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Conceptual Processing of Distractors by Older but Not Younger Adults

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Abstract
Evidence from perceptually based implicit memory tasks demonstrates greater priming from distracting information among older compared with younger adults. We examined whether older adults also show greater conceptually based implicit priming from distracting information. We measured priming using a general-knowledge test that was preceded by an incidental-encoding task (a color-naming Stroop task in one experiment and a 1-back task involving pictures with irrelevant words superimposed in a second experiment). Younger adults showed no priming from the distracting information in either experiment, whereas older adults showed reliable priming in both experiments. Thus, unlike young adults, older adults process irrelevant information conceptually and then can use that information to boost their performance on a subsequent task.

Keywords
aging, cognitive ability, implicit memory

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Distraction plays a prominent role in the mental lives of older adults, hindering performance in some situations and aiding it in others (Weeks & Hasher, 2014). For example, visual distraction disproportionately slows older adults in both unfamiliar and familiar tasks, it increases their likelihood of errors, and it affects their comprehension accuracy more than that of younger adults (e.g., Kemper, McDowd, Metcalf, & Liu, 2008; Lustig, Hasher, & Tonev, 2006; Rozek, Kemper, & McDowd, 2012). In addition, and particularly for older adults, distraction encountered in the context of one task has been found to facilitate performance on a subsequent task, at least when performance on the subsequent task can rely on perceptually based information (e.g., Biss, Campbell, & Hasher, 2013; Gopie, Craik, & Hasher, 2011; Rowe, Valderrama, Hasher, & Lenartowicz, 2006). The question addressed here is whether or not the meaning of distractors—as opposed to their perceptual aspects—is actually encoded.

Although no previous study has directly examined whether older adults conceptually encode distractors, we are aware of one study that suggests this possibility (Kim, Hasher, & Zacks, 2007). In the initial phase of that study, participants read passages that included distracting words, some of which later served as solutions to remote-association problems. For each problem, a triplet of words was presented, and the solution required retrieving a word related to all three (e.g., "space" is the solution for the triplet "ship," "outer," "crawl"). Only older adults showed priming from the distractors on the remote-association task. These results suggest that the older adults coded and retained meaning from the distractors, but it is worth noting that the critical items that ultimately served as solutions had each occurred as distractors 15 times. Previous research has demonstrated that repetition of stimuli promotes conceptual processing, such that it enhances priming on conceptual, but not perceptual, implicit tests (Challis & Sidhu, 1993). Thus, the reported effects might have been due to age-related differences in the effects of item repetition, rather than distraction processing.

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In the experiments reported here, we used a classic conceptual priming task, a test of general knowledge (Blaxton, 1989; Mulligan, 1998), to test whether the meaning of distracting stimuli from a previous task is encoded and accessible after limited (one or two) exposures. In the first study, the initial task was a Stroop task, in which younger and older adults named the font color of a series of task-irrelevant (noncolor) words, each of which was presented a single time. In the second study, the initial task was a 1-back task involving pictures, and the distracting words, each of which appeared twice, were individually superimposed on the pictures. Classic levels-of-processing work suggests that when items serve as targets, older adults do not benefit as much as younger adults from meaning-based encoding during cover tasks (e.g., Jelicic, 1995; Jelicic, Craik, & Moscovitch, 1996). From this perspective, if older adults also code distracting information shallowly, they would be expected to show less priming by such information than young adults do. However, in both experiments, only older adults showed a benefit on the general-knowledge questionnaire from words they had initially seen as distractors.

Experiment 1

In this experiment, younger and older adults first completed a Stroop task, in which they reported the font color of task-irrelevant words (e.g., "red" when the word *agnostic* appeared in red). After a brief filled interval, participants completed a conceptually based general-knowledge task on which the correct answers to half of the critical questions were distractors from the initial Stroop task. If the meaning of the distractors in the incidental encoding phase was processed and accessible by older, but not younger, adults, then only older adults would show reliable conceptual implicit memory of those items on the general-knowledge task.

