Published in final edited form as:
Psychol Aging. 2010 December ; 25(4): 911–921. doi:10.1037/a0019940.

Differential Age Effects for Implicit and Explicit Conceptual Associative Memory

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Abstract

Older adults show disproportionate declines in explicit memory for associative relative to item information. However, the source of these declines is still uncertain. One explanation is a generalized impairment in the processing of associative information. A second explanation is a more specialized impairment in the strategic, effortful recollection of associative information, leaving less effortful forms of associative retrieval preserved. Assessing implicit memory of new associations is a way to distinguish between these viewpoints. To date, mixed findings have emerged from studies of associative priming in aging. One factor that may account for the variability is whether the manipulations inadvertently involve strategic, explicit processes. In 2 experiments we present a novel paradigm of conceptual associative priming in which subjects make speeded associative judgments about unrelated objects. Using a size classification task, Experiment 1 showed equivalent associative priming between young and older adults. Experiment 2 generalized the results of Experiment 1 to an inside/outside classification task, while replicating the typical age-related impairment in associative but not item recognition. Taken together, the findings support the viewpoint that older adults can incidentally encode and retrieve new meaningful associations despite difficulty with the intentional recollection of the same information.

Keywords

associative priming; aging; implicit associative memory

Older adults do not perform as well as young adults on tests of episodic memory (for a review, see Hoyer & Verhaeghen, 2006). Episodic memories are contextually-specific, such as events that occurred at a particular place and time (Tulving, 1983). Age-related deficits have been found to be substantially larger for contextual details, or associative information, than for content items (Old & Naveh-Benjamin, 2008; Spencer & Raz, 1995). However, the exact mechanism that gives rise to this memory impairment remains uncertain. One explanation is an age-related impairment in the process of binding, or integrating, the separate elements of a to-be-remembered episode (Bayen, Phelps & Spaniol, 2000; Burke & Light, 1981; Chalfonte & Johnson, 1996; Lyle, Bloise, & Johnson, 2006; Mitchell, Johnson, Raye & D'Esposito, 2000; Ryan, Leung, Turk-Brown & Hasher, 2007), affecting both the

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creation and retrieval of associative information (the Associative Deficit Hypothesis, Naveh-Benjamin, 2000).

Although considerable evidence exists for an age-related impairment in binding processes, other evidence has identified a more specific role of impaired strategic recollection in producing the associative deficit (e.g., Naveh-Benjamin, Shing, Kilb, Werkle-Bergner, & Lindenberger, 2009; Smith, Park, Earles, Shaw, & Whiting, 1998). According to this viewpoint, age differences in episodic memory will be minimized on tests that rely less heavily on consciously-controlled retrieval, such as when performance can be driven by familiarity (Anderson & Craik, 2000; Hudson, 2008; Jacoby, 1999; Jennings & Jacoby, 1993; Light, Prull, LaVoie & Healy, 2000; Moscovitch & Winocur, 1995), even if associative, rather than item, information is tested (Cohn, Emrich & Moscovitch, 2008). Indeed, recent evidence in favor of this viewpoint comes from a differential age effect between tasks that require recognition of reinstated associations, which is less dependent on the conscious experience of recollection and shows less severe age effects, compared with tasks that require more active identification of associative information and which magnify age differences (Cohn, et al., 2008; see also Cohn & Moscovitch, 2007).

A way to distinguish between impaired binding processes and impaired strategic recollection is to examine implicit memory of new associations. Implicit memory refers to non-conscious, unintentional influences of memory, and is measured through priming, which is when performance is facilitated for repeated relative to new stimuli (Roediger, 1990; Schacter, 1987). Unlike explicit tests such as recall or recognition, implicit test instructions typically make no mention of the prior study episode. Priming of new associations is measured as facilitated task performance for items that are presented in the same context as at study, relative to a different context. If episodic memory declines stem from a generalized age-related decline in binding processes, then impaired associative priming is predicted. If episodic memory declines stem from an age-related impairment in strategic recollection of associative information, then no age difference in associative priming is predicted.

To date, however, studies of implicit associative memory in aging have produced mixed findings, depending on whether the paradigm emphasizes shallow or meaningful features of the to-be-associated information (for a review, see Dew, Bayen & Giovanello, 2007). For instance, the priming of *intra-item* associations requires the integration of an item and its surface-level features, such as its color or font; on these perceptual manipulations, older adults typically show priming to the same extent as younger adults (Gibson, Brooks, Friedman & Yesavage, 1993; Light, LaVoie, Valencia-Laver Albertson-Owens & Mead, 1992; Lloyd-Jones, 2005; Wiggs & Martin, 1994;). Age equivalence is also found on *inter-item* (i.e., item-item) associations if integration emphasizes perceptual rather than meaningful features of the items (Light, Kennison, Prull, LaVoie & Zuellig, 1996). For instance, Monti et al. (1997) compared text rereading speed when a globally meaningless sentence was repeated (e.g. reading *that a fades Mountain and before*, at both trials) relative to when the words but not the between-word associations were repeated (e.g., *that a fades Mountain and before* at trial one and *Mountain a that before and fades* at trial two). In both age groups, text rereading was equivalently faster for the intact sentences relative to recombined sentences. Findings from such paradigms suggest no age differences in implicit associative memory. In contrast, however, when tasks require the meaningful integration of unrelated items, such as via sentence creation, older adults have shown lower, or even no evidence of, associative priming (Ergis, Van der Linden, & Deweer, 1998; Howard, Fry, & Brune, 1991; Howard, Heisey & Shaw, 1986; Monti et al., 1997; O'Hanlon, Wilcox & Kemper, 2001; Spieler & Balota, 1996).

