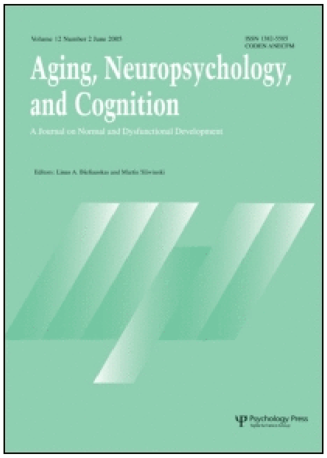

Aging, Neuropsychology, and Cognition
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713657683

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Online Publication Date: 01 June 2002
To cite this Article: Lazzara, Michele M., Yonelinas, Andrew P. and Ober, Beth A. (2002) 'Implicit Memory in Aging: Normal Transfer Across Semantic Decisions and Stimulus Format', Aging, Neuropsychology, and Cognition, 9:2, 145 - 156
To link to this article: DOI: 10.1076/anec.9.2.145.9545
URL: http://dx.doi.org/10.1076/anec.9.2.145.9545

Aging Neuropsychology and Cognition
2002, Vol. 9, No. 2, pp. 145–156

1382-5585/02/0902-145$16.00

Implicit Memory in Aging: Normal Transfer Across Semantic Decisions and Stimulus Format

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ABSTRACT

To investigate the effect of aging on the flexibility of implicit memory, the current study compared the performance of elderly and young participants on semantic decision tasks in which the processing task or the stimulus format was varied across study and test. In Experiment 1, the required semantic decision (i.e., size judgments vs. corner judgments) either remained the same or was varied from study to test. In Experiment 2, the stimulus format of the item (i.e., pictures vs. words) either remained the same or was varied. Elderly participants demonstrated normal priming effects, and equivalent transfer across manipulations of processing task and across manipulations of stimulus format, despite showing a deficit in recognition memory compared with young participants. The results suggest that aging does not influence the flexibility of implicit memory.

Aging leads to significant performance deficits on explicit tests of memory such as recall and recognition, but typically has smaller or no effects on implicit memory tests (see Fleischman & Gabrieli, 1998). For implicit tests, participants are engaged in some cognitive task, and memory is measured indirectly. Implicit memory effects can be measured as a reduction in response time or as an increase in accuracy or response bias for previously presented items compared with performance for new items (i.e., *priming*, Graf & Schacter, 1985). Implicit tests can be classified as perceptual or conceptual, based on the type of test cues (Roediger & McDermott, 1993). Perceptual implicit tasks focus on the analysis of stimulus features, and performance on these tasks reflects data-driven or sensory processes. In contrast, for conceptual tests, participants are given test cues that engage meaning-based processing, and performance reflects semantic processes. Aging generally does not disrupt priming on perceptual implicit tests such as fragment completion (e.g., Winocur, Moscovitch, & Stuss, 1996), stem completion (e.g., Light & Singh, 1987; Winocur et al., 1996; but see Chiarello & Hoyer, 1988; Small, Hultsch, & Masson, 1995), lexical decision (e.g., Balota & Ferraro, 1996; Ober, Shenaut, Jagust, & Stillman, 1991) or perceptual identification (e.g., Light, LaVoie, Valencia-Laver, Owens, & Mead, 1992). Although some exceptions have been reported, aging typically does not disrupt priming on conceptual implicit tests like category exemplar generation (e.g., Isingrini, Vazou, & Leroy, 1995; Light & Albertson, 1989; Light, Prull, & Kennison, 2000; Maki & Knopman, 1996; Monti et al., 1996; but see Jelicic, Craik, & Moscovitch, 1996; Maki, Zonderman, & Weingartner, 1999), general knowledge (Rastle & Burke, 1996; Small et al., 1995), or word-associate generation (Java, 1996;

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Accepted for publication: April 18, 2002.

McEvoy, Holley, & Nelson, 1995; but see Grober, Gitlin, Bang, & Buschke, 1992). When exceptions occur to this generalization, such that elderly adults show impaired conceptual priming, there are (at least) three factors that could be contributing to this aging effect: explicit memory contamination, the time pressure of latency-based tasks, and the compatibility of the tasks used in the study and test phases. Each of these factors will be discussed in detail.

