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Age and Inhibition: The Retrieval of Situation Models

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We present a test of whether age-related differences in the management of interference during memory retrieval can be explained, at least in part, by decreased inhibitory mechanisms in older adults. We conducted this test by measuring the ease of retrieval of situation model representations that were sources of interference on the preceding trial but that contained the target information for the current trial. Prior research has shown that situation model retrieval under these conditions exhibits inhibition relative to an unrelated control. This effect was replicated in the current study for younger but not older adults; at the same time, the older adults showed greater overall retrieval interference than the younger adults. This pattern is consistent with the idea that there are declines in inhibitory processing in older adults, and that this applies to memory retrieval.

THE study reported here reexamines data from an earlier report of age differences in long-term memory retrieval (Radvansky, Zacks, & Hasher, 1996) using a fan effect paradigm (Anderson, 1974). In the current study we elaborate on these findings by an assessment of retrieval inhibition (Radvansky, 1999). In the fan effect paradigm, people memorize a set of facts and are then given a speeded recognition test. The central finding is that, as the number of associations with a concept in the study list increases, there is an increase in response time and error rate. This increase is even greater for older than for younger adults (Radvansky et al.), an effect attributed to reduced inhibitory abilities associated with aging (Hasher & Zacks, 1988; Hasher, Zacks & May, 1999; Zacks & Hasher, 1994). The speculation offered in the earlier report was that older adults have more trouble suppressing the related but irrelevant associations learned in the context of the study. The current study provides a direct test of this speculation.

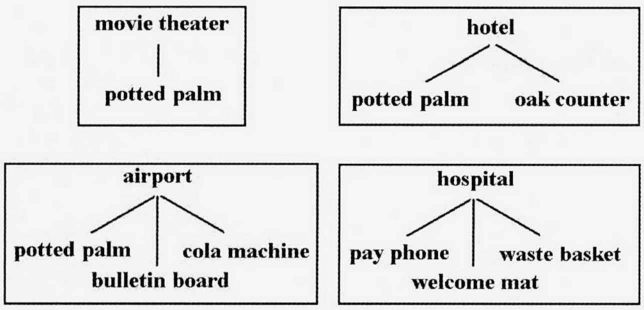
Other work on the fan effect has suggested that people can create situation models of the information in the study sentences (Johnson-Laird, 1983; van Dijk & Kintsch, 1983; Zwaan & Radvansky, 1998). Essentially, a situation model is a mental representation of the state of affairs described by a text, rather than the text itself, that serves as a mental simulation. When people learn sentences about objects in locations, they tend to organize that information in a location-based manner. This is because locations serve as frameworks for the situations and the objects are contained in them.

From this perspective, we can identify two conditions of interest. In one case, there may be multiple objects in a single location. This is the single-location condition. In this condition, because it is easy to think of a single situation in which multiple objects are in the same place, people can integrate this information into a common situation model. For example, having learned that the potted palm, bulletin board, and cola machine are all in the airport can be integrated into a common airport model. Integration enables information to be stored in a common memory trace, eliminating interference during retrieval among the items associated with a particular location and producing no fan effect.

In comparison, there are also cases in which a single object is in multiple locations. This is the multiple-location condition. In this condition, because it is difficult to think of one object being in several places as part of a single situation, several situation models are created, one for each location. For example, if the potted palm is in the movie theater, hotel, and airport, people are likely to create three situation models, one for each location. Because there are multiple models that share elements in common (the objects), the retrieval of any one of these models will trigger the activation of others that also contain a target object, creating interference with the retrieval of the desired model. In this way, as the number of associations increases, there is increased interference and there is a fan effect. This differential interference effect based on location is an indicator of the use of situation models during retrieval (Radvansky & Zacks, 1991).

The experimental paradigm that we use here is similar to one we used in an earlier study (Radvansky, 1999), which is a memory analog to the Tipper (e.g., 1985) negative priming paradigm. For a description of this paradigm, consider the situation illustrated in Figure 1. In the experimental condition, on trial t, suppose the recognition memory probe is "The potted palm is in the airport." Because the potted palm is also in the hotel and the movie theater, all three models (airport, hotel, and movie theater) will be activated, thereby producing interference. If inhibition is operating, we can expect that the hotel and movie theater models would be suppressed. On trial $t + 1$, assume that the memory probe is "The oak counter is in the hotel." Although this sentence does not share the object or location with the previous sentence, the hotel model would have just been inhibited, causing people with good inhibition to respond more slowly. The test sentence is the same for the control condition, but now the probe on trial t could be "The pay phone is in the hospital." This is a sentence that has the same number of associations as in the experimental condition but that is unrelated to the hotel model, so it should not trigger suppression, enabling faster performance on the test trial in this condition than in the experimental one.

