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A Double Dissociation of Implicit and Explicit Memory in Younger and Older Adults

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Abstract

This study examined whether age-related differences in cognition influence later memory for irrelevant, or distracting, information. In Experiments 1 and 2, older adults had greater implicit memory for irrelevant information than younger adults did. When explicit memory was assessed, however, the pattern of results reversed: Younger adults performed better than older adults on an explicit memory test for the previously irrelevant information, and older adults performed less well than they had on the implicit test. Experiment 3 investigated whether this differential pattern was attributable to an age-related decline in encoding resources, by reducing the encoding resources of younger adults with a secondary task; their performance perfectly simulated the pattern shown by the older adults in the first two experiments. Both older and younger adults may remember irrelevant information, but they remember it in different ways because of age-related changes in how information is processed at encoding and utilized at retrieval.

Keywords

explicit memory, implicit memory, aging, inhibition, divided attention

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There are few situations in which memory performance is better in older than in younger adults. Recently, however, some studies have found that older adults have better implicit memory than younger adults for material that was irrelevant, or distracting, during initial acquisition. One interpretation of these findings is that older adults are less able to inhibit irrelevant information than younger adults are (Hasher & Zacks, 1988; Hasher, Zacks, & May, 1999), so that older adults process more of such information (e.g., Kim, Hasher, & Zacks, 2007; Rowe, Valderrama, Hasher, & Lenartowicz, 2006). Other research, however, has paradoxically shown that young adults do access irrelevant information when it becomes goal relevant on tests of explicit memory (e.g., Dywan & Murphy, 1996; Kemper, McDowd, Metcalf, & Liu, 2008; Thomas & Hasher, 2010). These results seem inconsistent with inhibitory theory (Hasher & Zacks, 1988), according to which the ability to filter out irrelevant information is reduced in older adults. Given that both older and younger adults have better-than-chance memory for distracting information under certain circumstances, it seems rather that both groups must process distracting information in some way.

Considering age-related differences in both encoding and retrieval processes may allow researchers to resolve this paradox and extend the inhibitory account. It is known, for example, that success on implicit and explicit word-stem completion tasks depends on good perceptual and conceptual processing, respectively (Craik, Moscovitch, & McDowd, 1994). Thus, it is possible that older adults process irrelevant information in a shallow perceptual manner, whereas younger adults successfully ignore much distracting information but process at least some items in a more conceptual manner. In line with this possibility, a study by McCauley, Eskes, and Moscovitch (1996) showed that younger adults who engaged in elaborative imagery during study had improved explicit memory for target words on a word-stem completion task involving the study words but reduced implicit memory for the words. Elaborative processing also improved explicit memory for older adults, but to a lesser extent than for younger adults; additionally, elaborative processing did not reduce older adults' performance on the implicit test, as it did for younger adults. These latter effects suggest that the older adults may

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have paid more attention to the perceptual features of the target items at the expense of engaging in the more elaborative processing task.

Age-related differences may also occur at retrieval. For example, younger adults are able to withhold goal-irrelevant responses but can use this irrelevant information should task goals change such that previously irrelevant information becomes goal relevant (e.g., Dywan & Murphy, 1996; Kemper et al., 2008). Therefore, younger adults may be better able than older adults to constrain their cued retrieval processing so that only goal-relevant information comes to mind (i.e., source-constrained retrieval; Jacoby, Shimizu, Daniels, & Rhodes, 2005; Jacoby, Shimizu, Velanova, & Rhodes, 2005). They may continue to ignore previously encoded distracting information unless its relevance is signaled, at which time they can bring the information to mind.

To better understand how people encode and retrieve distracting information, we investigated younger and older adults' explicit and implicit memory profiles for such information. We found that younger and older adults remember irrelevant information in qualitatively different ways: Oder adults do better on an implicit memory test, whereas younger adults do better on an explicit memory test. In the General Discussion, we consider how age-related differences in both encoding and retrieval may contribute to this interaction between age and type of test.

