |
| | | | | Old | |
| | | | | S | 3.5; 3.0; 7.4 |
| | | | | NS | 3.4; 8.1; 19.0 |
| Experiment 3 | | | | | |
| Age | 3.2 | 1, 54 | 25 | Young | 1.2 |
| | | | | Old | 1.9 |
| S–NS | <1 | 1, 54 | 19 | S | 1.5 |
| | | | | NS | 1.6 |
| Age × S–NS | <1 | 1, 54 | 19 | Young | |
| | | | | S | 1.0 |
| | | | | NS | 1.4 |
| | | | | Old | |
| | | | | S | 2.0 |
| | | | | NS | 1.8 |
| Fan | 1.3 | 2, 108 | 23 | Fan level | |
| | | | | 1 | 1.2 |
| | | | | 2 | 1.9 |
| | | | | 3 | 1.6 |
| Age × Fan | 1.1 | 2, 108 | 23 | Young | 0.7; 1.3; 1.7 |
| | | | | Old | 1.6; 2.5; 1.6 |
| S–NS × Fan | 5.2* | 2, 108 | 21 | S | 1.7; 2.0; 0.8 |
| | | | | NS | 0.6; 1.8; 2.5 |
| Age × S–NS × Fan | <1 | 2, 108 | 21 | Young | |
| | | | | S | 1.3; 1.2; 0.6 |
| | | | | NS | 0.1; 1.3; 2.8 |
| | | | | Old | |
| | | | | S | 2.1; 2.8; 1.1 |
| | | | | NS | 1.1; 2.2; 2.1 |

*Note.* SL–ML = single location–multiple locations; S = studied, NS = nonstudied.
* $p < .05$. ** $p < .06$.

interactions that do not involve the SL–ML factor, as well as their means, are presented in Table 4.

*Overall mental model organization.* To aid in the presentation of the overall pattern of error data, the error rates collapsed across age are presented in Table 5. The SL–ML × Fan interactions were significant, $F_1(2, 108) = 8.0$, $MSE = 122$, and $F_2(2, 124) = 10.1$, $MSE = 88$. There was a fan effect for the ML conditions, $F_1(2, 108) = 15.2$, $MSE = 137$, and $F_2(2, 124) = 18.6$, $MSE = 146$, but not for the SL condition in Experiment 1, $F_1 < 1$. In Experiment 2, the main effect of fan was significant for the SL analysis, $F_2(2, 124) = 5.9$, $MSE = 32$; however, the increase in errors over fan was much smaller in the SL condition (1.8%) than in the ML condition (9.2%).

There were fewer errors in the SL conditions than the ML conditions, $F_1(1, 54) = 26.8$, $MSE = 99$, and $F_2(1, 62) = 48.2$, $MSE = 95$, respectively. In addition, the Studied–Nonstudied × SL–ML × Fan interactions were significant, $F_1(2, 108) = 3.2$, $MSE = 101$, and $F_2(2, 124) = 4.1$, $MSE = 97$. The differences in the SL and ML error patterns were more pronounced for the nonstudied probes than the studied probes. The SL–ML × Fan interactions were significant for the nonstudied probes, $F_1(2, 108) = 7.2$, $MSE = 167$, and $F_2(2, 124) = 8.1$, $MSE = 153$, but not for studied probes, $F_1(2, 108) = 1.8$, $MSE = 56$, $p = .17$, and $F_2(2, 124) = 1.6$, $MSE = 32$, $p = .20$.

*Aging effects.* The error rate data are summarized in Figures 3 and 4. As can be seen, there is little in the way of a consistent error rate fan effect, except for the ML condition for the older adults, which is quite large. Unlike the RT data, the Age × SL–ML, $F_1(1, 54) = 10.5$, $MSE = 99$, and $F_2(1, 62) = 9.3$, $MSE = 95$, and Age × SL–ML × Fan interactions were significant, $F_1(2, 108) = 5.2$, $MSE = 122$, and $F_2(2, 124) = 4.3$, $MSE = 88$. The SL–ML × Fan interactions were significant for the

