ASSESSING THE ROLE OF PAIR FAMILIARITY IN THE ASSOCIATIVE DEFICIT OF OLDER ADULTS

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The undersigned, appointed by the dean of the Graduate School, have examined the dissertation entitled

RECOGNIZING FAMILIARITY:
ASSESSING THE ROLE OF PAIR FAMILIARITY
IN THE ASSOCIATIVE DEFICIT OF OLDER ADULTS

presented by Angela Kilb,

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ASSESSING THE ROLE OF PAIR FAMILIARITY
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ABSTRACT

While aging causes relatively minor impairment in recognition memory for components, older adults' ability to remember associations between components is typically significantly compromised, relative to that of younger adults (see Naveh-Benjamin, 2000). Moreover, using dual process models of memory, Jennings & Jacoby (1997) have demonstrated that age differences are much larger for measures of recollection than for familiarity. Because older adults have intact use of familiarity, one possibility is that they rely too heavily on their familiarity of the components when making judgments about associations, causing them to mistakenly recognize novel pairings of familiar items. The purpose of the current study is to explore possible methods that allow older adults to capitalize on their intact familiarity in order to accurately remember pairings of information. Experiments 1 and 2 investigated this by unitizing two components of a pair such that the color information enables certain pairings to appear as one unit. In Experiments 3 and 4, participants were repeatedly presented with pairings prior to a study list so that the pairs were already familiar during the study phase. Remember/know judgments were collected in order to determine if any advantages in associative tests were related to reliance on familiarity or recollection. Evidence shows that both unitization and repetition increase associative memory in both younger and older adults. While recollection seems to mediate this effect in unitization, findings suggest that both familiarity and recollection are involved in enhancing associative memory via repetition.

INTRODUCTION

The Associative Deficit of Older Adults

Evidence shows that memory abilities decrease with age (see Old & Naveh-Benjamin, 2008a, for a review); however, older adults' memories are affected differentially depending on the type of information being processed. For instance, an older person may be able to retrieve obscure vocabulary words without a problem while being unable to recall where last Christmas was spent. One fundamental distinction here is between semantic memory (memory for general knowledge) and episodic, or context-specific, memory. Research shows that older adults are able to retain semantic information as well as younger adults (Rabinowitz, Craik, & Ackerman, 1982), yet it is more difficult for them to retain episodic information in which they must encode events along with their corresponding contexts (see Old & Naveh-Benjamin, 2008a, for a review).

A binding hypothesis was suggested to explain the memory deficits described above, stating that they are a result of problems in associating focal elements and their contexts (Bayen, Phelps, & Spaniol, 2000; Chalfonte & Johnson, 1996). Chalfonte & Johnson (1996) demonstrated this by presenting younger and older subjects with an array of pictures presented in arbitrary colors. When given recognition tests over either the colors or pictures, older adults' performance was comparable to younger adults. Recognition tests over the color of a given picture, however, produced poorer results for the older adults than the younger adults, showing that the older adults' memory for associations between focal elements and their contexts was worse than their memory for components relative to the younger adults.

Naveh-Benjamin (Naveh-Benjamin, 2000, 2002; Naveh-Benjamin, Hussain, Guez, & Bar-On, 2003) has also investigated this pattern of findings and proposes an associative-deficit hypothesis (ADH), suggesting that binding problems in older adults are not limited to the associations between an item and its context. Rather, binding problems can also occur with two focal items. This was demonstrated by presenting younger and older adults with unrelated word pairs or word-nonword pairs and giving separate tests over the items and their pairings (Naveh-Benjamin, 2000). Results show that older adults displayed poorer performance in the pair test than in the item test relative to the younger adults, characterizing an associative deficit. Naveh-Benjamin, Hussain, Guez, & Bar-On (2003; Experiment 1) have also demonstrated the associative deficit with pictorial stimuli. When younger and older adults were asked to learn pairs of unrelated pictures, it was found that older adults showed greater memory impairment for learning the pairings than for learning the individual pictures. In a more ecologically valid study, older adults' memories were comparable to younger adults' in remembering individual names or faces, yet they were poorer at remembering the name-face associations relative to the younger adults (Naveh-Benjamin, Guez, Kilb, & Reedy, 2004).