One potential cause of the reported deficits in implicit memory is that elderly participants are less likely to use explicit memory than the young control participants (e.g., Chiarello & Hoyer, 1988; Grober et al., 1992; Maki et al., 1999). That is, because young participants are more likely to explicitly remember the previously studied items, they are more likely to use explicit memory to increase performance on conceptual implicit tests. Use of explicit memory is thought to be particularly problematic for conceptual tasks because these tasks require meaning-based processing at test. One method for assessing the contribution of explicit memory is to question the participants after the test and separate the participants who reported using explicit memory strategies or who became aware that some of the study items could be used in the test phase, from those participants who did not report such strategies or awareness. Although this method of post hoc analysis can be useful, there are important limitations associated with this approach (for a brief discussion, see Roediger & McDermott, 1993). Another method is to look for tasks that are less likely to be contaminated by explicit memory. For example, using tests in which participants are required to make speeded responses may help reduce the contribution of explicit memory because the response times are not long enough to allow for explicit remembering (e.g., McKone & Slee, 1997; Vriezen, Moscovitch, & Bellos, 1995).

Reaction time (RT) measures of conceptual implicit memory have only rarely been used to measure priming in older participants, and the results have been somewhat mixed. Two studies have shown that both elderly and young participants are faster to make semantic classifications (e.g., animal/nonanimal decisions) to repeated items compared with new items, and the magnitude of the priming effect was equivalent between groups (Hamberger & Friedman, 1992; Kazmerski, Friedman & Hewitt, 1995). In contrast, in a similar study, aging was not found to disrupt priming in one experiment, but did lead to a significant deficit in another experiment (Light et al., 2000). Given that only a limited number of RT studies have been conducted, it is important to further examine the effects of aging on performance on these conceptual priming tasks.

One factor that may have played a role in the discrepancies observed in the pervious RT studies was the extent to which the tasks required processing flexibility. That is, for the studies in which the elderly consistently showed normal conceptual priming effects (Hamberger & Friedman, 1992; Kazmerski et al., 1995), subjects were required to make the same judgments during study and test. However, in the Light et al. (2000) study, participants made pleasantness judgments during the study phase and category membership judgments at the time of test. It is possible that aging does not influence priming when the tasks remain constant across study and test, but does adversely influence priming on RT tasks when there is minimal overlap between study and test processing.

To investigate the effect of aging on the flexibility of priming in RT tasks, the current study compared the performance of elderly and young participants on the semantic decision task. The experiments were based on a set of procedures developed by Vriezen et al. (1995). During the study phase, participants were presented with stimuli and asked to make "yes/no" decisions to meaning-based questions about the items. At test, the participants again made semantic decisions about previously presented and newly presented stimuli, and the RT required to make those decisions was recorded.

The semantic decision task has several advantages. First, because it is a speeded response time task it should be less susceptible to effects of explicit contamination (e.g., McKone & Slee, 1997; Vriezen et al., 1995) than nonspeeded tasks. Second, it allows us to examine both conceptual flexibility (i.e., the effects of changing the semantic decision between study and test) and perceptual flexibility (i.e., the effects of changing the perceptual format of the items between study and test) in implicit memory performance of older adults.

In Experiment 1, younger and older subjects made semantic decisions at test that were either the same or different from those made during study, in order to determine whether the older subjects exhibited normal flexibility across changes in semantic judgments. Vriezen et al. (1995) used this task with young participants and found that subjects were faster to make decisions for repeated relative to new items, even when different semantic decisions were made at study and test. These authors found that this cross-decision priming was significant for decisions that tapped information from the same semantic domain (e.g., size decisions primed dimension decisions), but not when the decisions tapped information from different semantic domains (e.g., size decisions did not prime man-made decisions). Whether aged subjects will show comparable transfer across semantic decisions is not known.

For Experiment 2, the same semantic decision was required during study and test, but the perceptual format of the items (picture vs. words) was varied in order to determine whether older individuals lack the flexibility required to support normal RT priming across changes in stimulus format. Vriezen et al. (1995) found that young participants showed significant priming on this task when the stimulus format changed from study to test. Although it is not known if the elderly will show comparable priming effects under these conditions, findings of intact priming on perceptual implicit tasks across manipulations of perceptual features among older individuals (e.g., Ergis, Van der Linden, & Deweer, 1995; Gibson, Brooks, Friedman, & Yesavage, 1993; Light et al., 1992; Sommers, 1999) suggest that the elderly might exhibit normal priming on the semantic decision task across changes in perceptual format.