Table 5
*Error Rate Means (in Percentages) for Experiments 1 and 2 Collapsed Across Age*

| | Level of fan | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | *M* |
| Experiment 1 | | | | |
| Single location | | | | |
| S | 3.0 | 3.7 | 2.8 | 3.2 |
| NS | 4.4 | 3.3 | 5.2 | 4.3 |
| Mean | 3.7 | 3.5 | 4.0 | 3.7 |
| Multiple locations | | | | |
| S | 3.6 | 7.2 | 6.8 | 5.9 |
| NS | 2.9 | 8.9 | 16.9 | 9.6 |
| Mean | 3.2 | 8.1 | 11.8 | 7.7 |
| Experiment 2 | | | | |
| Single location | | | | |
| S | 2.1 | 1.6 | 2.9 | 2.2 |
| NS | 2.3 | 1.7 | 5.0 | 3.0 |
| Mean | 2.2 | 1.6 | 4.0 | 2.6 |
| Multiple locations | | | | |
| S | 3.3 | 4.1 | 6.7 | 4.7 |
| NS | 2.9 | 9.9 | 17.9 | 10.2 |
| Mean | 3.1 | 7.0 | 12.3 | 7.5 |
| Experiment 3 | | | | |
| Single location | | | | |
| S | 3.3 | 2.2 | 2.3 | 2.6 |
| NS | 2.0 | 1.6 | 1.7 | 1.7 |
| Mean | 2.6 | 1.9 | 2.0 | 2.2 |
| Multiple locations | | | | |
| S | 3.0 | 4.3 | 1.8 | 3.0 |
| NS | 0.7 | 4.8 | 6.9 | 4.1 |
| Mean | 1.8 | 4.6 | 4.4 | 3.6 |

*Note.* S = studied; NS = nonstudied.

older adults, $F_1(2, 54) = 7.4$, $MSE = 213$, and $F_2(2, 62) = 9.2$, $MSE = 132$, with a substantial fan effect for the ML condition but not the SL condition. By contrast, the young adults showed very little evidence of a fan effect in either condition, $Fs \leq 1.4$. This is consistent with the notion that older adults are experiencing more retrieval interference than the young adults. Furthermore, the Age × Fan interactions were significant, with the older adults showing a much larger fan effect than the young adults (see Table 4).

Finally, for Experiment 2, the Age × Studied–Nonstudied × SL–ML interaction was also significant, $F_2(1, 62) = 10.5$, $MSE = 57$. In the case of the older adults, the SL–ML difference was larger for the nonstudied probes (11.2%) than for the studied probes (2.9%), $F_2(1, 31) = 18.14$, $MSE = 89$, but this was not true for the young adults, $F = 1.4$ (3.3% and 2.1%, respectively).

*Analysis of 1-1 versus 3-3 fan.* An additional analysis assessed the 1-1 to 3-3 fan effect for errors in Experiment 2, as was done for the RT data. More errors were made to nonstudied (11.3%) than to studied probes (5.7%), $F(1, 62) = 13.0$, $MSE = 153$, and there was a general fan effect, with 2.7% and 14.3% errors for 1-1 and 3-3 fans, respectively, $F(1, 62) = 58.6$, $MSE = 146$. There was also an interaction of these two variables, $F(1, 62) = 18.3$, $MSE = 113$. The fan effect was larger for nonstudied (2.7% and 19.9% errors) than for studied probes (2.8% and 8.7%).

The older adults made more errors (12.2%) than the younger adults (4.8%), $F(1, 62) = 20.2$, $MSE = 174$. There was also a significant Age × Fan interaction, $F(1, 62) = 14.5$, $MSE = 146$. The fan effect was larger for the older adults, with 3.6% and 20.9% errors, $F(1, 31) = 43.8$, $MSE = 220$, than the young adults, with 1.9% and 7.7% errors, $F(1, 31) = 14.7$, $MSE = 73$.

In addition, there was a significant Age × Studied–Nonstudied interaction, $F(1, 62) = 7.2$, $MSE = 153$. There was a main effect of studied–nonstudied probe type for the older adults, with means of 7.4% and 17.1% errors, $F(1, 31) = 13.45$, $MSE$