The above findings lead to questions regarding the source of this associative deficit in older adults. One possible mediator in the associative deficit that has been examined is reduced attentional resources. Craik (1982; 1983, 1986; Rabinowitz, Craik, & Ackerman, 1982; Craik & McDowd, 1987; Castel & Craik, 2003) suggests that age-related memory deficits are due to reduced attentional capacity in older adults, meaning that they are not able to process information as efficiently as younger adults. This has been demonstrated by experimentally manipulating younger adults' attentional resources by using a divided attention (DA) paradigm. Evidence has shown that younger adults under DA follow the same general patterns of memory performance as older adults under full attention (Rabinowitz, Craik, & Ackerman, 1982). In order to investigate the role of this reduction of attentional resources in the associative deficit, a similar DA paradigm has been implemented. If the associative deficit were mediated by a reduction of attentional resources, then one would expect that dividing attention would create an associative deficit in younger adults; however, research shows that dividing attention during encoding does not differentially affect memory for components and memory for associations (Kilb & Naveh-Benjamin, 2007; Naveh-Benjamin et al., 2004; Naveh-Benjamin et al., 2003). These results are inconsistent with the view that a reduction in resources is the cause of the associative deficit of older adults.

The Potential Role of Familiarity in the Associative Deficit of Older Adults

Another mediator for the associative deficit could be older adults' tendency to rely too much on automatic retrieval processes rather than more consciously controlled processes. An example of this tendency can be observed in Light & Singh (1987), in which younger and older adults were presented with both implicit and explicit memory tests. In the implicit tests, correct performance could be driven by automatic processes alone (e.g., complete the stem "cre__" with the first word that comes to mind), while the explicit tests required the use of conscious retrieval (e.g., complete the stem "cre___" with a word from the study list). Their results show minimal differences in the (automatic) implicit tests compared to much larger age differences in the (consciously controlled) explicit tests, demonstrating that older adults seem to have spared use of automatic retrieval despite a clear impairment in consciously controlled retrieval.

Jacoby and his colleagues (Jennings & Jacoby, 1993, 1997; Hay & Jacoby, 1999) have taken the findings of Light & Singh as evidence for the dual process model of memory. The notion here is that recognition can depend on one of two processes: recollection or familiarity (see Yonelinas, 2002, for a review). Here, recollection means that an item is (consciously) retrieved along with its original context, while familiarity refers to (automatic) recognition in the absence of any contextual information. For example, one might rely on familiarity when instantly recognizing someone's face, but recollection must be used in order to remember where that person was last seen. Tying this back to Light & Singh, one could argue that explicit tests require recollection, while implicit tests do not. Moreover, it has been suggested that people's ability to use recollection decreases with age, yet their ability to use familiarity does not. This suggestion is further supported via a newer approach known as the process dissociation procedure.

The idea behind the process dissociation procedure is that familiarity and recollection should be put into opposition so that purer measures of each can be collected. An example of this can be seen in the false fame paradigm. To begin, experimenters used repetition in order to increase familiarity for nonfamous names. In subsequent phases of the experiment, new lists were given and the participant's task was to determine which names were famous. To tease apart familiarity and recollection, participants were given separate instructions for these subsequent phases. In the "inclusion" test, they were told that any name that was previously seen in the experiment was a famous name;

consequently, if they remembered a name from earlier in the experiment, they should indicate that the name is famous. Note that in this test, an erroneous response of "famous" given to a nonfamous name could be made on the basis of familiarity (from repetition) or from recollecting that the name was shown in the context of the experiment. In contrast, the instructions for the "exclusion" test were that any name that was previously seen in the experiment was a *nonfamous* name. As a result, the appropriate strategy would be to say "nonfamous" if they recognized a name from an earlier phase (i.e., a recollection excludes earlier presented words from being famous). Erroneous responses of "famous" in this test would indicate that the participant did not recollect the names that were read earlier and automatically responded via familiarity. Using this procedure, separate measures for familiarity and recollection can be obtained.