GENERAL METHOD

Participants

The same group of elderly and young individuals participated in both Experiments 1 and 2. Twenty-four elderly participants were recruited from the communities of Davis and Sacramento, CA, and were paid \$10 per hour for participating. All elderly participants reported being in good health, with no history of stroke or neurological disorder. The group consisted of 7 male and 17 female participants, and ranged in age from 66 to 89 years, $M = 75.21$, $SD = 5.36$; and in education from 10 to 25 years, $M = 16.17$, $SD = 3.29$. A subset of the data from 19 of the 24 elderly participants was used previously as age-matched control data in a study examining conceptual priming in Alzheimer's disease (Lazzara, Yonelinas, & Ober, 2001). Twenty-four young subjects received extra credit in an introductory psychology course or were paid \$5 per hour for participating. Young participants ranged in age from 18 to 28 years, $M = 21.29$, $SD = 2.90$; and ranged in education levels from 13 to 20 years, $M = 15.42$, $SD = 2.17$. The young and elderly groups did not differ in education levels, $t(46) = .93$.

Elderly participants were given the Mini-Mental State Exam (MMSE; Folstein, Folstein, & McHugh, 1975). No participant scored below a 27 on the MMSE, $M = 29.25$, $SD = .90$, indicating that the elderly participants did not exhibit any gross cognitive impairments.

Procedure

Experiments 1 and 2 were conducted during two different experimental sessions, administered 1 week apart, and each lasted 1 hr. Because performance on the two different semantic decision tasks was of primary interest (i.e., the flexibility measures), those tasks were administered first during each experimental session. For one session (Experiment 1), all participants completed a semantic decision task that included the manipulation of processing task, and a recognition memory test. For another session (Experiment 2), all participants completed a semantic decision task that included the manipulation of stimulus format, and then all elderly participants were given the MMSE. Items were chosen such that materials did not overlap across tasks or experiments.

The significance level for all tests was $p < .05$, unless otherwise noted. For both experiments, separate variance t tests were used rather then pooled variance *t* tests when Levene's test for equality of variance (Levene, 1960) reached the .05 significance level, indicating unequal variance between groups. Note that using unequal variance *t* tests decreases the degrees of freedom of the statistical test.

EXPERIMENT 1

To investigate the flexibility of conceptual priming in normal aging, the semantic decision task was used to measure transfer of conceptual priming effects across different processing tasks. Elderly and young participants studied one list of words while deciding whether each of the items was bigger or smaller than a shoebox, and studied another list while deciding whether each of the items contained a corner. At test, participants were presented with new and repeated items, and decided whether each of the items was bigger than a shoebox. Half of the repeated test items were studied under the same semantic decision, and half were studied under the different semantic decision. Experiment 1 also included a recognition memory test to measure explicit memory performance.

METHOD

Materials

One hundred and forty words were chosen to be used as stimuli in this experiment. The words ranged from 3 to 10 letters in length and had Kucera–Francis (1967) frequency values of 0–500 per million, with a mean frequency value of 29.16, $SD = 48.98$, for this list. Words were chosen such that, for the objects named by the words, half were classified as being bigger and half were classified as being smaller than a shoebox. In addition, half of these items were classified as having a corner and half as not having a corner. Because the objective size and shape of an object is somewhat ambiguous given that many objects can take on several different forms (e.g., the word ''pizza'' represents an item that can be a large round object or a small individual piece with corners), items were chosen for which agreement was reached by three independent raters (two of the authors, A.Y. and M.L., and a third rater).