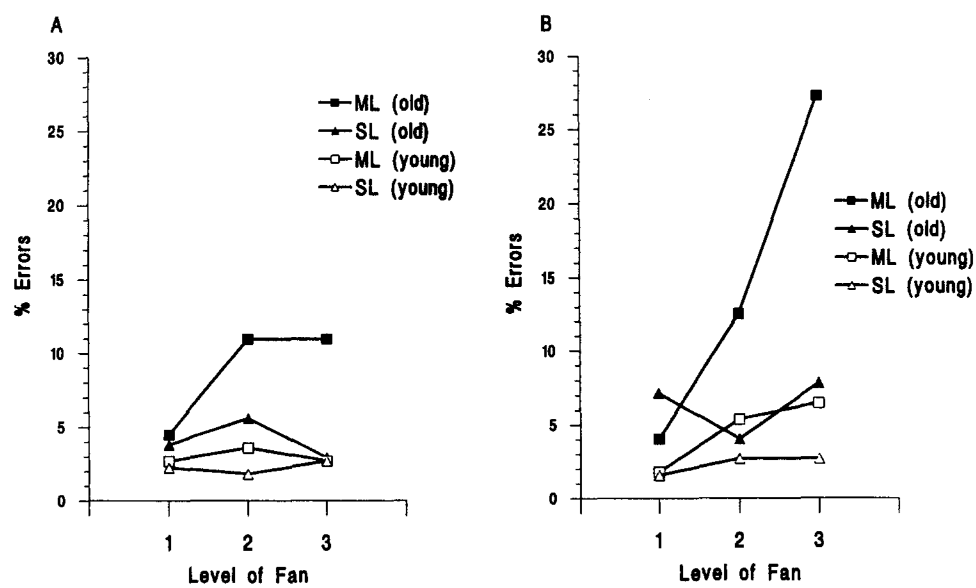


*Figure 3.* Error rates for single location (SL) and multiple locations (ML) conditions in Experiment 1 for both older and young adults. A = data from the studied trials; B = data from the nonstudied trials.

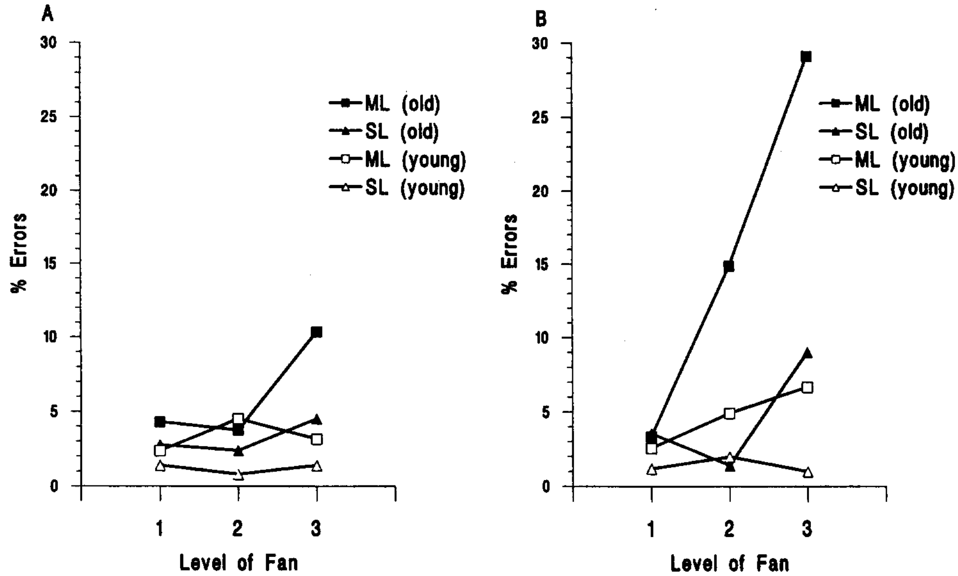


*Figure 4.* Error rates for single location (SL) and multiple locations (ML) conditions in Experiment 2 for both older and young adults. A = data from the studied trials; B = data from the nonstudied trials.

= 225, but not for the younger adults, with means of 4.1% and 5.5% errors, $F < 1$. Also, the three-way interaction was significant, $F(1, 62) = 9.8$, $MSE = 113$, with the older adults showing a larger fan effect for the nonstudied probes than the studied probes. There was also a significant interaction of studied–nonstudied probe type and fan for the older adults, $F(1, 31) = 24.80$, $MSE = 124$, but not for the younger adults, $F < 1$. For the older adults, the fan effect was larger for the nonstudied probes, with 3.5% and 30.7% errors, than the studied probes, with 3.6% and 11.1% errors.