In the false fame paradigm, it has been shown that age differences in familiarity are negligible, but age differences in recollection are quite large (Jennings & Jacoby, 1993; Multhaup, 1995). Similar patterns of performance can be seen in other process dissociation procedures using concrete nouns (Hay & Jacoby, 1999; Jennings & Jacoby, 1997) as well as in the remember/know procedure. In the latter case, measures of familiarity and recollection are taken from participants' own reports of their phenomenal experience. That is, if they could bring back to mind a recollection of something that occurred at the time the item was encoded, they were instructed to say "remember"; if they were merely aware of the item's prior occurrence, they were instructed to say "know" (see Tulving, 1985; Gardiner, Ramponi, & Richardson-Klavehn, 1998). Research demonstrates that older adults are less likely than younger adults to give "remember" responses, while there are only minor differences in "know" responses

(Java, 1996; Maylor, 1995). Finally, evidence reveals that having a response deadline at test largely eliminates the ability to use recollective processes while leaving familiarity preserved; furthermore, older adults show no change in performance when a deadline is enforced, but younger adults who encounter a deadline show a decrement and tend to simulate older adults (Jacoby, 1999; Light, Patterson, Chung, & Healy, 2004). All of these results converge to show that older adults often rely on familiarity rather than recollection, while younger adults more often rely on recollection.

Item and associative recognition tests may each require different levels of familiarity and recollection. For example, Hockley & Consoli (1999) have shown that participants are more likely to give a "know" response in an item test, yet are more likely to give a "remember" response in an associative test, demonstrating that associative tests require more recollective processing. Moreover, if a participant is able to rely on recollection, then it is expected that performance on both tests will be quite high. On the other hand, if a participant relies mainly on familiarity (i.e., in the absence of recollection), performance in the item recognition test may still be high, but performance in the associative recognition test would suffer. This is because the individual items of a recombined pair (i.e., a new pair created from two studied words) would look very familiar, causing the participant to mistakenly recognize the new pairing. When examining the empirical data, younger adults' performance is more consistent with patterns predicted by recollection, while performance of older adults is more consistent with patterns predicted by familiarity. Specifically, older adults are much more likely to falsely recognize new pairs in an associative test than new items in an item test, but younger adults show relatively low false alarm rates in both tests (Naveh-Benjamin, Shing, Kilb, Li, & Lindenberger, 2009; Old & Naveh-Benjamin, 2008b).

While it is not within the scope of the current project to investigate *why* older adults have deficits in recollection, one possibility is their diminished use of the hippocampus. In a 5-year longitudinal study, Raz et al. (2005) examined people aged 20-77 to evaluate the degree of deterioration in different brain structures. One area showing the largest volume shrinkage was the hippocampus, which has been implicated as a binder of memories (see Cohen et al., 1999, for a review). Recent evidence suggests that activation in the various structures within the hippocampal formation is differentially correlated with item and associative memory. For instance, Davachi, Mitchell, & Wagner (2003) have shown that performance in item but not associative tests can be predicted by perirhinal activation; meanwhile, associative but not item tests can be mapped to the hippocampus. Similar results can be observed from lesion studies. For example, patient YR who suffered damage to the hippocampus while leaving her perirhinal and entorhinal cortices intact, has performed within the normal range in item tests but shows significant impairment in associative tests (Mayes et al., 2004). Also, Yonelinas et al. (2007) found that recall (a test relying more on recollection than recognition) had a stronger correlation with hippocampal than entorhinal volume, whereas recognition was more correlated with entorhinal than hippocampal volume. Since Raz et al. (2005) found substantially greater depletion of the hippocampus than the perirhinal cortex with age, one might conclude that the hippocampus is responsible for recollective processing, while the entorhinal and/or perirhinal cortex is responsible for familiarity-based processing.

In summary, it has been clearly shown that older adults demonstrate an impairment in recollection despite having spared use of familiarity. The purpose of the following set of experiments is to enable older adults to capitalize on this intact familiarity in order to remember new associations. Specifically, younger and older adults were presented with information such that they acquired familiarity for the pairings. In Experiments 1 and 2, pair familiarity was enhanced by unitizing the components of a pair; in Experiments 3 and 4, pair familiarity was enhanced through pair repetition.