The specific prediction of the current experiment, beyond what has been shown before, is that the younger adults will



Examples of Retrieval Probes for the Inhibition Analysis

Control Prime: The pay phone is in the hospital.

Experimental Prime: The potted palm is in the airport.

Target: The oak counter is in the hotel.

Figure 1. Examples of location-based situation models assumed to be formed during the learning of a list of object-location sentences. Notice that *potted palm* is part of three situation models; all three are assumed to be activated when any one of them is accessed.

Table 1. Response Time and Error Rate Data for the Experiment

	No. of Associations		
Variable	1	2	3
Younger adults			
Single location	1,395 (1.3)	1,448 (1.4)	1,415 (1.3)
Multiple location	1,441 (2.5)	1,615 (4.9)	1,853 (4.8)
Older Adults			
Single location	1,811 (3.2)	1,772 (2.0)	1,867 (6.7)
Multiple location	1,833 (3.9)	1,975 (9.3)	3,209 (18.5)

Note: Response time is reported in milliseconds, and error rate is reported in percentages in parentheses.

show a significant inhibition effect, whereas older adults will show a smaller or absent inhibition effect. This is because of the difficulties older adults have in suppressing related and irrelevant information (e.g., Hasher et al., 1999).

Experiment

In this experiment we tested the idea that older adults are less able to suppress related but irrelevant situation models during long-term memory retrieval. This is the same experiment reported as Experiment 2 in an earlier article (Radvansky et al., 1996). In that article, we considered only the interference data. The reader should note that, because there was some collapsing of data in Experiments 1 and 2 of that earlier article, some of the statistics that we present here were not presented there.

Methods

Participants

We tested 32 people in each age group. The younger adults ranged in age from 18 to 28 years ($M = 19.8$) and had 12 to 15 years of education ($M = 13.3$). The older adults ranged in age from 60 to 79 years ($M = 69.3$) and had 8 to 20 years of education ($M = 14.0$). We arranged for participants to be given the vocabulary test from the Revised Wechsler Intelligence Scale (Wechsler, 1981). Younger adults score lower on this test ($M = 46.5$) than the older adults ($M = 51.6$), $t(62) = 2.26$, $SE = 2.27$, $d = .68$.

Materials

Each person memorized a set of 18 sentences of the form "The *object* is in the *location*." The structure of the study list design is detailed in an earlier article (Radvansky et al., 1996). The recognition test was composed of studied and nonstudied probe sentences.

Procedure

Using a study–test procedure, we first gave participants the vocabulary test and then had them memorize the sentences. After memorization, we gave the participants a speeded recognition test. They were to indicate whether a sentence was studied or not by pressing one of two buttons. We presented the entire set of studied and nonstudied probes once in each of eight blocks. We randomized the order of the trials within each block, except for constraints imposed by the prime-target trials for the test of inhibition. The prime-target pairs for this test followed the examples already described (for further details see Radvansky, 1999). Primes for the control condition were study sentences that were unrelated to the target trials but had the same number of associations as the experimental primes. There were 16 prime-target pairs in each of the experimental and control conditions for each person's recognition test. Essentially, the primes were interference trials for the fan effect analysis, and target trials were not, but were selected on the basis of their relation to the primes. We provided an 18-trial practice period to familiarize people with the recognition test procedure. In addition, if an error was made, either during practice or the actual test, we provided feedback.

For the analyses, we dropped from the response time analysis those trials for which either an error was made or for which responses were less than 500 ms, longer than 10,000 ms, or greater than 2.5 *SD* from a person's mean in a given cell, eliminating 2.3% of the data. Unless otherwise noted, we used a criterion in all significance tests of $p < .05$.

Results and Discussion

Learning

Younger adults required fewer learning cycles ($M = 3.9$) than the older adults ($M = 5.5$), $t(62) = 4.33$, $SE = 0.35$, $d = 1.22$.