For each participant, 40 items were randomly selected to be studied under the *shoebox* processing question (''Is it bigger than a shoebox?''), 40 items were randomly selected to be studied under the *corner* processing question (''Does it have a corner?''), and 40 items were selected to be new items. Five practice items were randomly selected and added to the beginning of each of the two study lists. The test list of the semantic decision task contained 60 items (i.e., 20 were items that had been studied under the shoebox question; 20 were items studied under the corner question; and 20 were new items) and participants were asked to make shoebox judgments about the items. Fifteen practice items were added to the beginning of the test list. Of those 15 practice items, 10 were the same practice items that were used during the study phase (5 items were the practice items from the shoebox study condition, and 5 items were the practice items from the corner study condition) and 5 items were not previously used during the study phase. For the recognition memory test, the test list contained 60 items (i.e., 20 were items that were studied under the shoebox question; 20 were items studied under the corner question; and 20 were new items). An additional 5 practice items were randomly selected and added to the beginning of the recognition test list.

Design and Procedure

The semantic decision task was presented before the recognition memory test. The study lists for the semantic decision task and for the recognition memory test were combined into a single study phase. Study items were presented one at a time in a randomized order on a laptop computer. During the study phase, the experimenter read the items aloud one at a time to the participant. For one list of words, participants were asked to make ''yes/no'' decisions indicating whether the object was bigger or smaller than a shoebox. For the other list of words, participants decided whether or not the object had a corner. The encoding conditions were blocked, and the order was counterbalanced across participants. All study phase responses were made verbally, and the experimenter recorded the responses. For the test phase of this semantic decision task, stimuli were presented on a laptop computer and participants responded via computer-monitored response buttons. The question ''*Is it bigger than a shoebox?*'' was printed below each item. Participants responded by pressing one of two labeled and differently colored response buttons (i.e., ''yes'' – green vs. ''no'' – red). The test was self-paced, but participants were told to respond as quickly and accurately as possible. Sixty items were presented for this semantic decision task, and the RT required for response was recorded by the computer. RTs greater than 30 s were not recorded by the computer, and thus, such responses were not included in the analyses.

The recognition memory test immediately followed the semantic decision task. During the recognition test, participants were presented with 60 words, one at a time, on the computer screen and were asked to decide if the word had been previously presented in the experiment ("old") or if it had not ("new"). Responses were made verbally, and the experimenter recorded each response. The recognition memory test only included the items from the study phase that were not presented during the test phase of the semantic decision task.

RESULTS AND DISCUSSION

Semantic Decision

Only decisions that did not exceed two standard deviations from the participant's mean RT, within each study-test condition, were included in the analysis, resulting in the elimination of 6% of the total number of responses for the elderly group, and 5% of the total number of responses for the young group (for a discussion of this method, see Ratcliff, 1993). In addition, a group-wide elimination of outliers was performed for which any participant having a mean RT in the new item condition that was greater than two standard deviations from the group mean for new items was excluded from all analyses. Data from two participants in each group were excluded from all analyses as a result of this additional group-wide method of elimination, and thus the young and elderly groups each contained 22 participants. Analyses were also conducted on median RTs, but these analyses led to a similar pattern of results and thus are not reported. Due to a computer programming problem in Experiment 1, the proportion of correct and incorrect responses were not available for analysis. However, the results from Experiment 2 indicated that participants made very few errors and that the priming effects were unaffected when the analyses excluded incorrect responses.

The mean RTs for items in each of the study-test conditions are presented in Table 1. Elderly participants were slower at responding to new items than were young participants, $t(26) = 3.86$. To compensate for this difference in baseline response rate, analyses were conducted on the proportional priming effects (for a discussion, see Chapman, Chapman, Curran, & Miller, 1994). That is, for each participant, priming was measured as the difference in RT for old and new items divided by the new item RT. Note, however, that an analysis of

Table 1. Mean RTs (ms) for the Semantic Decision Task That Included the Manipulation of Processing Task, and the Average Probability of Responding "old" to an Item in the Recognition Memory Test (Standard Deviations are in Parentheses). Test Phase for Semantic Decision Task Required Size Decisions for All Items.

Study condition	Size decision	Corner decision	New
Semantic decision task			
Elderly	996 (208)	1038 (227)	1077 (231)
Young	786 (88)	826 (117)	874 (86)
Recognition memory test			
Elderly	.79 (.12)	.85 (.13)	.08 (.07)
Young	.83 (.10)	.91 (.08)	.05 (.05)

absolute priming scores was also conducted and led to a similar pattern of results.