## *Discussion*

The results of Experiments 1 and 2 are consistent with the idea that older and younger adults are similar in the way that they use mental models during fact retrieval. In particular, when a set of facts is consistent with a single situation, this information is integrated into a single mental model, and no interference is observed during retrieval. This is reflected in the absence of an SL fan effect for the older and younger adults. In contrast, when a set of facts share a common concept, but refer to different situations, then different mental models are created and stored in long-term memory. During retrieval, the more mental models there are, the more retrieval interference is experienced, and retrieval time lengthens accordingly. This is the fan effect seen in the ML condition for both older and younger adults.

There was also some evidence consistent with the idea that older adults may be more susceptible to retrieval interference than the younger adults. While there were no significant interactions with age in the RT data, there were substantial effects for the error rate data. In particular, the older adults showed a much greater error rate fan effect in the ML condition than did the younger adults.

# Experiment 3

An additional issue that we would like to address is the ordering of the concepts in the study sentences. In Experiments 1 and 2, the object concept always came first in the study sentences and the location concept came second. Although previous research has indicated that concept order does not have an impact on the difference between the SL and ML fan effects (Radvansky et al., 1993; Radvansky & Zacks, 1991), we could not be sure that the same would be true for older adults. Specifically, the aging results for Experiments 1 and 2 may reflect some unexplored factor involving concept order. Experiment 3 was conducted to test this possibility. The method and procedure were identical to Experiment 2, with the exception that the study sentences were of the form "In the *location* is the *object,*" rather than "The *object* is in the *location.*" In this way, the order of the concepts in the study sentences in Experiment 3 was the reverse of that for Experiments 1 and 2.

## *Method*

### *Participants*

Twenty-eight native English-speaking participants were tested in each age group from the same subject populations as Experiments 1 and 2. Normative data for these participants are presented in Table 1. Subjects in Experiment 3 were given the Shipley vocabulary test (Zachary, 1986) rather than the WAIS-R vocabulary test. Compared with the younger adults, the older adults had significantly more education, $t(54) = 3.00$, $SE = 0.60$, and scored higher on the vocabulary test, $t(54) = 3.32$, $SE = 0.99$. Finally, 15 additional participants were replaced, including 8 older adults and 2 young adults, for failing to finish, usually because the experimenter or the participant had an appointment, 1 in each age group for not being a native English speaker, 1 in each age group because of a computer error, and 1 older participant for an excessive number of errors, possibly due to medication.

### Materials and Procedure

The materials and procedure for Experiment 3 were similar to those of Experiment 2. The primary difference between these studies was that the locations preceded the objects in the study sentences, resulting in study sentences of the form "In the *location* is the *object.*" In addition, participants in Experiment 3 were tested on IBM-PC compatible computers and made their responses by pressing one of two buttons on a computer mouse connected to the computer. The left mouse button indicated "Yes, I did study this sentence," whereas the right button indicated "No, I did not study this sentence." The younger adults required 4.3 study-test cycles to memorize the sentences, whereas the older adults required 7.6 cycles,[2] $t(54) = 5.84$, $SE = 0.58$. The trimming procedure eliminated 2.6% of the recognition data in Experiment 3. Finally, the younger adults made an average of 0.6 errors on the posttest compared with 1.0 error for the older adults, $t(54) = 1.14$, $SE = 0.31$, $p > .20$.

## Results

The results of this experiment partially replicated those of Experiments 1 and 2. In particular, there was a fan effect for conditions in which an object was in several locations (the ML condition) but not when several objects were all in the same location (the SL condition), and this pattern was present for both the older and younger adults. Furthermore, the older adults showed some evidence of more interference for their ML condition error rates, although this effect was not as dramatic as in Experiments 1 and 2.

### Response Times

The RT data were submitted to a 2 (age) × 2 (studied-nonstudied) × 2 (SL–ML) × 3 (fan) mixed ANOVA. The first variable was between subjects and the rest were within. Those main effects and interactions not involving the SL–ML difference are reported in Table 2.

*General mental model organization.* The relevant data collapsed over age are presented in Table 3. The SL–ML × Fan interaction was significant, $F(2, 108) = 7.9$, $MSE = 156{,}694$. Simple effects tests showed that the fan effect was significant for the ML condition, $F(2, 92) = 10.9$, $MSE = 227{,}165$, but not the SL condition, $F < 1$.