Experiment 1

In our first experiment, we used an incidental encoding task to determine younger and older adults' implicit and explicit memory profiles for irrelevant information. Participants responded to the color of words by pressing colored buttons. The words themselves were task irrelevant. After a retention interval, half the participants from each age group completed an implicit word-fragment completion test, and half completed an explicit word-fragment completion test. Words from the encoding task were solutions to one third of the fragments.

Method

Participants. Table 1 presents demographic data for the participants in this experiment. The older adults had more years of education and a higher Shipley (1976) vocabulary score than the younger adults (ps < .01). Participants were randomly assigned to one of the memory-test conditions.

Stimuli. Two study lists were created from 30 common words (mostly nouns) and 30 random letter strings that were four to eight letters long. Each list contained a unique set of 10 words that would be tested later, 10 filler words, and all 30 random letter strings. Lists were counterbalanced across participants within each age group. Stimuli were presented in uppercase, 18-point bold Arial font, in one of four colors (red, blue, green, or yellow). They were displayed individually at the center of a computer screen against a black background.

The test consisted of 30 word fragments. Ten of these fragments could be completed with target words from the encoding task, and 10 could be completed with words that had not been seen during encoding but were target words for the other half of the participants (completion rates for the previously unseen words thus provided a baseline for these words). In addition, to hide the connection between test and study for participants who received the implicit memory test, we included 10 filler word fragments that were easily solved. Although the fragments on the test had multiple completion possibilities, a target fragment could be completed by only one of the studied words. Fragments were presented at the center of the screen in a black, 18-point bold Arial font against a white background.

Procedure. During the study phase, participants responded to the color of each stimulus by pressing the corresponding button (out of four) on a response box as quickly and as accurately as possible. They were told to ignore the words' identity and to pay very close attention to their color. Participants

Table 1. Demographic Characteristics of Participants in Experiments 1, 2, and 3

	Age (years)			Education (years)		Vocabulary score		Mini-Mental State Exam	
Experiment and group	*M*	Range	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Experiment 1									
Younger (n = 32)	19.0	17–21	1.1	13.4	1.2	29.5	4.1	—	—
Older (n = 32)	68.1	60–81	5.9	16.2	2.8	35.0	3.5	29.6	0.6
Experiment 2									
Younger (n = 20)	18.7	17–22	1.5	12.9	1.4	28.6	5.5	—	—
Older (n = 20)	68.6	59–76	5.1	15.3	3.0	36.8	2.5	29.0	1.3
Experiment 3									
Younger (N = 20)	19.3	17–27	2.4	13.3	1.4	30.1	3.9	—	—

Note: There were no color-blind participants. No participant reported having a psychiatric or neurological history or taking medications known to interfere with cognitive functioning. Vocabulary was tested with Shipley's (1976) Institute of Living Scale. Older participants were screened for cognitive impairment using the Mini-Mental State Examination (Folstein, Folstein, & McHugh, 1975), and all had scores of 28.0 or higher.

practiced with a seven-item Stroop task in which color words were in congruent ("RED" in red) and incongruent ("RED" in blue) colors. A button press initiated a 1,000-ms interstimulus interval with a white fixation cross on a black background. After practice, participants began the experiment proper and were told that they would see words (e.g., "HOUSE") and random letter strings ("XOTGH"). Inclusion of nonword letter strings highlighted that the task was about color judgments and not word reading. Eight nonword letter strings were presented first as a primacy buffer. They were followed by 34 items (20 words and 14 random letter strings) in random order. Finally, 8 random letter strings were presented as a recency buffer. During the subsequent 10-min retention interval, participants performed a nonverbal task.

The test phase consisted of 30 word fragments presented one at a time on a computer screen. For the implicit test, the fragments were presented at a 4-s rate. Participants were instructed to respond aloud with the first solution that came to mind. On a follow-up questionnaire, no participants in this condition reported noticing a connection between study and test. Participants in the explicit memory condition were instructed to complete as many fragments as possible with words from the first task. The test was self-paced, with a 30-s limit per fragment. Each word fragment was followed by a blank screen for 500 ms.

Results

Accuracy on the color judgment task was nearly perfect for all participants (older adults: .98; younger adults: .97).