Figure 1 shows the proportional priming effects for the elderly and young groups when the semantic decision was either the same or different across study and test. Priming effects were equivalent between the young and the elderly participants, $F(1, 42) = 1.11$, $MSE = .013$. Moreover, there was no significant interaction between decision type and group, $F < 1$, showing that the magnitude of priming for the same- and different-decision conditions was not affected by aging. There was a marginal effect of decision type, $F(1, 42) = 3.59$, $MSE = .009$, $p < .07$, reflecting slightly greater proportional priming effects for items studied and tested following the same semantic decisions compared with the proportional priming effects for items studied and tested following different semantic decisions. It is important to note that when the same analysis was conducted on the absolute priming effects, the effect of decision type was significant, $F(1, 42) = 4.34$, $MSE = 8555.59$. Similarly, the median RT analysis also indicated that the effect of decision type was significant, $F(1, 42) = 5.75$, $MSE = .006$.

Recognition Memory Test

Data from the recognition memory test is presented in Table 1. False alarm rates (i.e., incorrectly labeling a new item as "old") did not differ

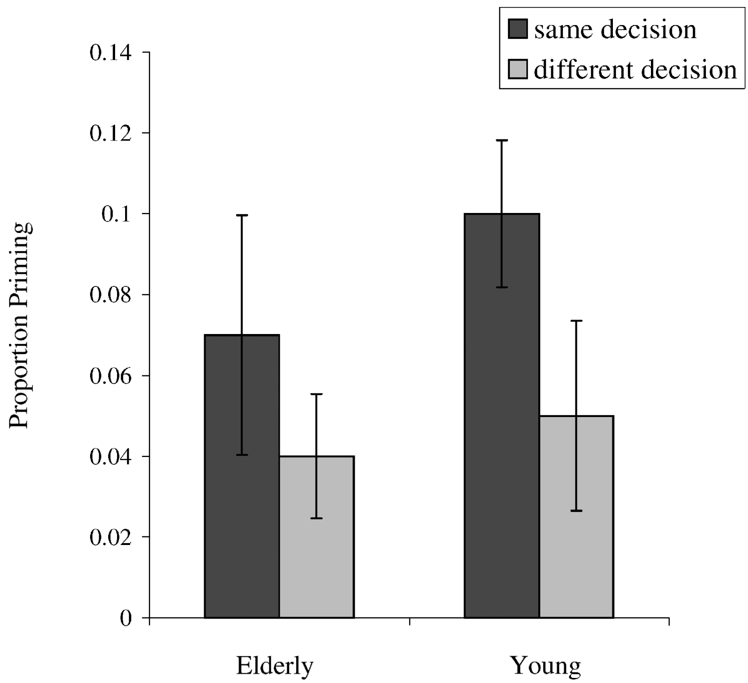

Fig. 1. The proportional priming effects on the semantic decision task for items studied and tested following the same and different processing tasks (Experiment 1).

between groups, $t(46) = 1.70$; and analyses were conducted on the corrected recognition scores (hits minus false alarms) for the two different study conditions (i.e., shoebox decisions vs. corner decisions). An ANOVA revealed greater recognition memory performance for items that were studied under the corner decision compared with the performance for items studied under the shoebox decision, $F(1,46) = 12.12$, $MSE = .010$. Better recognition performance was found overall for young compared with elderly participants, $F(1,46) = 6.88$, $MSE = .022$. The interaction between study condition and group was not significant, $F < 1$, suggesting that both groups were affected similarly by the study conditions. Greater recognition memory performance following the corner study decision compared to the shoebox study decision may reflect more elaborate encoding in the corner study condition. Deciding if an object has a corner may involve greater processing demands because the individual details of the object must be scrutinized; whereas, deciding if an object is bigger than a shoebox may be a whole-object based decision that may be easier to make. Important for the purposes of the current study, however, was the finding of impaired explicit memory performance among elderly participants.

In sum, the elderly participants exhibited significant deficits in recognition memory but showed normal priming effects in the semantic decision task when the semantic decision was the same at study and test, and when the semantic decision changed between study and test. Thus, the results indicate that the transfer of priming effects across processing tasks was not influenced by normal aging. These results provide no support for the assertion that implicit memory is less flexible in elderly than in young individuals.