In addition, the SL probes were responded to faster than the ML probes, $F(1, 54) = 15.0$, $MSE = 154{,}104$. The Studied–Nonstudied × SL–ML interaction was also significant, $F(1, 54) = 10.8$, $MSE = 53{,}673$. The SL–ML difference was larger for nonstudied probes (186 ms) than for studied probes (59 ms). Simple effects tests showed that the SL–ML difference was significant for nonstudied probes, $F(1, 54) = 54.0$, $MSE = 98{,}436$, but not for studied probes, $F(1, 54) = 2.5$, $MSE = 113{,}843$, $p = .12$.

The Studied–Nonstudied × SL–ML × Fan interaction was significant, $F(2, 108) = 5.0$, $MSE = 445{,}003$. The SL–ML × Fan interaction approached significance for studied probes, $F(2, 108) = 2.6$, $MSE = 81{,}735$, $p = .08$, and was significant for nonstudied probes, $F(2, 108) = 6.1$, $MSE = 193{,}335$. There was no SL fan effect for either the studied or nonstudied probes. In contrast, there were fan effects for the ML probes, although it was much smaller for studied probes than the nonstudied probes.

*Aging effects.* The RT data involving age differences are summarized in Figure 5. The Age × SL–ML interaction was significant, $F(1, 54) = 5.1$, $MSE = 154{,}104$, with the older adults showing a larger SL–ML difference (186 ms) than the younger adults (49 ms). This is consistent with the notion that older adults would experience more interference in the ML condition than the younger adults. However, the Age × SL–ML × Fan interaction was not significant, $F(2, 108) = 1.1$, $MSE = 155{,}694$, $p > .10$.

*Analysis of 1-1 versus 3-3 fan.* The RT data from Experiment 3 were also submitted to a 2 (age) × 2 (studied-nonstudied) × 2 (Fan 1-1 versus Fan 3-3) mixed ANOVA. Although the main effect of age was significant, $F(1, 54) = 9.3$, $MSE = 1{,}436{,}776$, with older adults responding slower (2,319 ms) than younger adults (1,831 ms), neither the Age × Fan nor the Age × Studied–Nonstudied × Fan interaction was significant, $F(1, 46) = 2.5$, $MSE = 138{,}821$, $p > .10$, and $F < 1$, respectively. However, there were significant main effects of studied–nonstudied and fan, $F(1, 54) = 15.8$, $MSE = 145{,}912$, and $F(1, 54) = 90.1$, $MSE = 138{,}821$, respectively. These were both qualified by a significant Studied–Nonstudied × Fan interaction, $F(1, 54) = 15.2$, $MSE = 119{,}414$. While there was a fan effect for both types of probes, it was clearly larger for the nonstudied probes (Fan Level 1 = 1,851; 3 = 2,503 ms) than for the studied probes (Fan Level 1 = 1,828; 3 = 2,120 ms).

### Error Rates

The error rate data were submitted to an ANOVA similar to the one for the RTs. Those main effects and interactions that do not involve the SL–ML factor, as well as their means, are presented in Table 4. One of the most striking differences between Experiment 3 compared with Experiments 1 and 2 is that there were far fewer errors in Experiment 3 relative to the first two experiments. One possible cause for this difference is that participants in this experiment spent more time memorizing the sentences relative to those participants in Experiments 1 and 2. As a result, these error rate data do not show the clear patterns that are evident in the first two experiments. Despite this, the older adults still show some evidence of experiencing more interference than the younger adults at the higher fan level in the ML condition.

*Overall mental model organization.* The error rates collapsed across age are presented in Table 5. The SL–ML × Fan interaction was significant, $F(2, 108) = 3.0$, $MSE = 20$. The fan effect approached significance for the ML condition, $F(2, 108) = 2.6$, $MSE = 33$, $p = .08$, and was not significant for the SL condition, $F < 1$.

There were fewer errors in the SL condition than the ML condition, $F(1, 54) = 7.2$, $MSE = 21$. In addition, the Studied–Nonstudied × SL–ML interaction was significant, $F(1, 54) = 4.2$, $MSE = 13$. The SL–ML difference was more pronounced for the nonstudied probes, $F(1, 54) = 8.1$, $MSE = 24$, than the studied probes, $F(1, 54) = 1.2$, $MSE = 10$, $p > .20$.