Target word-fragment completion rates (Table 2) were calculated as the proportion of word fragments completed by studied words. Baseline word-fragment completion rates (Table 2) were measured by the completion rates among participants for whom the fragments served as new items (recall that a given fragment could be completed by a word on a study list received by only half the participants). Baseline and target completion rates were therefore measured from identical sets of words, although calculated from different participants (see also Rowe et al., 2006). Baseline values were calculated separately within each age group and condition and were then analyzed in a 2 (age: younger, older) × 2 (memory test: implicit, explicit) ANOVA. There was no main effect of age ($F < 1$). The significant main effect of memory test, $F(1, 64) = 7.25$, $p < .01$, $\eta_p^2 = .11$, indicated that completion rates were higher overall for the explicit memory test than for the implicit memory test. There was no interaction between age and memory test, $F(1, 64) = 2.32$, $p > .10$, $\eta_p^2 = .04$.

Memory performance was computed for each participant by subtracting the appropriate baseline completion rate from the appropriate target completion rate (see Table 2). These data were submitted to a 2 (age: younger, older) × 2 (memory test: implicit, explicit) ANOVA. There were no main effects (Fs < 1), but there was a significant interaction, $F(1, 64) = 27.45$, $p < .001$, $\eta_p^2 = .31$. Follow-up t tests indicated that older adults had better implicit than explicit memory and had better implicit memory than younger adults did (ps < .01). The pattern was reversed, however, for the explicit memory test: Younger adults had better explicit than implicit memory and had better explicit memory than older adults did (ps < .01).

Table 2. Proportions of Target and Baseline Fragment Completions and Overall Memory Performance in Experiments 1, 2, and 3

	Experiment 1 (between-subjects design)		Experiment 2 (within-subjects design)		Experiment 3 (within-subjects design)
Measure	Younger adults	Older adults	Younger adults	Older adults	Younger adults with divided attention
Target completions					
Implicit test	.21 (.15)	.33 (.09)	.25 (.16)	.36 (.14)	.41 (.15)
Explicit test	.38 (.14)	.27 (.16)	.41 (.15)	.27 (.13)	.24 (.15)
Baseline completions					
Implicit test	.11 (.09)	.08 (.07)	.23 (.16)	.19 (.15)	.19 (.11)
Explicit test	.14 (.13)	.19 (.12)	.23 (.15)	.24 (.12)	.27 (.19)
Memory performance (target – baseline)					
Implicit test	.10 (.12)	.25 (.08)	.02 (.19)	.17 (.18)	.22 (.19)
Explicit test	.24 (.12)	.08 (.14)	.18 (.19)	.03 (.16)	−.03 (.30)

Note: Standard deviations are shown in parentheses. Target completion rates were calculated as the proportion of word fragments completed with target words by participants who saw those targets at study. Baseline word-fragment completion rates were the completion rates for the same fragments by participants who did not see the corresponding targets at study but nonetheless used them to complete the fragments. Therefore, each fragment acted as a target fragment for half the participants and a baseline fragment for the other half. Memory performance was calculated by subtracting the completion rates for baseline fragments from the completion rates for identical target fragments, within each group and test type.

Discussion

Despite the commonly reported age-related decline in explicit memory, this experiment demonstrated that older adults had higher levels of implicit memory than younger adults did. This pattern is consistent with a prediction derived from inhibitory theory (Hasher & Zacks, 1988): Older adults allow more distracting information to be encoded into memory because of inefficient filtering of (or access control over) such information, as well as failure to suppress material from one task when switching to another. The pattern of better implicit memory performance by older adults than by younger adults replicates a number of previous findings (e.g., Campbell, Hasher, & Thomas, 2010; Kim et al., 2007; Rowe et al., 2006).

In contrast, younger adults had substantially better explicit memory for the irrelevant information than older adults did. An inhibitory explanation focused on age-related encoding differences can account for the age differences in implicit memory performance, but does not readily explain the results for explicit memory for the irrelevant information. Younger adults clearly encoded some words despite not having a reason to remember them, and despite not showing effects of this encoding in the implicit test. Given the striking pattern of results, we replicated Experiment 1 in a within-subjects design.