EXPERIMENT 2

Although the test decision in Experiment 1 required semantic processing, it is possible that priming was supported at least in part by perceptual processes given that the format of the item was identical from study to test. To further investigate the findings in Experiment 1 of normal flexibility in aging, the semantic decision task was used to measure the transfer of priming effects across manipulations of stimulus format (i.e., from words to pictures and pictures to words) in elderly and young participants. At study, participants were shown a mixed list of words and pictures and asked to make "yes/no" decisions indicating whether the item was bigger than a shoebox. At test, participants were asked to make the identical decision for new and repeated items. Half of the items within each class (i.e., words and pictures) repeated in the same format as presented at study, and half repeated in the opposite format from study. For the new items, half were presented as new pictures and half were new words. Experiment 2 also examined whether a previous finding of normal transfer across changes in stimulus format using a perceptual implicit task with elderly participants (Ergis et al., 1995) generalizes to elderly performance on conceptual tasks.

METHOD

Materials

One hundred and twenty pictures from the study of Snodgrass and Vanderwart (1980) and their corresponding names were selected as target items. Half of the stimuli represented items that were bigger than a shoebox and half were smaller than a shoebox. Because the Snodgrass and Vanderwart materials are not drawn to scale, items were chosen for which agreement regarding the size of the object was reached by three independent raters (two authors, A.Y. and M.L., and a third rater). For each participant, 80 items were randomly selected to serve as study items, half of which were to be presented as pictures and half as words. The test list contained 120 items (i.e., 20 were pictures at study and test; 20 were words at study and test; 20 were pictures at study and words at test; 20 were words at study and pictures at test; 20 were pictures at test and were not studied; and 20 were words at test and were not studied). Twenty additional items were selected from the Snodgrass and Vanderwart materials to serve as buffer items at the beginning of the study list (15 items) and the test list (5 items).

Design and Procedure

For the semantic decision task, stimuli were presented on a laptop computer and participants responded via computer-monitored response buttons. At study, participants were presented with a mixed list of 80 items, half of which were presented as words and half as pictures. The question "*Is it bigger than a shoebox?*" was printed below each item. Participants responded to the question by pressing one of two labeled and differently colored response buttons (i.e., "yes" – green vs. "no" – red). The test was self-paced, but participants were told to respond as quickly and accurately as possible. Participants again made shoebox decisions during the test phase, and the test phase was identical to the study phase except that 120 items were presented, with 80 of these items repeating from the study phase. During the test phase, half of the repeated items were presented in the same format and half were presented in the alternate format from which they had been studied. The RT was recorded by the computer. RTs greater than 30 s were not recorded by the computer, and thus, were not included in the analyses.

RESULTS AND DISCUSSION

Only decisions that did not exceed two standard deviations from the participant's mean RT, within each study-test condition, were included in the analysis, resulting in the elimination of 6% of the total number of responses for the elderly group, and 5% of the total number of responses for the young group. In addition, any participant having a mean RT in the new item condition that was greater than two standard deviations from the group mean for new items was excluded from all analyses. Data from 1 participant in each group was excluded from all analyses as a result of this additional group-wide method of elimination, and thus the elderly and young groups each contained 23 participants. Elderly and young participants made similar percentages of errors at test (i.e., incorrect decisions about the relative size of an item compared to a shoe box), $t(44) = .34$, with each group averaging 9% incorrect responses overall. Similar analyses were conducted on median RTs, and on mean RTs following the elimination of incorrect responses. However, these analyses led to the same pattern of results, and thus, are not reported.

The mean RTs for old and new items for the different study-test formats are presented in Table 2. Elderly participants were slower at responding to new items than were young participants, $t(30) = 3.37$ for new pictures; and $t\,(25) = 3.69$ for new words. Thus, as in Experiment 1,

Table 2. Mean RTs (ms) for Items in the Different Study-Test Conditions of the Semantic Decision Task That Included the Manipulation of Stimulus Format (Standard Deviations are in Parentheses). Test Phase Required Size Decision for All Items.

Test format	Pictures			Words		
Study format	Same	Different	New	Same	Different	New
Elderly	882 (213)	980 (287)	1001 (279)	939 (306)	977 (308)	1068 (316)
Young	678 (83)	742 (123)	787 (122)	749 (73)	798 (76)	814 (95)

analyses were conducted on the proportional priming effects to compensate for this difference in baseline response rate. Note, however, that analyses conducted on the absolute priming effects led to similar results. A preliminary analysis conducted on the proportional priming effects comparing the effect of item test format (picture vs. word) with study-test format match (same study-test format vs. different study-test formats) between groups indicated no significant effect of test format or any significant interactions with test format; thus, the data were collapsed across words and pictures at test.