*Aging effects.* The error rate data are summarized in Figure 6. Although the Age × SL–ML interaction was not significant, $F < 1$, the Age × SL–ML × Fan interaction was, $F(2, 108) =$

[2] These data include 3 older participants who, due to an experimenter oversight, only learned the study sentences up to one perfect cycle. An analysis excluding these individuals did not change the results.

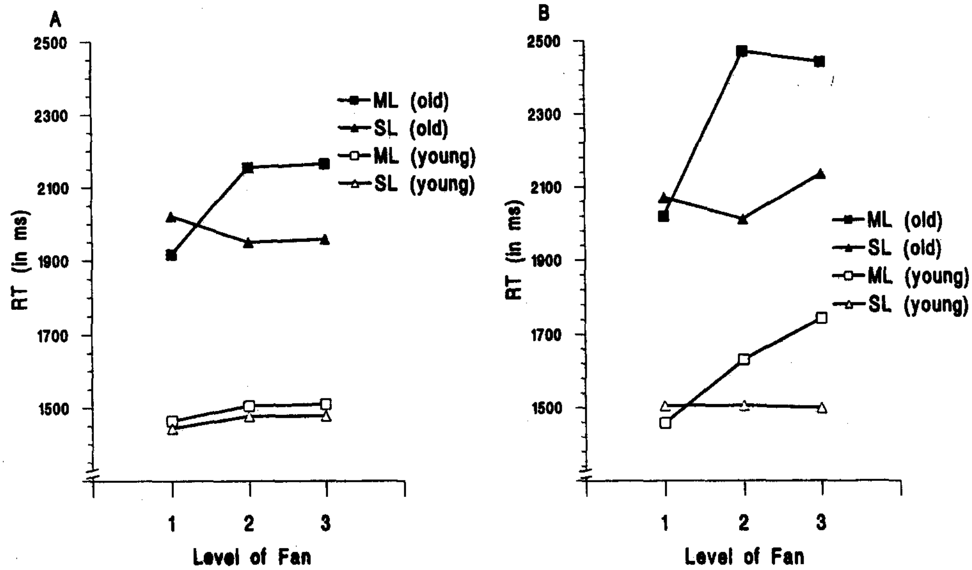


*Figure 5.* Response times (RTs) for single location (SL) and multiple locations (ML) conditions in Experiment 3 for both older and young adults. A = data from the studied trials; B = data from the nonstudied trials.

4.1, $MSE = 20$. The SL–ML × Fan interaction was significant for the older adults, $F(2, 54) = 4.2$, $MSE = 28$, but not for the young adults, $F(2, 54) = 2.1$, $MSE = 12$, $p = .13$. The ML fan effect for the older adults is not as systematic as seen in Experiments 1 and 2 (presumably due to the fewer number of errors overall), however, it is still clear that they are experiencing more interference in this condition at Fan Level 2 than the young adults for both probe types, and for Fan Level 3 for the nonstudied probes, consistent with the first two experiments. The only deviation from Experiments 1 and 2 is that while the older adults are affected by fan level for the studied probes, the younger adults are not. This is presumably related to the overall low error rate of the younger adults.

*Analysis of 1-1 versus 3-3 fan.* The error rate data from Experiment 3 were submitted to a 2 (age) × 2 (studied–nonstudied) × 2 (Fan 1-1 versus Fan 3-3) mixed ANOVA. The main effect of age was not significant, $F(1, 54) = 1.3$, $MSE = 28$, $p > .20$, nor were the Age × Fan and the Age × Studied–Nonstudied × Fan interactions, $Fs < 1$. However, there were significant main effects of studied–nonstudied and fan, $F(1, 54)$