Method

Participants. Thirty-four younger adults (18–24 years old, M = 19.41 years, SD = 1.67; 12 male) and 32 older adults (61–81 years old, M = 68.81 years, SD = 5.25; 9 male) were tested. To determine the sample sizes, we first averaged the effect sizes reported in previous studies (Biss, Ngo, Hasher, Campbell, & Rowe, 2013; Campbell, Grady, Ng, & Hasher, 2012) showing priming for perceptual aspects of distractors. This average effect size (d) was 0.74. We then calculated that a minimum of 30 subjects would be required per group in order to have 80% power to detect an age difference of this magnitude. Thus, we tested approximately 32 subjects in each group.

The younger adults were undergraduates at the University of Toronto and received course credit or monetary compensation. The older adults were recruited from the community and received monetary compensation. All participants were native English speakers or had learned English before age 6, had completed at least 12 years of education, were free from psychiatric or neurological illness, and (with the exception of 1 older adult) had lived in North America at least since childhood (a criterion adopted because of the nature of the general-knowledge questions used). All the older adults were cognitively intact, as demonstrated by their scores on the Mini-Mental State Exam (MMSE; Folstein, Folstein, & McHugh, 1975; M = 29.09, SD = 1.06), Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005; M = 26.87, SD = 2.4), and Short Blessed Test (SBT; Katzman et al., 1983; M = 0.62, SD = 1.21). We replaced the data from 2 younger adults who intentionally used words from the initial Stroop task on the general-knowledge task (see Procedure for more details) and from 1 younger and 1 older adult who performed poorly on the initial Stroop task (accuracy > 4 SD below the group mean). The older adults had more years of education (M = 17.06 years, SD = 2.65) than the younger adults (M = 13.33 years, SD = 1.22), $t(63)$ = 7.33, p < .0001, and also scored better on the Shipley (1946) vocabulary test (older adults: M = 36.84, SD = 2.92; younger adults: M = 29.39, SD = 3.70), $t(64)$ = 9.04, p < .0001, as would be expected given the growth of vocabulary over adulthood (e.g., Park et al., 2002). Education data were missing from 1 younger adult. All experimental protocols were reviewed and approved by the ethics committee of the University of Toronto.

Stimuli. Two lists of 40 words each (mostly common nouns) were created for the Stroop task. Each participant saw one of these lists. Twenty of the 40 words on each list served as answers on the general-knowledge task (i.e., critical words); the remaining 20 filler words (same in both lists) were matched to the critical words in length, frequency of occurrence, naming time, and lexical decision accuracy using the English Lexicon Project database (Balota et al., 2007). The critical words (and their corresponding general-knowledge questions in the test phase) were selected from Blaxton (1989). An additional 12 words were added to each list to serve as primacy and recency buffers, so that each list had a total of 52 words. The Stroop stimuli were presented on a computer screen in lowercase, 18-point bold Arial font, against a black background; each word was presented in one of four colors (red, blue, green, or yellow).

There were 40 critical questions in the general-knowledge task. Answers for half of these questions (target questions) were previously presented as distractors in the Stroop task, and answers for the other half (baseline questions) were the critical words on the alternate Stroop list (thus, counterbalancing provided a baseline measure of general knowledge). Six easy questions were added both at the beginning and at the end of the task to boost