EXPERIMENT 1:

Manipulating Perceptual Unitization in Order to Increase Associative Memory

One possibility for improving older adults' memories for associations is to create a situation in which they can use their intact familiarity in order to successfully remember pairings. Yonelinas (2002) has argued that this can occur if pairs are sufficiently *unitized* – that is, if two components are encoded as if they were only one unit. There is some existing evidence to suggest that younger adults are able to rely on pair familiarity alone to remember associations.

Parks, Murray, Yonelinas, & Smith (2006) presented younger adults with word pairs to be later tested in item and associative recognition tests. In the control condition, each pair was accompanied by a sentence comprising both words (e.g., "milk burden: Carrying the ____ was a heavy ____."), while in the unitized condition, each pair was accompanied by a description (e.g., "milk burden: An unfavorable duty at a dairy"). These conditions were used in order to equate the depth of processing while discriminating between the encoding of two units in the control condition ("milk" and "burden") and the encoding of one unit in the unitized condition (a "milk burden"). The authors found that there were no differences in item memory between the two conditions, but they found a significant increase in associative test performance in the unitized condition relative to the control condition. To demonstrate that this advantage in associative memory was driven by familiarity, they showed qualitative differences in performance via an ROC (Receiver Operating Characteristics) curve as well as in estimates of familiarity and recollection. This provides evidence that younger adults were able to rely on familiarity of pairings in order to increase their performance in associative tests.

Similar conclusions can be reached using alternative methods. For instance, Rhodes & Donaldson (2007) presented younger adults with word pairs that varied in judgments of unitization. Three types of pairs were presented: *association* (e.g., traffic-jam), *association* + *semantic* (e.g., lemon-orange), and *semantic* (e.g., cereal-bread). When a separate group of pilot subjects rated the degree of unitization for these stimuli on a 5-point Likert scale (i.e., To what degree do you think these word pairs can be considered as a single unit?), it was found that *association* and *association* + *semantic* pairs were judged as more unitized than *semantic* pairs. Consequently, it was predicted that associative memory for semantic pairs would be worse than the others. During test, the subjects' task was to identify previously seen pairs among a list of intact pairs, rearranged pairs, and pairs of new items. The results show that accuracy was higher and response times were faster for pairs that were previously judged to be more unitized. ERP (Event Related Potential) data show that superior performance for the unitized pairs was associated with more bilateral frontal activity, indicating that underlying familiarity processes may be responsible for the benefit to associative memory. Parietal activity, which has been associated with recollection,[1] showed no differences among the pair types.

Additionally, lesion patients who have impaired use of recollection also show effects of unitization. Kroll, Knight, Metcalfe, Wolf, & Tulving (1996) have shown that people with hippocampal damage[2] show a specific deficit for associations despite relatively intact memory for the individual components, which is the same pattern displayed by healthy older adults. Interestingly, such patients benefited from unitization, showing that it was easier to remember integrated word pairs compared to a control condition (Giovanello, Keane, & Verfaellie, 2006; Quamme, Yonelinas, & Norman, 2007). Since these hippocampal patients have minimal use of recollection, it is suggested that their advantage of unitization occurs because of familiarity, which is supported by surrounding brain structures. Further evidence for this notion comes from a recent study revealing that unitized pairs are associated with both higher levels of familiarity (as observed in ROC curves) and increased activation in the perirhinal cortex (Haskins, Yonelinas, Quamme, & Ranganeth, 2008).

In summary, it has been suggested that unitization benefits associative memory through increased familiarity of pairings. Because older adults have shown intact familiarity relative to younger adults (e.g., Jennings & Jacoby, 1993), it is predicted that

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[1]While parietal activation is often associated with recollective experiences, patients with parietal damage do not show any impairment in memory for associations (Simons et al., 2008), suggesting that activation here is not necessary for a recollection.