What complicates the interpretation of differences in perceptual- versus conceptual-associative priming, however, is that the paradigms employed have also diverged in the involvement of strategic retrieval processes. When new associative learning occurs via the integration of surface-level features, associative priming has been shown to be insensitive to encoding manipulations that typically affect explicit memory, such as divided attention (Gabrieli et al, 1997; Light et al., 1996; Micco & Masson, 1991; Musen & O'Neill, 1997). Conversely, when the formation of associations occurs via the semantic integration of distinct items, associative priming has not been successfully dissociated from explicit retrieval. Instead, associative priming has been sensitive to the same manipulations that affect explicit retrieval processes, including divided attention (Kinoshita, 1999), and levels-of-processing manipulations (Graf & Schacter, 1985; O'Hanlon et al., 2001; Reingold & Goshen-Gottstein, 1996). Importantly, if explicit retrieval strategies could be used to enhance performance on a nominally implicit test, it is likely that such strategies would be used more often and more successfully by younger adults (Habib, Jelicic & Craik, 1996). Thus, a difference in explicit contamination may be partly responsible for age differences (for further discussion see also Laver, 2009; Light et al., 1996; Wegesin, Ream & Stern, 2004).

For this reason, despite the theoretical usefulness of the implicit memory approach, it is unclear whether prior tasks of conceptual associative priming have validly reflected implicit retrieval operations. In the present studies, we examine whether priming of new meaningful associations might be preserved in aging yet also dissociated from strategic associative retrieval. In this effort, we present a novel paradigm of conceptual associative priming in which subjects make speeded classification judgments about the relationship between previously unrelated objects. In Experiment 1, subjects make a relational size judgment, and in Experiment 2, subjects make a relational inside/outside judgment. These paradigms were selected based on evidence that automatic processes are engaged faster than consciously controlled processes (Yonelinas & Jacoby, 1994), and that speeded response measures are well-suited to access automatic retrieval mechanisms (Horton, Wilson & Evans, 2001; Horton, Wilson, Vonk, Kiry & Nielson, 2005). If older adults have a generalized deficit in associative processing, then they should show impairments in retrieving associations regardless of whether they are accessed at an implicit or explicit level of awareness. However, if the associative deficit in aging stems from a more specialized impairment in the strategic retrieval of associative information, then young and older adults should show equivalent levels of conceptual associative priming.

Experiment 1

The primary goal of Experiment 1 was to evaluate the status of implicit memory of new meaningful associations in aging, using a novel paradigm designed to minimize opportunities for intentional recollection. In this experiment, subjects performed an associative version of a speeded classification task. In the standard version, subjects make decisions about presented objects, and are later asked to make the same judgment again as quickly as possible without sacrificing accuracy. Priming is observed if subjects are faster to make correct judgments on previously studied relative to new objects. A common classification task is a size judgment, in which subjects classify the size of presented objects relative to a standard-sized referent object, such as a shoebox (e.g., as used in Buckner et al., 1998; Dobbins, Schnyer, Verfaillie, & Schacter, 2004; Koutstaal, Wagner, Rotte, Maril, 2001). In our associative version, subjects judged whether two presented objects were, together, smaller than a referent object (a desk drawer). The implicit test was a speeded version of the same task, using intact (presented together), recombined (each presented but not together), and new object pairs, thus mirroring the conditions in a prototypical associative recognition test. If the associative memory decline in older adults stems from generalized binding deficits, then young but not older adults will show associative priming. If, however, the associative memory decline stems from a deficit in strategic retrieval of bound information, then no age differences in associative priming will emerge.

Method

Participants—Thirty-six young adults (ages 18–21, *M* = 18.5, *SD* = .77; mean education = 13.3 years, *SD* = .91) participated in partial fulfillment of a course requirement in an Introduction to Psychology course at the University of North Carolina at Chapel Hill. Twenty-four community-dwelling older adults (ages 65–87, *M* = 76.5, *SD* = 5.6; mean education = 16.3 years, *SD* = 1.95) were compensated $10 per hour to participate. To ensure that the older adults were healthy, in a separate testing session they completed a battery of neuropsychological tests to assess memory, language, attention, visuo-spatial abilities, and general intellectual functioning. These tests included the Mini Mental State Examination (MMSE), American National Adult Reading Test (ANART), Trail Making Test parts A and B, Vocabulary from the WAIS-III, and the Morningness-Eveningness questionnaire. Mean scores are listed in Table 1.

Design and Materials—The stimuli consisted of basic drawings of familiar objects taken from the Microsoft Online Clip-Art Database and the website http://www.clipart.com. The line drawings were colored in one of eight singular, plausible real-world colors (e.g., a blue couch; a red shoe) to maximize similarity across items on complexity and visual-perceptual characteristics. The colors were manipulated systematically using Adobe Photoshop. All materials were pilot-tested for clarity of object depiction and for consistency in classification response. Trials consisted of two objects, presented side-by-side.[1] Objects were randomly paired together with the constraint that they had zero forward- or backward- semantic association strength (Nelson, McEvoy & Schreiber, 2004). In total (across subjects), each object appeared in either the left or right screen location an equal number of times. Objects maintained the same left-right status from study to test. Each object was framed by a simple line box. Pairs were counterbalanced across retrieval conditions using the Latin square method, although a few replacements were made so that each list would produce approximately 50% yes responses and 50% no responses to the classification task. The counterbalance produced 12 study lists and 12 corresponding test lists composed of intact, recombined, and critical new object pairs. The study list began with 8 practice pairs followed by 24 critical pairs, and ended with two additional buffer pairs to reduce recency effects. The test list included the 24 study pairs, half of which were presented as intact pairs, and half of which were rearranged with each other to create recombined pairs, plus 24 unstudied critical new pairs. To increase test length and decrease the likelihood that subjects would notice a study-test overlap in stimuli, 20 additional filler pairs that were not included in analyses (i.e., and not counterbalanced) were added to the test. Order of the test pairs was randomized with the constraint that it began with two filler pairs. The experiment was presented on an Apple iBookG4 using the program MacStim (WhiteAnt Occasional Publishing).