Experiment 2

Experiment 2 was similar to Experiment 1 except that all participants completed both an implicit and an explicit memory test.

Method

Participants. One older adult and 2 younger adults were aware of the connection between the study phase and the implicit memory test, and their data were replaced. Table 1 presents demographic data for the participants in this experiment. The older adults had more years of education and a higher vocabulary score than the younger adults (ps < .01).

Stimuli. Two 40-word study lists were counterbalanced across participants within each age group. Each list contained a unique set of 20 common words (mostly nouns), half of which were included on the implicit memory test and half of which were included on the explicit memory test. An additional 12 words served as primacy and buffer items. The implicit word-fragment completion test consisted of 30 word fragments; 10 could be solved with words from the study phase, 10 had not been seen previously and belonged to the other study list, and 10 were easily completed fragments that were included to boost the implicit nature of the task by diluting the overall proportion of target fragments. The stimuli for the explicit word-fragment completion test were constructed according to the same 10-10-10 division, and fragments from the explicit and implicit tests were rotated across participants so that each fragment served in both implicit and explicit tests.

Procedure. The procedure for the study phase and retention interval was the same as in Experiment 1. The sole change from the previous experiment was that participants first completed the implicit memory test and then completed the explicit memory test.

Results

Accuracy on the color judgment task was nearly perfect for all participants (older adults: .96; younger adults: .98).

Baseline word-fragment completion rates were measured and analyzed in the same way as in Experiment 1. The baseline completion rates did not differ between the age groups or memory tests (Table 2; Fs < 1).

After subtracting baseline completion rates from target completion rates, we submitted the resulting memory scores to a 2 (age: younger, older) × 2 (memory test: implicit, explicit) ANOVA. There were no main effects of age or memory test (Fs < 1), but there was a significant interaction, $F(1, 38) = 32.3$, $p < .001$, $\eta_p^2 = .46$. Follow-up t tests indicated that older adults had better implicit than explicit memory and had better implicit memory than younger adults did (ps < .01). The pattern reversed, however, for the explicit memory test: Younger adults had better explicit than implicit memory and had better explicit memory than older adults did (ps < .01).

Discussion

The pattern of results was identical to that found in Experiment 1: Older adults had higher levels of implicit memory for irrelevant words than younger adults did, but the pattern reversed on the explicit memory test. Although a version of inhibitory theory directed at encoding processes can account for the implicit memory data, it is not obvious how that version of the theory can account for the complete data pattern. If younger adults are better able to inhibit irrelevant information than older adults are, then they should not have better memory for irrelevant information on an explicit test. What might account for this striking pattern of results?

One major determinant of test performance is the overlap between the operations engaged during encoding and retrieval—what is referred to as transfer-appropriate processing (Morris, Bransford, & Franks, 1977; Roediger, Weldon, & Challis, 1989). Optimal performance on the two tests used in these experiments relies on two distinct types of processing. The explicit memory test draws more on the meaning of events (i.e., performance is conceptually driven), and the implicit test draws on more perceptual (data-driven) aspects of mental processing (e.g., Jacoby, 1983; Roediger & Blaxton, 1987). From this perspective, the results suggest that there may be age-related differences in the relative amounts of conceptually driven and data-driven processing engaged by older and younger adults performing this task. That is, older adults may process the words during the incidental study phase in a predominantly perceptual fashion, which would be consistent with a previously observed reduction in the amount of conceptual processing carried out spontaneously by older adults (Craik & Byrd, 1982; Craik & Simon, 1980). Such low-level processing of the irrelevant information would be well suited for the implicit test. In contrast, despite the absence of any necessity to do so, younger adults may process at least some of their study words in a more conceptual manner that is better suited for the explicit test. Age-related differences in encoding styles may therefore explain the performance differences on the implicit and explicit tests.

Overall, this age-related differential-encoding account parsimoniously explains the pattern of results. Moreover, the suggestion that older adults process irrelevant information in a relatively shallow, or automatic, way because of reduced attentional resources (e.g., Craik, 1983, 1986; Hasher & Zacks, 1979) suggests that younger adults with reduced attentional resources (e.g., whose attention is divided at encoding) might manifest a pattern of results similar to that observed among older adults.