Figure 2 presents the proportional priming effects for the elderly and young participants for the same and different stimulus format conditions. There was a significant effect of format match, $F(1, 44) = 22.72$, $MSE = .005$, indicating greater priming for items studied and tested in the same-format conditions compared with the priming in the different-format conditions. The effect of group was not significant, $F < 1$, indicating equivalent performance between elderly and young participants. The format match by group interaction was not significant, $F < 1$, showing that the magnitude of priming for the same versus different study-test format conditions was not affected by aging.

In Experiment 2, elderly participants demonstrated priming effects that were equivalent to

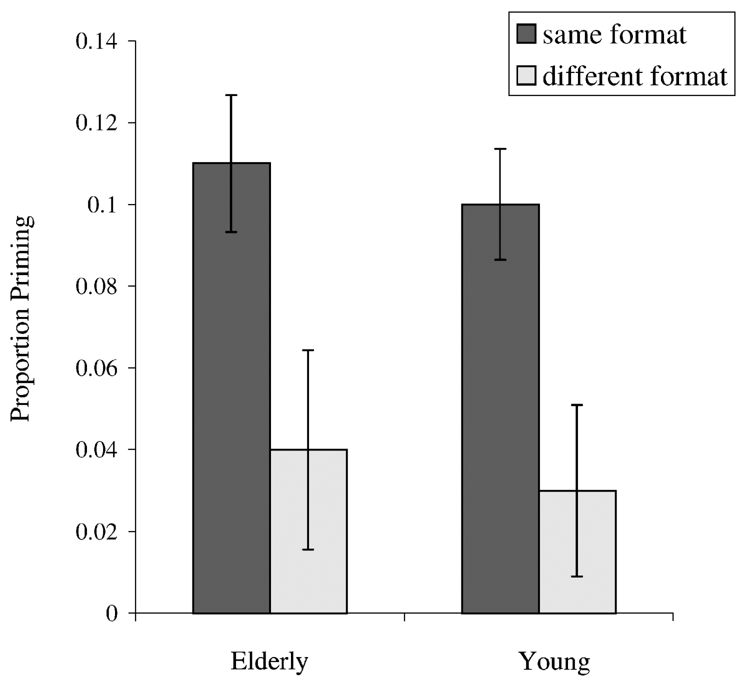

Fig. 2. The proportional priming effects on the semantic decision task for items studied and tested in the same and different formats (Experiment 2).

those of young adult participants. Moreover, equivalent priming effects were obtained between groups when the format was the same at study and test (picture to picture and word to word), and when the format changed (picture to word and word to picture), indicating that aging did not disrupt the flexibility of conceptual priming for the semantic decision task.

GENERAL DISCUSSION

In both Experiments 1 and 2, the elderly exhibited priming effects that were equivalent to those of young adult participants on the semantic decision task, indicating that aging does not disrupt conceptual implicit memory performance. RT tasks such as the semantic decision test are useful because they require the participants to respond quickly, thus reducing the likelihood that explicit memory will contribute to performance (McKone & Slee, 1997; Vriezen et al., 1995). As previously discussed, the age-related deficits sometimes found in studies using tasks that allow extended periods of time to make responses could have been due in part to the fact that the younger participants relied more on explicit memory than did the elderly participants. The current results indicate that under conditions in which explicit memory is not expected to contribute to performance, conceptual priming is intact in older individuals.

The current experiments also showed that aging did not affect the flexibility of implicit memory. Changing the semantic decision (Experiment 1) or the stimulus format (Experiment 2) between study and test reduced priming in the young and elderly to a similar extent, indicating that the flexibility of the processes supporting implicit memory was not compromised in the aged, at least as measured in the current experimental context. The equivalent priming effects among elderly and young participants observed in both experiments implies that normal aging does not reduce or alter the degree to which conceptual or perceptual processes contribute to semantic decision performance. For both elderly and young participants, study-phase decisions about whether the item contained a corner facilitated test phase decisions about whether that item was bigger than a shoebox. Priming was slightly enhanced, however, when the decision was identical from study to test, suggesting that both groups benefited when perceptual and conceptual overlap existed between study and test in this paradigm (see Vriezen et al., 1995). Similarly, priming was enhanced in Experiment 2 for both groups when the perceptual format of the item was identical across study and test compared with the cross format conditions, indicating that perceptual processes provided an equivalent boost to performance in both groups (also see Vriezen et al., 1995).