Procedure—Participants were tested individually in a quiet, enclosed room. After informed consent procedures, the experiment was described as being concerned with object perception and knowledge. No mention was made of an ensuing memory test. Participants

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[1] The study and test lists in Experiment 1 also included trials in which only single, colored objects appeared. Because the results of the single object priming condition do not contribute to the theoretical distinction between binding and strategic retrieval, they are not reported or analyzed here. However, for an accurate methodological description it is critical to note that a single object condition was included in Experiment 1. On these trials, subjects were instructed to make a standard size judgment rather than the associative version. At test, subjects completed a speeded version of the same task. No objects were repeated between conditions. Experiment 2 did not include this condition.

were instructed to view the presented objects and decide, by pressing Y or N on the computer with their dominant hand, whether the objects would fit together in a desk drawer of 1’ × 2’ dimensions. A desk drawer of this size was provided for each participant’s direct reference. Instructions emphasized that judgments should be based on the typical *real-life* size of the objects, as the presented objects were not drawn to scale. Each trial remained on the screen for 8000ms at which point the next trial was presented. Following encoding, participants completed a five-minute distractor task consisting of anagram puzzles. Next was the implicit test, in which subjects were asked to complete the object classification task again, as quickly as possible, without sacrificing accuracy. After a response was pressed for each trial, the objects were cleared from the screen and were replaced with a fixation cross, which remained on the screen until the next trial was presented, always 4000ms from the onset of the prior trial. The subjects were instructed to keep their eyes focused on the cross, because the next trial would appear there, and this would make it easier to respond quickly.

Following the implicit test, an awareness questionnaire was administered (see Barnhardt & Geraci, 2008, for a recent positive assessment of the validity of these questionnaires). Awareness questionnaires probe whether subjects were aware of the connection between the study and tests portions of the experiment, and are typically included in studies of implicit memory in order to test for the possibility of explicit contamination. Critically, prior findings in the literature suggest that it is not awareness itself that affects associative priming, but rather the adoption of an explicit retrieval strategy that may occur once subjects become aware. McKone and Slee (1997) compared performance on an associative lexical decision task between subjects who were test-aware, but who continued to follow the implicit test instructions, with subjects who, upon awareness, altered their approach to the task and attempted to recall studied items. The authors found a difference in priming between these two groups, with the former group producing the same pattern as those who were unaware, and the latter group producing the same pattern as those who were explicitly instructed to recall the studied words. Given these findings, those who reported awareness of the connection between the study and test pairings in the present experiment were subsequently asked whether they consciously attempted to think back to their prior responses during the speeded task. Performance was later compared between those who did and did not claim to have used an explicit retrieval strategy, so as to test for the possible influence of explicit contamination.

Results and Discussion—Accuracy on the classification task was defined as a “correct” response based on pilot-testing of the object pairs. Mean accuracy for the classification task during the implicit test was high for both age groups (young adults = 95.4%; older adults = 91.8%). This difference was not significant, $p = .54$, nor did accuracy differ as a function of trial condition in either age group (Fs <1). Mean reaction times and standard deviations for each condition on the implicit test are listed in Table 2, with outliers of +/− two standard deviations from the mean in each condition removed from the analysis of each subject. This procedure resulted in the removal of 4.2% of outlying trials in young adults and 5.4% in older adults, a nonsignificant difference, $p = .67$.

To assess priming of single objects in the absence of an association, we compared reaction times to new trials relative to recombined trials. This was accomplished with a mixed ANOVA using trial type (recombined, new) as a within-subjects factor and age as a between-subjects factor. This analysis yielded a significant effect of item priming, $F(1, 58) = 11.02$, $p < .01$, and no interaction between age and priming, $p = .54$. We then assessed whether priming of associations was significant above and beyond priming of single objects. This was accomplished with a mixed ANOVA using trial type (intact, recombined) as a within-subjects factor and age as a between-subjects factor. There was a significant effect of trial type, $F(1, 58) = 16.03$, $p < .001$, demonstrating significantly faster reaction times for intact relative to recombined trials. Thus, priming was greater for objects whose context was reinstated relative to objects re-presented in a new context. Critically, there was no interaction between associative priming and age, $F<1$, with young and older adults producing equivalent levels of associative priming. As seen in Table 2, insufficient power to detect reliable age differences is not a viable explanation for the results, as the raw RTs were in the direction of greater differences between conditions in old than young.

Twenty-nine young adults reported having noticed a connection between the study and test pairings. Of these, 11 of these subjects reported having used an explicit retrieval strategy to aid performance on the test. Twenty-three older adults reported noticing the study-test connection, 7 of whom reported use of an explicit retrieval strategy. These numbers raised the concern that priming performance may have been mediated by explicit processing. To examine this possibility, test-awareness and reported strategy use were entered into separate mixed ANOVAs as between-subjects factors, with RTs to the retrieval conditions (intact, recombined, or new) entered as a within-subjects factor. There was no interaction between retrieval condition and awareness of the study-test connection, $F < 1$, and no interaction between retrieval condition and the reported use of explicit retrieval, $F < 1$. However, given the small number of subjects when split into the above subgroups, it is possible that these comparisons suffer from a lack of power to determine reliable differences. For this reason, the pattern of reaction times was compared between those who did and did not claim to have used an explicit retrieval strategy, and are displayed in Table 3. The direction of performance was the same for both groups, with RTs to intact pairs faster than to recombined, which were faster than baseline. These analyses show that the pattern of priming performance did not depend on whether the participant claimed to use an explicit retrieval strategy. These results stand in contrast to the pattern that has emerged for other conceptual associative priming tasks (e.g., in McKone & Slee, 1997), and provide evidence that intentionally thinking back to prior responses is not useful for performance in the present paradigm. Of note, when only the reaction times to accurate responses were included in the analyses, the pattern of all reported results remained unaffected, demonstrating that neither age group produced a speed-accuracy trade-off.