Experiment 3

Much like older adults, younger adults with divided attention have reduced resources available for conceptual processing (e.g., Castel & Craik, 2003; Troyer & Craik, 2000). Our goal in Experiment 3 was to determine whether younger adults performing the color judgment task under divided-attention conditions would show the same pattern of memory for distracting information that older adults do (i.e., poor explicit memory and better implicit memory). Such a finding would bolster the differential-encoding hypothesis.

Method

Participants. Table 1 summarizes the participants' characteristics.

Procedure. During the study phase, participants responded to the color of words, as in Experiment 2, but in this case they were additionally engaged in an auditory digit-monitoring task. They listened to single digits (0–9) presented in random order at a 1.5-s rate and monitored the series for two odd digits in a row (e.g., 3, 9). Participants reported aloud the second odd digit (e.g., "9") in any run of two odd digits. The testing procedure was identical to that in Experiment 2 (no digit-monitoring task was performed).

Results

Accuracy on the color judgment task was nearly perfect (.95).

Baseline word-fragment completion rates for the younger adults in this experiment (Table 2) were compared with those of the younger and older adults in Experiment 2, as their test conditions were identical. A 3 (group: divided-attention younger adults, full-attention younger adults, older adults) × 2 (memory test: implicit, explicit) ANOVA revealed no baseline differences between the groups.

Memory scores (target completion rates minus baseline completion rates; see Table 2) were submitted to a 3 (group: divided-attention younger adults, full-attention younger adults, older adults) × 2 (memory test: implicit, explicit) ANOVA. There was a main effect of memory test, $F(1, 57) = 9.40$, $p < .01$, $\eta_p^2 = .14$; no effect of group ($F < 1$); and a reliable Memory Test × Group interaction, $F(2, 57) = 26.03$, $p < .001$, $\eta_p^2 = .48$. Follow-up t tests indicated that divided-attention younger adults had higher levels of implicit memory but lower levels of explicit memory than full-attention younger adults (ps $< .001$). In addition, divided-attention younger adults did not differ from the older adults in Experiment 2 in either implicit or explicit memory performance (ps $> .10$).

Discussion

These results support the proposal that younger and older adults encode irrelevant information in different ways. The linchpin of the differential-encoding hypothesis is the amount of resources available at encoding. Both Craik (1983, 1986) and Hasher and Zacks (1979) proposed that older adults have reduced encoding resources relative to younger adults, and that this reduction in resources, in turn, results in a reduced ability to engage in elaborate memorial processing. Thus, we suggest that the older adults in Experiments 1 and 2 processed their words more perceptually, whereas the younger adults processed their words more conceptually. These different encoding styles differentially benefited performance on the implicit and explicit tests as a result of transfer-appropriate processing: Older adults did better on the perceptually based implicit test, whereas younger adults performed better on the conceptually based explicit test. Experiment 3 provided the critical test of the differential-encoding hypothesis. When the encoding abilities of older adults were simulated by dividing the attention of younger adults, the performance of the younger adults perfectly replicated the performance of older adults. This outcome provides good support for the proposal that a reduction in attentional resources at encoding is associated with a reduction in the amount of conceptual processing carried out (Craik & Byrd, 1982). It also seems probable that there are age-related differences in the usage of encoded material during retrieval, and we consider this idea in the next section.

General Discussion

A growing body of evidence indicates that older adults often have better implicit memory for distracting, or irrelevant, information than younger adults do. The current study replicated this implicit memory advantage but also demonstrated that younger adults had better explicit memory for irrelevant information than older adults do. Older adults' better implicit memory for distracting information can be explained by inhibitory theory, which holds that older adults' reduced inhibitory efficiency causes them to process more irrelevant information than younger adults process (Healey, Campbell, & Hasher, 2008) and to sustain activation of that information even when tasks change (the deletion function of inhibitory theory; Campbell et al., 2010; Thomas & Hasher, 2010).