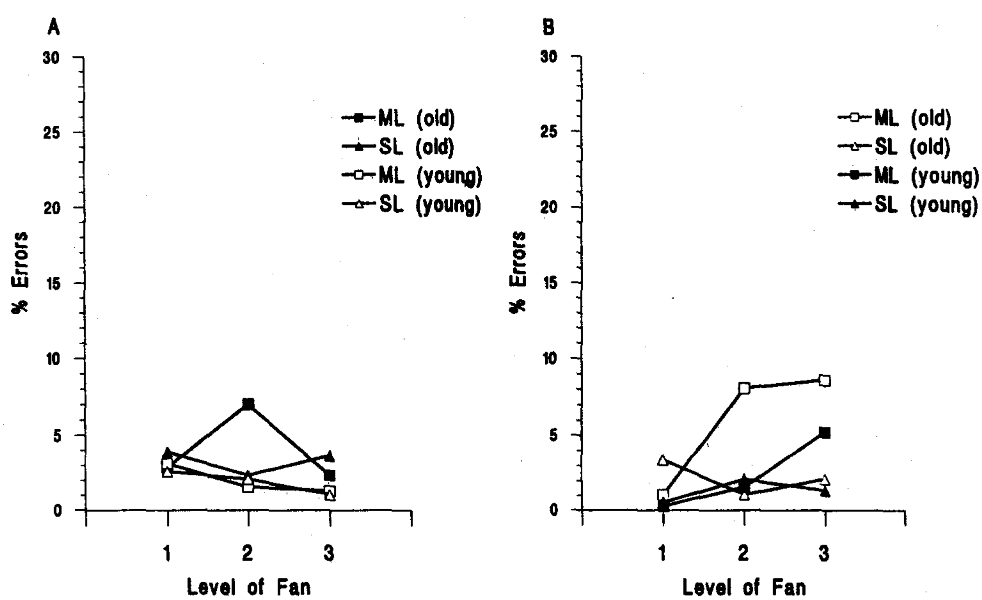


*Figure 6.* Error rates for single location (SL) and multiple locations (ML) conditions in Experiment 3 for both older and young adults. A = data from the studied trials; B = data from the nonstudied trials.

= 4.3, $MSE = 19$, and $F(1, 54) = 35.2$, $MSE = 28$, respectively. These were both qualified by a significant Studied–Nonstudied × Fan interaction, $F(1, 54) = 12.3$, $MSE = 21$. While there was a fan effect for both types of probes, it was clearly larger for the nonstudied probes (Fan Level 1 = 1.5%; 3 = 3.6%) than for the studied probes (Fan Level 1 = 0.6%; 3 = 7.0%).

### *Discussion*

The results of Experiment 3 demonstrate that, as before, for both older and young adults, no fan effect was observed for the SL condition, but a fan effect was observed for the ML condition. This is consistent with the view that people are building mental models based on the situations described by the facts, that these mental models influence the process of retrieval, and that older and younger adults behave similarly on this dimension. Finally, although participants in Experiment 3 made fewer errors overall, it was still clear from the error rates that older adults experience more interference in the ML condition. Thus, it is clear that the pattern of retrieval times observed in Experiments 1 and 2 was not due to the ordering of the object and location concepts in the study sentences.

## General Discussion

The major data from the present study suggest that there are circumstances under which older and younger adults show equal resistance to sources of forgetting. In particular, based on the pattern of retrieval times and error rates in the single location conditions, young and older adults integrate randomly presented facts (e.g., concerning the potted palm, the waste basket, and the cola machine) into mental models of a described situation (e.g., the hotel). This is consistent with previous research that has demonstrated that younger and older adults generate mental models in much the same way (Morrow et al., 1992; Radvansky et al., 1990).

Further, when people are able to successfully integrate facts in a SL condition, no fan effect is observed in either speed of recognition or errors. That is, the number of facts integrated into a single situation model does not influence retrieval of any single fact. The absence of a fan effect is as characteristic of older adults as it is of young adults. That this is so may be taken as surprising given the large literature demonstrating older adults' differential susceptibility to competition among potential candidates for responses that result in proactive interference (e.g., Kane & Hasher, in press; Winocur & Moscovitch, 1983). Thus, organizing information into mental models spares retrieval performance for both younger and older adults.

By contrast, when facts cannot be organized into a single mental model, as is the case in the present ML condition, the findings are consistent with views that older adults are indeed more susceptible to retrieval interference. That is, older adults show a larger fan effect, particularly in the error rate data. This is presumably because, relative to young adults, older adults are less able to confine the memory retrieval process to the most relevant items. On studied trials, an inability to discriminate a particular mental model from the set of distractors leads to an increased miss rate, whereas, on nonstudied trials, the large number of mental models being activated may lead to a greater feeling of familiarity, thus leading to an increased false-alarm rate. Overall, it appears that older adults are more likely to become confused when the concepts in the probe sentence are stored across several representations.