Given the lack of age differences in Experiment 1, one question was whether the results might be partly explained by having tested a relatively high-performing older adult sample. Indeed, increased variability in cognitive functioning with age is a well-established finding (e.g., Albert, Duffy, & Naeser, 1987), and patterns of performance may vary both within and between samples of older adults. For instance, Faust, Balota, and Spieler (2001) found that young-old adults (60–80) demonstrated inter-associative priming but old-old adults (81–90) did not. In the present study, we note that the sample of older adults was more educated than the young adults, a difference that was significant, $t(58) = -8.01$, $p < .01$. However, years of education did not correlate with general slowing (i.e., did not correlate with baseline reaction times, $p = .18$), nor did it correlate with the reaction time benefit for studied trials (i.e., with magnitude of associative priming, $p = .93$, or item priming, $p = .41$). There was also no relationship between age and baseline reaction times ($p = .49$), age and associative priming ($p = .66$), or age and item priming ($p = .46$). These results argue against the possibility that preservations in associative priming occur only for a special subset of older adults. Lastly, the raw reaction times in each condition were also more variable among older adults. Critically, however, the variability in proportion of priming did not show an age difference, with older adults producing 4.6% ($sd = .14$) associative priming, and young adults producing 5.0% ($sd = .15$) associative priming. Thus, the increase in variability in overall reaction times appears to be independent from the priming effects.

Taken together, the results indicate that older adults can show priming for new meaningful inter-item associations. These data provide evidence against a general deficit in associative processing. Rather, they imply a critical role of strategic recollective processes in producing the associative deficit (Cohn et al., 2008; Naveh-Benjamin et al., 2009). More generally, these results fit with a more general pattern in the literature of spared implicit or automatic processes in aging (Light et al., 2000), even for conceptual-associative materials on which explicit impairments are often found.

Although the results of Experiment 1 are interpretable within this theoretical framework, several components of the design merited follow-up. First, although the object classification task was designed to be integrative by instructing participants to decide whether the objects would fit into the drawer *together*, it is plausible that the subjects completed the classification judgment by engaging in a sequence of item-level decisions in which they decided, first, whether the left object would fit, and subsequently, whether the right object would fit. This would be especially problematic on trials in which a nominally pair-wise response could be made simply on the basis of the first item. In turn, it is possible that some of the overall priming was driven by item-specific, rather than relational, processing. Experiment 2 improved on this potential limitation by using a categorization task in which both objects must be considered in each trial.

Second, some studies have shown that age differences even in explicit associative memory are minimized under incidental relative to intentional encoding conditions (e.g., Hogan, Kelley & Craik, 2006; Naveh-Benjamin, 2000; Naveh-Benjamin et al., 2009). For this reason, Experiment 2 also included a within-subjects comparison between associative priming and associative recognition. In a paradigm that shows no age difference in the implicit access of associative information, it is critical to determine whether the typical age-related decline in associative recognition would occur following the same incidental encoding task.

Lastly, a criterial variable in classifying implicit tests as conceptually-driven is whether priming performance is sensitive to changes in perceptual features of the presented stimuli (Roediger & McDermott, 1993). Thus, Experiment 2 also included a perceptual manipulation check to determine if the pattern of reaction times would be insensitive to surface-level changes. If not, this would help to classify associative priming as driven by the reengagement of conceptual, rather than perceptual, processes.

Experiment 2

Experiment 2 tested two primary questions. The first question was whether the age equivalence found in Experiment 1 would generalize to a new associative semantic classification task in which subjects decide *which of two objects is more likely to be found inside a house*. This classification task is a modified version of the item-level task in which subjects view single objects and make speeded judgments of whether each is found inside or outside. Of note, Bruce, Carson and Burton (2000) examined priming in the single object version by presenting a different exemplar of objects at study and test. Importantly, this global change in perceptual form had no impact on the magnitude of priming – a finding that served to classify priming on this task as conceptually- rather than perceptually-driven. In the present experiment, we also checked whether our associative version of this task was insensitive to perceptual alterations. Specifically, some of the objects at test appeared in a different color than their initially studied form. Because older adults have been shown to perform similarly to young adults on tests of perceptual-associative priming (Light et al., 1992; Monti et al., 1997), it was critical to determine whether associative priming in this task reflects, at least in part, the reengagement of perceptual analysis. The second question addressed in Experiment 2 was whether a within-subjects dissociation would be found between conceptual associative priming and explicit, associative recognition. If so, this dissociation would provide more direct support for the hypothesis of spared conceptual implicit associative retrieval processes coupled with impaired explicit retrieval associative processes in aging.

Method

Participants—Thirty-two younger adults (ages 18–33, *M* = 20.9, *SD* = 3.3; mean education = 14.8 years, *SD* = 1.7) participated in partial fulfillment of a course requirement in an Introduction to Psychology course at the University of North Carolina at Chapel Hill. Thirty-two healthy community-dwelling older adults (ages 61–89, *M* = 73.5, *SD* = 5.9; mean education = 16.8 years, *SD* = 2.6) participated and were compensated $10 per hour. Health screening and neuropsychological testing remained the same as in Experiment 1.

Design and Materials—Pilot-testing created ratings on a scale of 1–5 for each object as a function of likelihood of being found inside a house. These ratings were used to construct object pairings, such that at least a two-point rating difference existed between paired objects (e.g., *paintbrush-keyboard; necklace-balloon; teapot-goggles*). This system created pairs for which a consistent, but not necessarily obvious, inside-outside judgment would be made on every trial, in order to ensure that both objects must be considered in order to make an accurate judgment. Object pairs were then pilot-tested for consistency in classification. The object more likely to be found inside a house appeared on the left side of the screen in 50% of the trials. Each object’s relative location remained constant from study to test. Critically, each object’s relative classification status also remained constant, such that the object more likely to be found inside a house at study would remain the object more likely to be found inside a house at test, regardless of whether it would later appear in an intact pair (e.g., *necklace-balloon*) or a recombined pair (e.g., *necklace-goggles*). This procedure increased the sensitivity of priming to the relational, rather than object-level, classification decision. For the perceptual manipulation check, a second version of all pairs was created in which each object appeared in a modified color. The colors in both versions of the object pairings represented plausible real-world colors for each object; thus, this perceptual manipulation did not affect the abstract conceptual representation of the object or its task-specific classification.