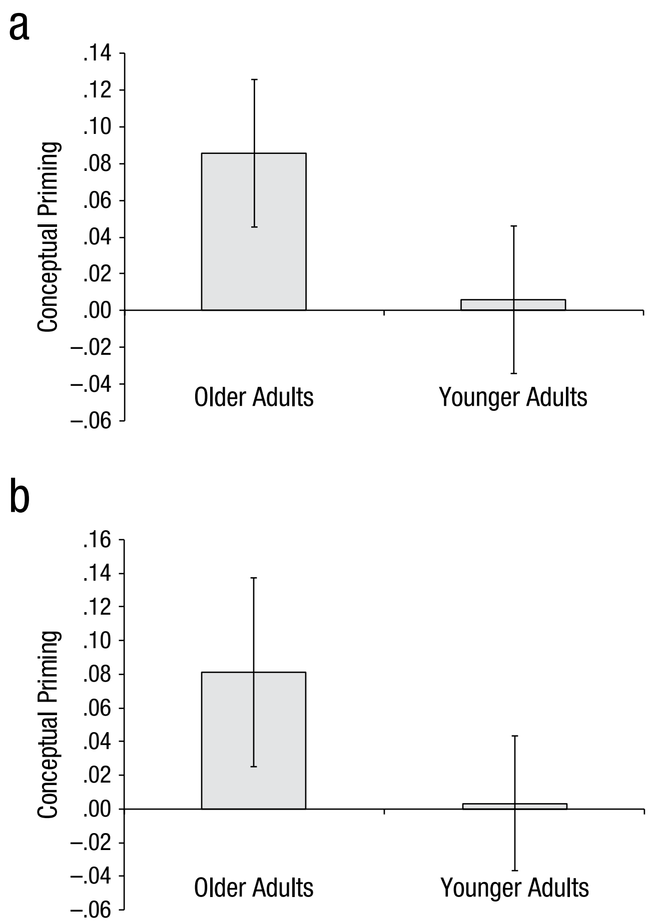

Fig. 1. Mean conceptual priming from previous distractors in (a) Experiment 1 and (b) Experiment 2. Error bars are 95% confidence intervals of the means.

morale and to disguise the task's implicit nature. Thus, there were 52 questions in the task.

Procedure. During the Stroop task, participants responded to the color of the stimuli by pressing one of four buttons on a response box. Each word was presented individually at the center of the screen until a response was made, for a maximum of 2,000 ms. A response initiated an interstimulus interval (ISI) of 2,000 ms. Six words were presented first as a primacy buffer. They were followed by 40 words (20 critical and 20 filler) in random order. Finally, 6 words were presented as a recency buffer. The task was preceded by a 7-item practice Stroop task in which color words were presented in congruent (e.g., "RED" in red) or incongruent (e.g., "BLUE" in red) colors. After completing the Stroop task, participants performed a 10-min nonverbal task (a computerized version of Corsi's, 1972, Block-Tapping Test, adapted from Rowe, Hasher, & Turcotte, 2008) that was included to hide the connection between the initial task and the subsequent general-knowledge task.

Participants then performed the general-knowledge task, with questions presented one at a time on a computer screen, giving the first response that came to mind. They were informed that the task was being administered to obtain norms for future research. Each question was presented for 10 s, followed by an ISI of 500 ms. Two practice questions were administered first, followed by the 52 task questions. Target and baseline questions were presented in the same alternating order to each participant.

Following the general-knowledge task, participants were asked if they had noticed a connection between the tasks and, if so, whether they had intentionally used words from the initial Stroop task on the general-knowledge task. As in previous studies (e.g., Biss, Ngo, et al., 2013), we excluded participants who reported having used such a strategy. Finally, participants completed a background questionnaire and the Shipley (1946) vocabulary test, and older adults were administered the MMSE, SBT, and MoCA (in that order).

Results

Because accuracy scores on the Stroop task were not normally distributed, a nonparametric Mann-Whitney test was used to compare the performance of the two age groups. Accuracy was near perfect for both younger (*Mdn* = 98%) and older (*Mdn* = 98%) adults, and did not differ between the two groups, $U = 497.5$, $z = 0.63$, $p > .5$. Stroop reaction times (RTs) were trimmed by removing RTs on trials responded to incorrectly and RTs that were 2.5 standard deviations (or more) above or below the mean for each participant (1.8% of trials for younger adults and 1.7% of trials for older adults). Younger adults (M = 631 ms, SD = 114) responded faster on the Stroop task than older adults (M = 846 ms, SD = 157), $t(64) = 6.40$, $p < .0001$, $d = 1.58$.