Interference

We submitted the response time and error rate data, shown in Table 1, to a 2 (age) × 2 (studied–nonstudied) × 2 (condition: single location vs multiple location) × 3 (interference level) mixed analysis of variance (ANOVA). The first variable was between participants and the rest were within. The studied–nonstudied variable reflects the fact that the nonstudied sentences were generated through recombinations of concepts from within the same cell of the design. As such, the nonstudied probes had the same fan levels as the studied sentences. Therefore, we could analyze correct rejections in the same manner as hits. Only those results pertaining to the differential interference effects are given here. As reported in an earlier article (Radvansky et al., 1996), for the response time data, there was a significant Condition × Interference interaction,

$F(2, 124) = 22.5$, $MSE = 97{,}744$, $d = 1.22$, with simple effects tests showing an interference effect for the multiple-location condition, $F(2, 124) = 50.8$, $MSE = 106{,}184$, $d = .88$, but not the single-location condition, $F < 1$. The three-way interaction was not significant, $F < 1$.

For the error rate data, like the response time data, there was a significant Condition × Interference interaction, $F(2, 124) = 10.1$, $MSE = 88$, $d = .61$, with simple effects test showing interference for both the multiple-location condition, $F(2, 124) = 18.6$, $MSE = 146$, $d = .82$, and single-location conditions, $F(2, 124) = 5.9$, $MSE = 32$, $d = .32$, although it was much larger in the multiple-location condition. In addition, the Age × Condition × Interference interaction was significant, $F(2, 124) = 4.3$, $MSE = 88$, $d = .66$. Separate analyses showed that the Condition × Interference interaction was significant for the older adults, $F(2, 54) = 7.4$, $MSE = 213$, $d = .95$, but not the younger adults, $F < 1$. These data show that older adults had more difficulty managing interference.

Inhibition

We submitted the response time data for the target trials to a 2 (age) × 2 (condition: control vs experimental) mixed ANOVA, with the first variable being between participants. These trials were always composed of studied items. There was a significant main effect of age, $F(1, 62) = 6.94$, $MSE = 424{,}175$, $d = .67$, with older adults responding slower (2,124 ms) than younger adults (1,815 ms). Although people responded slower to experimental (1,997 ms) than control targets (1,943 ms), the main effect of condition was not significant, $F(1, 62) = 2.60$, $MSE = 35{,}304$, $p = .11$. Importantly, the interaction was $F(1, 62) = 3.99$, $MSE = 35{,}304$, $d = .45$. Separate analyses showed that the younger adults had an inhibition effect, $F(1, 31) = 7.75$, $MSE = 29{,}651$, $d = .24$, with responses to experimental targets being slower (1,875 ms) than to control targets (1,755 ms). In contrast, for the older adults, this difference was not significant, $F < 1$, with response times being similar for the experimental (2,118 ms) and control targets (2,130 ms). Twenty-two younger adults had slower response times to experimental trials than to the control trials, and 10 had the opposite pattern. This difference was significant by a sign test, $p = .05$. However, for the older adults, 16 people had slower responses to experimental trials than to control trials, 15 had the opposite pattern, and 1 showed no difference.

A similar analysis of the error rate data revealed a significant main effect of age, $F(1, 62) = 4.78$, $MSE = 129$, $d = .56$, with older adults making more errors (9.8%) than younger adults (5.5%). The main effect of condition and the interaction were not significant (both Fs < 1), with younger and older adults producing similar numbers of errors in response to the experimental (young = 5.9%; old = 10.2%) and control targets (young = 5.1%; old = 9.6%).

Comparison of fan effect and priming trials.—In an earlier study, we found a negative correlation between the fan effect and the inhibition effect (Radvansky, 1999). That is, the more interference a person experienced on one trial, the smaller the inhibition effect. Here the fan effect is operationalized as the difference between the Fan 3 and Fan 1 trials, and the inhibition effect as the difference between the control and experimental trials. As before, the greater the interference seen on a prime trial, the less the suppression seen on the probe trial ($r = -.45$, $p = .01$). However, for the older adults, we observed no such relation ($r = -.03$, $p = .88$). If inhibition is not used to suppress competing responses (here, from different situation models), then there is no carryover effect of the suppression from one trial to the next. The results of the current study confirmed our predictions. In addition to the replication of previously reported findings, of greatest importance is that we found that older adults were less likely to show evidence of inhibition than the younger adults. Specifically, we observed a clear inhibition effect for the younger adults, but there was no inhibition effect for the older adults. This is consistent with the idea that older adults are less effective at suppressing irrelevant information than younger adults.

In summary, aging seems to involve declines in inhibitory processing. We observed evidence for such a decline in the present study by an absence of an inhibition effect for selected-against memory representations, which in this case were situation models. This pattern of data is best fit by an account that assumes that an active inhibitory process is involved, rather than simply being the product of interference.

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