The first encoding list included 5 practice pairs followed by 30 critical pairs, and ended with 2 recency buffer pairs. The implicit test list included 10 counterbalanced critical new pairs plus the 30 studied pairs, 10 of which were intact, 10 of which were recombined, and 10 of which were re-colored versions of pairs that were otherwise intact (studied together). Like Experiment 1, the test also included 23 filler pairs that were not included in analyses. List order was randomized with the constraint that it began and ended with two filler pairs. The second encoding list, to be matched with the explicit test, began and ended with two buffer pairs, and included 20 critical pairs that were not presented in the first two tasks. The explicit recognition test included these 20 encoded pairs, 10 of which were intact and 10 of which were recombined, plus 10 counterbalanced critical new unstudied pairs. Individual stimuli were unique to each condition for individual subjects. Pairs were counterbalanced using the Latin Square method such that, across subjects, pairs appeared in each condition an equal number of times. This counterbalance produced 7 list versions for each task.

Procedure—During the first encoding task, subjects decided which of two presented objects was more likely to be found inside a house by pressing either the j or k keys (labeled as “left” and “right”) with their dominant hand. Each trial remained on the screen for 6000ms. This encoding task was followed by a three-minute distractor task consisting of anagram puzzles. Next was the implicit test, in which subjects were instructed to complete the object decision task again, as quickly as possible, without sacrificing accuracy. After key-pressing a response for each trial, the objects were cleared from the screen and replaced with a fixation cross, which remained on the screen until the next trial was presented, always 4000ms from the onset of the prior trial. Subjects were instructed to keep their eyes focused on the cross, because the next trial would appear there, and this would make it easier to respond quickly. The implicit test was followed by a second incidental encoding task that was identical to the first, with the exception that a new set of object pairs was presented. Encoding was followed by a 3-minute distractor task consisting of arithmetic problems. Lastly, subjects completed the explicit, associative recognition test. Subjects were instructed to view each object pair and decide by pressing either the *i* or *o* keys (labeled as “Yes” and “No”) whether the objects were *seen together previously*. After key-pressing a response, the objects were cleared from the screen and were replaced with a cross, which remained until the next trial was presented, with an SOA of 6000ms. Participants were told that if they did not make their choice within 6 seconds, the next trial would appear; however, it was emphasized that they should feel free to use all the time available to make their best decision. Task order was not counterbalanced, a necessary feature of a within-subjects implicit/explicit memory design, to avoid explicit contamination during implicit testing. However, we note that although task order could have given rise to unintended differences in fatigue effects, the entire testing session lasted approximately 30 minutes, thus limiting influences of fatigue.

Results and Discussion—Like Experiment 1, accuracy on the classification task was defined as the “correct” response as assessed by pilot-testing. Mean accuracy on the classification task was high for both age groups (young adults = 97.6%; older adults = 95.3%). This numerical difference was not significant, $p = .73$. Like Experiment 1, accuracy did not differ as a function of trial condition in either age group (*F*s <1). In addition, 2.3% of trials were removed as outliers in young adults and 3.2% of trials in older adults, a nonsignificant difference, $p = .69$. Mean reaction times and standard deviations are listed in Table 2.

To assess priming of objects in the absence of an association (i.e., item priming), we conducted a mixed ANOVA with trial type (recombined, new) as a within-subjects factor and age as a between-subjects factor. This analysis yielded a significant effect of item priming, $F(1, 62) = 40.79$, $p < .001$. Intriguingly, we did observe an interaction between age and item priming that approached significance, $F(1, 62) = 3.17$, $p = .08$, with in fact more item priming in the older relative to younger adults. To determine whether this direction of more priming in the older adults was magnified by the age-related slowing in baseline reaction times, we re-analyzed priming as a function of proportion rather than raw RTs. Critically, there was no age difference in proportion of item priming ($p = .72$).

To assess associative priming, we conducted a mixed ANOVA with trial type (intact, recombined) as a within-subjects factor and age as a between-subjects factor. There was a significant effect of associative priming, F(1, 62) = 11.65, $p = .001$, demonstrating significantly faster reaction times for intact relative to recombined trials. Critically, there was no interaction between associative priming and age, $F<1$, indicating that young and older adults demonstrated associative priming to the same extent.[2] Like Experiment 1, insufficient power to detect reliable age differences is not a viable explanation for the results, as the raw RT scores were in the direction of greater differences in old than young.

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[2] We also considered the possibility that associative priming might be biased by trials in which the *inside*-classified object was perceived first (e.g., on the left). Importantly, the stepwise pattern of reaction times across intact, recombined, and new conditions did not differ in either age group based on whether the *inside*-classified object was on the left versus right side of the screen.

Of note, no difference was found between intact and re-colored pairs in young ($p = .34$) or older ($p = .70$) adults, showing that reaction times were not affected by the perceptual manipulation. Thus, consistent with the single object version of the inside/outside classification task (e.g., Bruce et al., 2000), the comparison between intact and re-colored trials here indicated no sensitivity in priming for either age group to changes in the visual form of the objects. Importantly, this result is not indicative that older adults do not produce perceptual priming generally, but rather that the associative priming paradigm employed in this experiment is not sensitive to changes in surface-level stimulus features.