Priming for each participant was calculated by subtracting the corresponding group's average proportion of correctly answered baseline questions from the individual's proportion of correctly answered target questions, as is typical in the priming literature (e.g., Rowe et al., 2006). Older adults ($M = .26$, $SD = .14$) correctly answered more baseline questions than did younger adults ($M = .18$, $SD = .12$), $t(64) = 2.4$, $p < .05$, $d = 0.59$, which is consistent with the typical increase in general knowledge across the life span (e.g., Park et al., 2002). As illustrated in Figure 1a, older adults, $t(31) = 3.52$, $p < .005$, $d = 0.62$, but not younger adults, $p > .7$, showed reliable, above-baseline performance on questions whose answers had previously occurred as distractors on the Stroop task, and older adults showed a significant advantage over younger adults in conceptual priming for these distractors, $t(64) = 2.43$, $p < .05$, $d = 0.60$. There was no overall relationship between Stroop RT and priming, $p > .1$.

Discussion

The data from this experiment suggest that older adults encode the meaning of distracting stimuli and have that information available subsequently to answer general-knowledge questions. These findings contrast with data showing that older adults encode target information less deeply than younger adults (e.g., Craik & Byrd, 1982). Given the counterintuitive pattern of results in this experiment, we conducted a conceptual replication.

Experiment 2

In our second experiment, distraction was presented in the context of a 1-back task involving pictures (adapted from a previous study; Biss, Ngo, et al., 2013, Experiment 2) with superimposed irrelevant words, some of which served as answers on the subsequent general-knowledge test. Given the findings from Experiment 1, we expected older, but not younger, adults to show reliable conceptual implicit memory for distractors seen on the 1-back task.

Method

Participants. Participants were 32 younger adults (17–24 years old, $M = 18.97$ years, $SD = 1.91$; 11 male) and 32 older adults (61–80 years old, $M = 69.81$ years, $SD = 5.31$; 9 male). Sample size was determined by the power analysis described for Experiment 1. Participants were recruited as in our first experiment, and all met the language, education, and health criteria. As in Experiment 1, older adults performed well on the MMSE ($M = 29.19$, $SD = 1.15$), MoCA ($M = 27.13$, $SD = 2.03$), and SBT ($M = 0.74$, $SD = 1.41$), and had more years of education than the younger adults (older: $M = 17.25$, $SD = 2.74$; younger: $M = 13.09$, $SD = 1.38$), $t(62) = 7.68$, $p < .0001$, as well as higher Shipley (1946) vocabulary scores (older: $M = 37.40$, $SD = 2.46$; younger: $M = 30.26$, $SD = 3.79$), $t(62) = 8.93$, $p < .0001$. Data from 3 younger and 2 older adults were replaced: One younger and 1 older adult performed poorly on the 1-back task (accuracy close to 4 *SD* below the group mean), 1 younger adult reported awareness of the connection between the tasks and conscious use of words from the 1-back task in the general-knowledge task, and 1 younger and 1 older adult failed to follow general task instructions. All experimental protocols were reviewed and approved by the ethics committee of the University of Toronto.

Stimuli. For the 1-back task, we used two 20-word lists (a subset of the words used in Experiment 1), which were counterbalanced across participants. The words were individually superimposed on line drawings selected from Snodgrass and Vanderwart (1980). Ten of the 20 words on each list were critical, target items, which served as answers to subsequent general-knowledge questions, and the remaining 10 filler words (same on both lists) were matched to the targets in length, frequency of occurrence, naming time, and lexical decision accuracy. Twenty nonwords, matched to the words in length, were also used as distractors; 16 additional nonwords served as primacy and recency buffers. The words and nonwords were presented in uppercase, 18-point bold Arial font in black. They were individually superimposed on the line drawings, which were colored red to make them easily distinguishable.

The general-knowledge task was identical to the one used in Experiment 1, with the exception that it consisted of 20 critical questions (10 target and 10 baseline) rather than 40. As in Experiment 1, 12 easy questions were added, for a total of 32 questions.