The effects of aging on the flexibility of conceptual implicit memory had not been previously examined, and it was unclear whether such processing would interact with the time pressure in RT tasks. Several related studies, however, have been conducted using perceptual implicit tests, and the conclusions are consistent in showing that aging does not influence the flexibility of implicit processes. For example, several studies have found that priming effects of elderly and young participants are similar across study-test changes in typography (Gibson et al., 1993), modality (Light et al., 1992; but see Habib, Jelicic, & Craik, 1996), voice (Schacter, Church, & Osowiecki, 1994; Sommers, 1999, Experiment 3), speaking rate (Sommers, 1999, Experiment 1), and stimulus format (Ergis et al., 1995).

Few studies have examined conceptual priming in normal aging using RT measures. Tasks for which the semantic classification was the same at study and test showed no evidence of an age-related deficit in priming (e.g., Hamberger & Friedman, 1992; Kazmerski et al., 1995). In contrast, results were somewhat mixed when the semantic classification was varied between study and test, and hinted at the possibility of an age-related deficit in conceptual priming (Light et al., 2000). Why age-related deficits were found in Light et al.'s study are not known. Light et al. speculated that the discrepancy in results obtained across their two experiments might be attributed, at least in part, to procedural changes that reduced RTs. The current results further indicate that the discrepancy between the previous RT studies is probably not due to the fact that the study-test decisions were either constant or varied, because the elderly participants in the current study exhibited normal priming under both types of test conditions. One caution regarding the current results is that the power was low (approximately .17 for each comparison of flexibility), thus it is possible that increased power may reveal an age-related deficit in the flexibility of conceptual priming processes (for a meta-analysis of implicit memory in aging, see Light, Prull, LaVoie, & Healy, 2000). In general, however, the results from RT studies appear consistent with accuracy studies in that aging does not adversely affect conceptual implicit memory performance.

The study of aging may provide insights into the neuroanatomical substrates of conceptual implicit memory. Recent neuroimaging studies of young individuals indicate that conceptual priming is associated with activity in the frontal and, less consistently, temporal lobes (Blaxton et al., 1996; Demb et al., 1995; Gabrieli et al., 1996; Raichle et al., 1994; Wagner, Desmond, Demb, Glover, & Gabrieli, 1997), suggesting that these two regions may play important roles in this form of memory. If the frontal lobes are playing a necessary role in conceptual implicit memory, then participants with frontal lobe atrophy, such as normal elderly individuals (for reviews, see Ivy, MacLeod, Petit, & Markus, 1992; Woodruff-Pak, 1997) may exhibit deficits on those tests. The finding that conceptual implicit memory performance is intact in older individuals does not provide support for the claim that the frontal lobes play a necessary role in this form of memory. It may be that the frontal lobes are normally associated with conceptual priming, but that other regions are capable of supporting priming when frontal lobe function is compromised. Alternatively, the extent of frontal lobe damage in normal aging may not be extensive enough to lead to significant deficits. However, even patients with extensive frontal lobe lesions can exhibit normal conceptual priming performance (e.g., Gershberg, 1997; Swick & Knight, 1996).

The current study joins a growing body of research indicating that although aging leads to deficits in explicit memory, implicit memory is relatively spared in normal aging. Moreover, the current study found that the flexibility of priming effects remained intact in normal aging across conditions in which the processing tasks were manipulated from study to test, and across conditions in which the stimulus formats varied from study to test.

ACKNOWLEDGEMENTS

This research was supported by the University of California at Davis Alzheimer's Disease Center via funding from the National Institute on Aging (AG-10129), and a grant from the National Institute of Mental Health (MH-59352-01). We would like to thank Jennifer Stidham, Michelle Dong, and Erin Wintersteen for their assistance with data collection.

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