Twenty-nine young adults reported having noticed a connection between the study and implicit test pairings, with 9 of these subjects reporting use of an explicit retrieval strategy. Twenty-nine older adults also reported noticing the study-test connection, 11 of whom reported use of an explicit retrieval strategy. Using the awareness questions as between-subjects factors in separate mixed ANOVAs, test-awareness and explicit strategy use did not participate in any significant effects ($F<1$) for either question in either age group. Reaction times for each trial type as a function of explicit strategy use were compared and are included in Table 4. The same overall pattern was produced by those who did and did not claim to use an intentional retrieval strategy, with reaction times to intact pairs faster than to recombined, which were faster than baseline. Like Experiment 1, the pattern of priming in both age groups suggests that there is limited utility of an explicit retrieval strategy for this paradigm. Additionally, we ran a correlational analysis between associative priming and associative recognition scores, to determine whether subjects who demonstrated better recognition memory would also produce more priming. There was no relationship between performance on the two tests in young adults ($r = .12$, $p = .51$) or old adults ($r = .04$, $p = .85$).

Finally, we examined whether task performance might be partly related to age differences in variability. Like Experiment 1, the older adults were more educated than the young adult sample, $t(62) = -3.6$, $p < .01$. Interestingly, mean years of education was negatively correlated with baseline reaction times ($r = -.45$, $p = .01$), indicating a relationship between highly educated older adults and a lower degree of general cognitive slowing. Critically for present purposes, however, education was unrelated to the associative priming effect, $p = .62$. Additionally, given the relatively wide range in age (61–89), we also examined whether age was related to task performance. We found no relationship between age and reaction time in any condition, nor between age and associative priming or between age and item priming (all *p*s >1). As such, it does not appear that associative priming in our paradigm declines as healthy older adults increase in age. Lastly, like Experiment 1, although the reaction times in each condition were more variable in older adults, the variability in proportion of associative priming was not different, with older adults producing 4.9% ($se = .13$), and young adults producing 4.8% ($se = .99$) associative priming. This slight difference in standard errors was not significant, $p = .83$. As such, the increase in variability that accompanied aging is unrelated to the priming effects observed.

For the explicit test, mean proportions of hits to intact pairs, false alarms to recombined pairs, and false alarms to new pairs are listed in Table 5. Item recognition accuracy was calculated as the proportion of hits to intact pairs relative to the proportion of false alarms to new pairs. Item recognition accuracy was significantly greater than zero in both young ($t(31) = 32.27$, $p<.001$) and older adults ($t(31) = 34.45$, $p<.001$). Associative recognition accuracy was calculated as the proportion of hits to intact pairs relative to the proportion of false alarms to recombined pairs. Given the incidental encoding, we anticipated that overall associative recognition accuracy would be relatively low (e.g., as in Naveh-Benjamin et al., 2009). Critically, however, performance was significantly greater than zero in both young ($t(31) = 6.46$, $p<.001$) and older adults ($t(31) = 2.35$, $p<.05$). Furthermore, young and older adults showed no difference in hit rates to intact pairs (p = .19) or in false alarms to new pairs (p = .17), but young adults produced significantly fewer false alarms to recombined pairs than the older adults, ($t(62) = -5.73$, $p <.001$) This pattern produced an interaction ($F(1,62) = 18.19$, $p<.001$), such that the age groups showed no difference in item recognition accuracy (p = .93) coupled with the typical benefit for young adults in associative recognition accuracy, $t(62) = 4.24$, $p<.001$. Although this interaction was significant, interpretations are limited by the fact that item memory was at ceiling for both age groups. Thus, the present experiment cannot provide definitive support for a disproportionate deficit in associative recognition relative to item recognition. However, a larger impairment in associative memory than item memory has been reliably replicated in many previous studies (see Spencer & Raz, 1995, and Old & Naveh-Benjamin, 2008 for meta-analyses), and the critical comparison for present purposes was between associative recognition and associative priming.

We also explored the possibility that the hit and false alarm rates on the explicit measure could have been influenced by reported use of an explicit retrieval strategy on the implicit measure. If subjects became aware of the connection between the encoding and test stimuli during the implicit test, and if they consequently thought back to prior responses, this could influence the way they approached the subsequent encoding task despite the incidental instructions. The hits to intact pairs, false alarms to recombined pairs, and false alarms to new pairs are broken down by reported explicit strategy use status in Table 5. Interestingly, while strategy use had a negligible effect on the subsequent explicit test in older adults, it appears that young adults who used explicit retrieval on the implicit test had both higher hits as well as higher false alarms on the explicit test. This increase in both hits and false alarms indicates that while strategy use on the implicit test did not affect accuracy on the explicit measure, it did change response bias in young adults such that they became more likely to endorse both old and new pairs as “old.” This change in response bias has little impact on the main interpretation of the age effect in the present paper; however, variables that differentially affect response bias in young and old adults are an important avenue for future research.

In summary, Experiment 2 generalized the results of Experiment 1 to a different semantic classification task. This pattern provides evidence of age-related preservations in the incidental formation and implicit retrieval of meaningful inter-item associations. The present experiments are consistent with the recent suggestion that prior evidence of age-related impairments in associative priming might in fact be explained by the use of paradigms that inadvertently involve explicit processes (e.g., Laver, 2009; Wegesin et al., 2004). Within the associative recognition data, the age difference in accuracy was driven by a disproportionately high rate of false alarms to recombined pairs. This pattern fits with the viewpoint older adults have difficulty using recollection of contextually-specific attributes to counteract the familiarity recombined lures (e.g., Jacoby, 1999). Furthermore, despite the age difference in associative recognition, we observed no age difference in item recognition. Critically, some studies have found a disproportionate deficit in associative relative to item recognition only following intentional but not incidental encoding (e.g., Naveh-Benjamin et al., 2009), implying a critical role of impaired intentional encoding processes in producing the associative memory deficit. The present results do not examine intentional encoding directly, but still offer a different interpretation. The disproportionate deficit in associative relative to item recognition following incidental encoding suggests a critical role of impaired strategic recollection of associative information.