Procedure. During the 1-back task, participants were presented with a stream of pictures and instructed to press a certain key whenever two consecutive pictures were identical and another key whenever consecutive pictures were different, while ignoring superimposed words or nonwords. Each picture was presented for 1,000 ms, and the ISI was 500 ms. Each picture, word, and nonword occurred twice over the course of the task; a given critical word was always superimposed on the same picture, and fillers and nonwords occurred with different pictures to ensure that participants could not respond to the 1-back trials on the basis of the distracting items rather than the pictures. A total of 17 pictures were repetitions of the immediately preceding picture, and no critical words were presented on these repetition trials. Following a practice session with 20 pictures presented alone with no distractors, there were a total of 100 trials, presented in the following order: 4 pictures presented alone, 8 pictures with superimposed nonwords, 80 pictures with superimposed words (10 critical and 10 filler words, each occurring twice, for a total of 40 trials) or nonwords (20 occurring twice, for a total of 40 trials), and finally 8 pictures with superimposed nonwords. Following the 1-back task, participants performed a 10-min computerized Corsi (1972) Block-Tapping filler task and then a general-knowledge task, as in Experiment 1. The procedure for administering the questionnaire and cognitive tests after the tasks was identical to that in Experiment 1.

Results

A nonparametric Mann-Whitney test showed that younger adults ($Mdn = 98\%$) were more accurate than older adults ($Mdn = 94\%$) on the 1-back task, $U = 271.5$, $z = 3.27$, $p < .005$, $r = .41$, which is consistent with the findings from Biss, Ngo, et al. (2013). Given that age differences in accuracy are seldom reported for traditional 1-back tasks with no distracting items (e.g., Mattay et al., 2006), the results suggest that older adults were more negatively influenced than younger adults by the presence of the concurrent distractors. As in Experiment 1, RTs on the initial task were trimmed by removing trials responded to incorrectly and trials with RTs 2.5 standard deviations (or more) above or below each participant's mean (2.8% of trials for younger adults and 1.3% of trials for older adults). Younger adults (M = 499 ms, SD = 78) responded faster on the 1-back task than older adults (M = 606 ms, SD = 77), $t(62) = 5.56$, $p < .0001$, $d = 1.39$.

As in Experiment 1, older adults (M = .39, SD = .18) correctly answered more of the baseline questions in the general-knowledge task than did younger adults (M = .26, SD = .14), $t(62) = 3.33$, $p < .005$, $d = 0.83$. In addition, analyses of priming scores (calculated as in Experiment 1) revealed that older adults, $t(31) = 2.83$, $p < .01$, $d = 0.50$, but not younger adults, $p > .8$, showed reliable priming for distractors, and that older adults showed more conceptual priming for distractors than did younger adults, $t(62) = 2.15$, $p < .05$, $d = 0.54$ (see Fig. 1b). There was no relationship between RT on the 1-back task and conceptual priming, $p > .05$.

Discussion

The age differences in conceptual priming seen in these experiments might have been the result of older adults' greater knowledge of the information needed to answer the general-knowledge questions, given that older adults had higher baseline scores than did younger adults. Greater knowledge might have provided older adults with easier access to the previously encountered distractors at retrieval. To examine this possibility, we correlated Shipley vocabulary scores (used as a proxy for knowledge) with individual priming scores (calculated as each individual's priming score divided by the maximum priming score possible for that individual given the number of baseline questions he or she had answered correctly) separately for each group, collapsed across both studies. For older adults (N = 64), there was no relationship between knowledge and conceptual priming, $r = .03$, $p > .8$. For younger adults (N = 66), however, there was an interesting *negative* correlation between general knowledge and priming, $r = -.37$, $p < .005$; the fact that younger adults with greater knowledge were less likely to show conceptual priming for previous distractors suggests that suppression of distraction is related to crystallized intelligence. Thus, the results suggest that although greater knowledge or crystallized intelligence is related to improved inhibitory control in younger adults, older adults show transfer of conceptual information from previous distractors irrespective of how much knowledge they possess.

As in Experiment 1, we found evidence of conceptual priming for previous irrelevant information in older, but not younger, adults (see Butler & Klein, 2009, for similar findings with young adults). This study, then, supports the hypothesis that older adults engage in more elaborate processing of irrelevant information (and have access to that information after a 10-min delay) than do younger adults.