The corollary of this view is that younger adults are more efficient at filtering out irrelevant information, but the present finding of good explicit memory among younger adults calls into question whether this encoding account tells the whole story. The results from our study suggest instead that there are situations in which both younger and older adults process distracting information. The observed pattern of results can be explained—at least in part—by differential encoding styles of younger and older adults, which may in turn result in differential implicit and explicit memory profiles. Older adults may be less able to add richness and depth to their memorial processing because there is an age-related decline in controlled processes as a result of frontal lobe deterioration (e.g., Moscovitch, 1992, 1994; Moscovitch & Winocur, 1992). This shallow, or relatively automatic, processing style is not restricted to older adults, but apparently extends to anyone with limited encoding resources: Younger adults whose attention was divided encoded their words in an automatic manner that was characteristic of older adults. Therefore, we suggest that one factor underlying the age-related difference in implicit and explicit memory for distracting information is the amount of available encoding resources; reduced resources are associated with shallower perceptual processing.

It also seems likely that group differences occurred at retrieval, and we suggest two such factors that may help to account for the overall data pattern. First, older adults transfer their implicit knowledge of distraction only under circumstances in which use of distraction is itself implicit. For example, Campbell et al. (2010) showed that after performing an initial task in which irrelevant words were superimposed on relevant pictures, older adults learned not only the distracting words but also the picture-word associations. Further, they could use that information in an implicit fashion, although there was no evidence that they had explicit knowledge of the original pairings. In the case of the present experiments, this factor may explain why older adults successfully used the distracting information from the first phase to complete word fragments when their memory was tested implicitly, but not when they were instructed to use the information explicitly.

Second, younger adults have more control of their memory retrieval processes than do older adults and are better able to focus on relevant sources; they show better source-constrained retrieval (Jacoby, Shimizu, Daniels, & Rhodes, 2005; Jacoby, Shimizu, Velanova, & Rhodes, 2005). When presented with a word-fragment completion task under implicit conditions, younger adults would therefore focus on their general semantic knowledge, rather than on information in a seemingly quite different task from the recent past. When presented with the word-fragment completion task under explicit instructions, however, younger adults could bring in information from the study phase and so perform at a much higher level. Thomas and Hasher (2010) similarly demonstrated that younger participants were able to use unattended words from an incidental-learning phase to boost recall of subsequently studied words only if they were explicitly instructed before the intentional-study phase that some of their study words had been included in the initial learning phase. When our study's first phase was carried out under divided-attention conditions, however, the irrelevant words were encoded at a superficial level, so that the younger adults had no relevant information to utilize in the explicit test. Together, the findings of Campbell et al. (2010), Thomas and Hasher (2010), and the present study suggest that, in addition to differential encoding processes, events occurring at retrieval play a crucial role in producing age-related differences in explicit and implicit memory for distracting information.

Our results illustrate a double dissociation between the effects of aging and the type of memory test: Older adults, and younger adults working under divided-attention conditions, used previously irrelevant information in an implicit memory test but not in an explicit memory test. This finding suggests that these two groups of participants failed to inhibit the irrelevant words in the color judgment task, but rather processed those words in a relatively superficial way. In turn, this perceptually weighted information was effective for solving word-fragment problems when participants were given implicit retrieval instructions, but not when they attempted to recollect the words under explicit instructions to do so. In contrast, younger adults working under full-attention conditions appeared to possess information about the irrelevant words that facilitated explicit but not implicit fragment completion. We suggest that these younger participants were more able to prevent interference from the irrelevant words in the color judgment task, but also processed at least some of these words in a more conceptual manner. In the second phase of the experiments, they did not spontaneously access this information in the implicit test, but could do so when test instructions indicated that words from the first phase were in fact relevant. We propose that the conceptual information encoded about at least some words was not transfer appropriate for the implicit test or that in some sense the encoded information was segregated and simply not accessed under implicit retrieval instructions because it was irrelevant to task goals. It seems reasonable to suggest that there are age-related differences both in the manner in which irrelevant words are initially encoded and in the manner in which this information is utilized during retrieval.

Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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