General Discussion

In two experiments, we presented a novel paradigm of associative priming in which subjects made speeded associative classification judgments. Using an associative size classification task, Experiment 1 showed no age difference in associative priming, and Experiment 2 generalized these results to an inside/outside classification task. Of note, the perceptual manipulation in Experiment 2 (recombination of object colors) had no affect on priming, supporting the classification of priming in the inside-outside task as conceptually-driven. Experiment 2 also replicated the typical age-related impairment in associative recognition but not item recognition, following the same incidental encoding manipulation. These results fit with recent findings in the literature suggesting that retrieval of associative information can be relatively preserved in aging to the extent that strategic recollection is not involved (Cohn et al., 2008).

The lack of age difference in associative priming contrasts with some previous studies (e.g., Ergis et al., 1998; O'Hanlon et al., 2001), in which young but not older adults demonstrated priming of new associations. Although the effects in prior studies were interpreted as an age-related impairment in associative priming, the paradigms employed have been difficult to dissociate from explicit memory, even in the young adult literature (Bowers & Schacter, 1990; Kinoshita, 1999). The present studies suggest that the reason prior conceptual associative priming paradigms found age differences may not simply be because they required the creation of and access to meaningful associative links, but rather because they may have been affected by explicit processes. In the present studies, two findings argue against the possibility – or utility – of explicit contamination. First, Experiment 2 produced an age-related dissociation between implicit and explicit associative memory. Importantly, if explicit retrieval processes were to be used to aid performance on the implicit test, the age-related dissociation between explicit and implicit memory suggests that the young adults would have benefitted more than the older adults. Second, as shown in Tables 3 and 4, young and older subjects who claimed on the awareness questionnaire to have used explicit retrieval produced a similar pattern of reaction times in each of the retrieval conditions, a pattern that argues against the utility of explicit retrieval in the speeded response measure (see also Horton et al., 2001). As such, the present experiments speak to the importance of selecting appropriate measures of implicit memory and validating assumptions of the paradigms employed, especially when evaluating age differences. Within the broader context of priming, our paradigm might be seen as consistent with manipulations in the item priming literature that show no or minimal age difference for implicit memory tasks that use reaction time rather than accuracy as the dependent measure (Light et al., 2000), and that require identification/classification rather than production-based responses (Fleischman & Gabrieli, 1998). Future studies should evaluate the role of these variables in the priming of associative information.

In addition to informing the status of implicit versus explicit associative memory, the present results can also be used to inform broader theoretical frameworks of episodic memory decline. Controlled recollective processes and associative/binding processes are known to work together intricately to support episodic memory, at both cognitive and neural levels. As of yet, however, there have been mixed findings as to whether age-related declines in episodic memory stem from impairments in one or both of these processes. Indeed, the hypotheses of impaired recollection and impaired binding processes share several common predictions, and both are consistent with the typical finding of disproportionately impaired explicit memory for associative information relative to item information in the absence of contextual detail (Bayen et al., 2000; Naveh-Benjamin, 2000; Old & Naveh-Benjamin, 2008; Spencer & Raz, 1995), the typical pattern replicated here in Experiment 2. As such, we note that some aspects of the current data do not necessarily distinguish between these theories. Indeed, while a disproportionate decline in associative relative to item memory could be consistent with a general age-related deficit in associative processing (Chalfonte & Johnson, 1996; Naveh-Benjamin, 2000), this pattern could also be explained by impaired recollection of contextual details coupled with preserved familiarity of individual items (Jacoby, 1999; Jennings & Jacoby, 1999; Naveh-Benjamin et al., 2009). However, the fact that a larger age difference in associative relative to item memory was only observed using an explicit retrieval measure (i.e., and not during implicit retrieval) is consistent with an hypothesis that emphasizes impairments in controlled associative recollection. Indeed, a generalized decline in associative processing is inconsistent with preserved implicit associative memory. Moreover, a generalized decline in strategic, consciously-controlled memory retrieval is not necessarily consistent with preserved explicit item memory. Thus, the present results are consistent with recent research emphasizing the role not only of strategic or explicit retrieval, but of differences between varying measures of explicit retrieval, with age deficits magnified under conditions that emphasize the recollection of associative features (e.g., Cohn et al., 2008).

Although the primary goal of the present studies was to manipulate retrieval processes, the results can also be used to infer the status of processes operative at encoding. Specifically, the finding that new object associations were accessible at an implicit level of awareness can be seen as evidence that the associations were indeed encoded. As such, the current results are supportive of age-related preservations in associative encoding under incidental conditions. Importantly, despite evidence of age-related preservations in incidental associative encoding, our findings do not necessarily advocate a more general position of no age difference in other forms of associative encoding. Indeed, there is evidence that age differences in intentional encoding can at least partly account for later disproportionate age-related declines during associative retrieval (Naveh-Benjamin et al., 2009). A challenge for the implicit memory literature will be to compare and interpret the role of incidental versus intentional encoding without introducing opportunities for explicit contamination.

Relatedly, although the present study only evaluated within-domain (i.e., object-object) associations, the results also fit with related findings from our laboratory (Dew & Giovanello, in press) showing age-related preservations in the incidental encoding of cross-domain (object-response) associations, assessed by a *rapid response learning* paradigm. Rapid response learning refers to a phenomenon established in the repetition priming literature, in which an incidental association is formed between a studied object and the task-specific response required for that object. This stimulus-response association manifests as a reduction in priming if the learned response becomes inappropriate for a new task, even if the task reengages the same perceptual as well as abstract knowledge representation of the object (e.g., Dobbins et al., 2004; Horner & Henson, 2009). Applying this manipulation to aging, we demonstrated recently that reversing the task-specific decision cue equivalently reduced priming in young and older adults in the single-object as well as associative version of the speeded inside/outside judgment (Dew & Giovanello, in press). These findings fit well with the present experiments and provide further evidence of age-related preservations in incidental associative encoding.