General Discussion

Previous work had shown that older adults encode and maintain access to perceptual aspects of irrelevant information (e.g., Rowe et al., 2006). The question here was whether they do the same for semantic aspects of irrelevant information. To answer this question, we compared younger and older adults' implicit memory for words previously seen as distractors, using a classic, conceptually based general-knowledge task. Across two experiments with different incidental-encoding tasks, older adults showed greater conceptual implicit memory for distractors than did younger adults, who showed no reliable priming in either experiment.

A relatively large literature has established that older adults are less likely than younger adults to engage in deep processing of target stimuli, as assessed by tests of implicit memory for information originally presented in the targets (e.g., Geraci, 2006; Jelicic, 1995; Jelicic et al., 1996). Researchers have proposed two alternative explanations for these findings: (a) an age-related decrease in cognitive resources or capacity (e.g., Craik & Byrd, 1982; Craik & Simon, 1980) and (b) reduced ability of older adults to handle competition among competing candidates for responding (e.g., Fleischman & Gabrieli, 1998). Both explanations successfully account for patterns of conceptual priming based on information in targets, but neither can easily account for conceptual priming based on information in distractors, as both would predict less priming by older than by younger adults.

Instead, the present findings are consistent with evidence that older adults have less efficient inhibitory mechanisms for suppressing irrelevant information, both at the time of encoding and when the task or topic switches (e.g., Lustig, Hasher, & Zacks, 2007). The failure to suppress irrelevant information results in broader attention, such that more information is encoded by older adults than by younger adults (e.g., Campbell, Hasher, & Thomas, 2010).

Age deficits in suppression have been widely reported in the behavioral literature and, recently, increasingly in the neuroimaging literature. For example, using a 1-back task with distraction similar to the task used here, Campbell et al. (2012) found that older adults show less activity than younger adults in frontoparietal attention control regions that appear to be responsible for downregulating activation in more perceptual, or downstream, sensory regions.

Campbell et al. reported that lesser activity in these attention control regions was correlated with greater perceptual knowledge of distractors (see also de Fockert, Ramchurn, van Velzen, Bergstrom, & Bunce, 2009; Schmitz, Cheng, & De Rosa, 2010). It is possible, then, that age-related declines in the functioning of these control regions also results in less top-down modulation of regions involved in forming high-level conceptual representations of to-be-ignored information, allowing such processing to occur and resulting in overall weaker controlled processing (see Gazzaley, Cooney, Rissman, & D'Esposito, 2005). This hypothesis gains further support from a recent finding that when performing a 1-back task on words, older adults show greater activity than younger adults in conceptual processing regions (e.g., the left inferior frontal cortex); this finding suggests that in older adults, these regions are automatically activated when verbal material is presented (Anderson, Campbell, Amer, Grady, & Hasher, 2014).

Recent work has shown a number of instances in which knowledge of distracting information transfers to new tasks, including new learning tasks (e.g., Campbell et al., 2010; Rowe et al., 2006), but for older adults only. In all these studies, however, the items themselves were re-presented, such that the positive transfer can be tied to perceptual-level information. The present study dramatically demonstrates that semantic-level information is extracted from distractors and influences performance on a subsequent conceptual test. These findings highlight the possibility that older adults do encode information at multiple levels, and potentially raise interpretational difficulties for using levels of processing to explain at least some differences in performance between younger and older adults (e.g., Gopie et al., 2011). We conclude by speculating that conceptual knowledge of distractors can add to or form part of the basis of the greater wisdom reported for older than younger adults (e.g., Grossmann et al., 2010). Such knowledge may also form the basis of the information that enables older adults to compensate for the loss of efficiency of other basic cognitive functions, accounting for the preserved functioning that many older adults demonstrate in their everyday lives (e.g., Salthouse, 2012; Zimerman, Hasher, & Goldstein, 2011).

Author Contributions

Both authors contributed to the study concept and design, drafted the manuscript, and approved the final version for submission. Data collection and analysis were performed by T. Amer under the supervision of L. Hasher.

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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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