The absence of significant Age × Fan and Age × SL–ML × Fan interactions in the RT data may be a function of the older adults' high error rate in the condition with the greatest nominal interference. Specifically, the older adults' higher error rates may reflect a less thorough search, relative to the younger adults, for the appropriate information. This less effective search is the result of more information reaching some retrieval threshold overall, thereby making it more difficult to select the desired piece of information. It should also be noted that when the error rate was lower, as it was in Experiment 3, although the Age × SL–ML × Fan interaction failed to reach statistical significance, the Age × SL–ML interaction was significant. Based on this result, a significant Age × SL–ML × Fan interaction would be expected if error rates were successfully equated in both age groups.

The ML data obtained in the present experiments are consistent with fan effect data reported earlier by Gerard et al. (1991; see also Cohen, 1990) in that in both instances differential age-related fan effects were seen for errors. In addition, Gerard et al. showed greater fan effects for older adults in the response time data as well. In the Gerard et al. study, the facts that were memorized referred to separate situations that could not be easily integrated into single mental models. Each of these facts was probably stored separately. In contrast, in the present experiments, some of the facts could be interpreted as being coreferential and, therefore, could be integrated. This integration could have facilitated overall retrieval processes during the recognition test. Furthermore, in the Gerard et al. study, the facts tested at larger fan sizes had multiple associations with both the sentence subject and predicate. Thus, participants consistently had to search a more complex collection of memory traces. In contrast, in the present experiments, the recognition test included facts at larger fan sizes that had only a single association for one of the concepts along with multiple associations with the other, rather than multiple associations for both.

Another explanation that could be offered for the different ML error rate fan effects is that the older adults may have become more confused during the recognition test as to which items had been studied before and which had not. This could occur because there were multiple repetitions of both the studied and nonstudied items throughout the recognition test. A prediction of this alternative view is that the performance of the older adults should become dramatically worse over the course of the recognition test. To assess this, we conducted some additional analyses that included half of test (first or second) as a factor. To briefly summarize, there were few effects involving half of the recognition test. If anything, performance improved from the first to the second half, and older adults showed a larger improvement than the younger adults. Therefore, the data do not support this alternative explanation. This increasing confusion explanation is also unsatisfactory because it does not account for why there is such a large difference between the younger and older adults only on the ML conditions, not on the SL conditions. Such confusion should be evident across all of the materials.

The present experiments are also consistent with the Hasher and Zacks (1988) age and inhibition hypothesis that takes the position that because of reduced efficiency of inhibitory attentional mechanisms, older adults have a greater difficulty regulating the contents of working memory than young adults. Older adults are less able to ignore or suppress irrelevant information so as to keep it from entering the current stream of processing. For a review of studies supporting this hypothesis, see Zacks and Hasher (1994; see also Stoltzfus, Hasher, & Zacks, in press). According to this view, in the ML condition of the present experiments, people may need to suppress related and irrelevant mental models during fact retrieval. If the suppression of these related and irrelevant mental models is less effective, then the ML fan effect should increase. This is what was found in the present experiments.

When a mental model is not invoked, however, the present findings are consistent with those reported earlier by Gerard et al. (1991) and by Cohen (1990): Older adults are more susceptible to retrieval confusion during recognition and are more likely to make errors when the concepts in the probe fact are associated with several memory traces. However, older adults appear to be able to create mental models in much the same way as younger adults and to use mental models to retrieve stored information in much the same way as younger adults. That is, the otherwise negative impact on retrieval of large fan sizes can be reduced, for both younger and older adults, when a mental model is invoked.

One intriguing possibility that might be raised with respect to the development and utilization of mental models is the degree to which they are spatially tied, as are the models formed here. Specifically, the concept that ties objects together is a location. Older adults, despite an otherwise greater vulnerability to interference effects, are spared in their performance relative to young adults in this unique circumstance. This sparing may be the conceptual equivalent of a sparing observed in a number of perceptually based selective attention tasks (Carlson, Hasher, Connelly, & Zacks, 1995; Connelly & Hasher, 1993; Connelly, Hasher, & Zacks, 1991) in which older and young adults are equally able to efficiently process target information even when maximally abstracting information from the environment. This sparing effect is seen when the location of targets, distractors, or both is predictable (e.g., Carlson et al., 1995).

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