We do note an interesting limitation of the encoding-based interpretation. Although the finding of unimpaired implicit associative memory might be seen as evidence that the associations were incidentally encoded, an alternative possibility is that implicit and explicit memory are sensitive to different features of an encoded event. That is, it may be the case that implicit and explicit memory do not share access to the same mnemonic information, implying that the features of an encoded event that are available for implicit memory are fundamentally different from the features that are available for explicit memory. This would suggest that only certain aspects of the initial stimuli may have been encoded and bound by the older adults. Research in the neuropsychological literature distinguishes between systems that support declarative (explicit) memories, which are described as fundamentally flexible in nature, and nondeclarative (implicit) memories, which are fixed and rigid (Cohen, Poldrack & Eichenbaum, 1997). Little is currently known about the flexibility of implicit associative memories. An interesting direction for a future study might be to examine the effects of aging on flexible versus fused associative memory representations, in order to help determine whether equivalent priming in young and older adults reflects access to the same or a different memory representation.

Lastly, neural structures within the MTL, and in particular the hippocampus, have been shown to make a unique contribution to episodic memory by linking together various aspects of a learning event into a bound memory representation (Davachi, Mitchell, & Wagner, 2003; Eichenbaum, Yonelinas & Ranganath, 2007; Giovanello, Schnyer & Verfaellie, 2004). Importantly, the MTL appears to be involved in associative processing during both explicit and implicit memory tasks (Henke et al., 2003). However, there have been mixed findings as to the extent of MTL decline in healthy aging, with some evidence that the medial temporal lobes are relatively unaffected by healthy aging, compared with regions of more substantial change such as the prefrontal cortex (PFC) (Head, Snyder, Girton, Morris, & Buckner, 2005), and other evidence that older adults may rely on PFC regions to compensate for MTL-related dysfunction (e.g., Giovanello, Kensinger, Wong, & Schacter, 2009). Future research should determine whether the age equivalence in behavioral associative priming is linked with the same or different pattern of neural activity. A functional neuroimaging approach would complement the current findings by working toward disentangling the source of differential age effects in the implicit versus explicit access of associative information.

Acknowledgments

We are grateful to Amy Abramowitz, Kathryn Dunlap, Will Moore, K. Brooke Taylor, and Deborah Zimmerman for their help in subject recruitment and data collection. This research was supported in part by Grant AG028774 from the National Institute on Aging awarded to Kelly Giovanello, in part by a Ruth L. Kirschstein National Research Service Award Predoctoral F31 Fellowship (AG031660) from the National Institute on Aging awarded to Ilana Dew, and in part by a Dissertation Research Award from the American Psychological Association awarded to Ilana Dew.

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Table 1

Mean scores on battery of neuropsychological tests among older adult participants in Experiments 1 and 2.

	MMSE	ANART	Vocab	Trail Making A	Trail Making A Errors	Trail Making B	Trail Making B errors	Morn/Eve
Exp. 1	29.30	42.87	56.48	27.65	0.00	63.83	0.00	58.59
Exp. 2	29.13	43.58	60.25	33.08	0.00	65.58	0.08	60.46

Note: Total possible score for the MMSE is 30; ANART, 50; Vocabulary, 66; Morningness-Eveningness ranges from 16 (definitely evening) to 86 (definitely morning). Trail Making is measured in seconds; Trail Making Errors includes the average total number of errors.

Table 2

Mean reaction time (and standard deviation) in msec for each for each implicit trial type, in Experiments 1 and 2.

	Intact	Re-colored	Recombined	New
	Experiment 1			
Young	969 (183)	N/A	1039 (179)	1101 (198)
Old	1320 (322)	N/A	1431 (272)	1531 (368)
	Experiment 2			
Young	868 (142)	882 (168)	917 (156)	1054 (198)
Old	1284 (266)	1293 (305)	1373 (313)	1615 (431)

Table 3

Mean reaction times (and standard deviations) in msec for each implicit trial type as a function of reported use of an explicit retrieval strategy in Experiment 1.

		n	Intact	Recombined	New
Young Adults	Explicit Strategy	12	967 (139)	1043 (147)	1152 (165)
	No Explicit Strategy	24	970 (204)	1037 (195)	1086 (212)
Older Adults	Explicit Strategy	8	1405 (361)	1489 (238)	1580 (212)
	No Explicit Strategy	16	1277 (303)	1402 (291)	1506 (429)

Table 4

Mean reaction times (and standard deviations) in msec for each implicit trial type, and proportions of hits and false alarms to recombined and new pairs, as a function of reported use of an explicit retrieval strategy in Experiment 2.

		n	Intact	Recombined	New	Hits	FA (Rec)	FA (New)
Young Adults	Explicit Strategy	9	898 (124)	966 (163)	1134 (213)	.94 (.07)	.72 (.23)	.10 (.03)
	No Explicit Strategy	23	856 (150)	898 (153)	1022 (182)	.89 (.13)	.64 (.19)	.07 (.14)
Older Adults	Explicit Strategy	11	1164 (218)	1254 (347)	1423 (379)	.93 (.11)	.89 (.12)	.09 (.03)
	No Explicit Strategy	21	1346 (271)	1436 (282)	1716 (430)	.94 (.08)	.88 (.11)	.13 (.03)

Table 5

Proportions of hits to intact pairs, false alarms to recombined pairs, and false alarms to new pairs (and standard deviations) in Experiment 2.

	Hits	**FA-Recombined**	**FA-New**
Young	0.90 (.11)	0.66 (.20)	0.03 (.08)
Old	0.94 (.09)	0.88 (.11)	0.06 (.12)