[2] It is unknown whether the damage reported is limited to the hippocampus proper or extends into the perirhinal and entorhinal cortices.

unitization will help older adults at least as well as younger adults. At least two studies of the associative deficit have already demonstrated that increasing the links between items increases associative memory. Naveh-Benjamin, Hussain, Guez, & Bar-On (2003) presented younger and older adults with semantically related and unrelated word pairs. They found that the associative deficit of older adults was significantly reduced for related pairs when compared to unrelated pairs, suggesting that the relationships between items may have helped to unitize each pair into one cohesive unit. Similarly, Naveh-Benjamin, Brav, & Levi (2007) found that the associative deficit was smaller when subjects were asked to create a sentence using both words of a pair than when simply studying pairs under intentional learning.

Although it is evident that both younger and older adults can take advantage of conceptual unitization in an associative test, it remains unclear as to whether this advantage will translate to perceptual unitization. One recent finding, however, demonstrates that temporal proximity can affect the strength of unitization. Parks & Yonelinas (2008) observed that simply presenting pairs simultaneously rather than sequentially increased associative memory via added familiarity for simultaneous presentation. The question addressed in Experiment 1 is whether other perceptual manipulations will show similar effects. For instance, can two words of a pair be unitized via color information?

According to Gestalt psychology, one might expect color to be a powerful tool in how information is perceived. Specifically, the law of similarity states that similar items (e.g., objects of the same color or shape) appear to be grouped together (Wertheimer, 2000). More interestingly, Beck & Palmer (2002) suggest that grouping by color is an automatic process since it is not influenced by instructions intended to create a strategy shift. In terms of its impact on memory, Bower (1972) showed that placing adjacent nonsense syllables in the same color increased the likelihood that those syllables are recalled in order, thereby increasing relational memory. In summary, these results argue that grouping items by color is an automatic process that can improve memory for associations.

Evidence has also been established to demonstrate that older adults are quite capable of encoding perceptual detail. For instance, the work of Koutstaal, Schacter, Galluccio, & Stofer (1999) shows that when given a cue to attend to two specific details of each picture in a categorized picture paradigm, younger and older adults benefit to the same degree, showing reduced false alarms to related picture lures. Other research also shows no age differences in the use of perceptual information. Koutstaal et al. (2003, Experiment 1) presented younger and older adults with study lists of ambiguous pictures that were all variants of a nonpresented prototype. When participants were given disambiguating labels (e.g,. all pictures in a study list may resemble "trucks"), older adults were much more likely to false alarm to related lures than younger adults; however, when no disambiguating labels were given, there were no age differences in false alarms. The authors concluded that when given labels, older adults are especially more susceptible to relying on gist-based information than younger adults. Yet, when gist-based information is not available, older adults use perceptual information as effectively as younger adults. In other work, Koutstaal (2003) showed that older adults encoded perceptual information as effectively as younger adults, as evidenced by implicit tests, but older adults made more gist-based errors in an explicit recognition test. These studies indicate that older adults may not be impaired in encoding perceptual information, even though they may prefer to primarily rely on conceptual information if it is made available. Curiously, older adults seem to maximize the use of perceptual information when they must use it implicitly.

The purpose of the first experiment is to determine whether both younger and older adults' associative memory will benefit from unitization if it is manipulated perceptually rather than conceptually. In the current experiment, unitization is manipulated through the use of color.

In order to determine the extent to which younger and older adults take advantage of perceptual unitization, participants representing both age groups studied word pairs shown in different colors. For the unitized conditions, words of a given pair were shown in the same color, but each member of a pair in the non-unitized conditions was shown in one of two different colors. In order to make the learning of colors more implicit, participants were asked to study the words and pairings while ignoring the colors[3]. After a short filler task, they were given separate item and associative tests. The predictions are that both groups should show a benefit of unitization in the associative tests, but not in the item test.

Since the associative deficit is typically seen when words are all presented in one common font color, one might argue that all previous studies showing an associative deficit presented "unitized" pairs. While presenting both words of a given pair in the same color should increase the relationship between the words, this also increases the

[3] It should be noted here that during the piloting phase, participants were instructed to remember the colors along with the words/pairings; however, participants who followed these instructions performed at chance levels.

relationship between the different pairs, making it more difficult to keep the pairs separate from each other. In other words, any benefit of unitization would be cancelled out by the negative effects of interference between pairs. The current experiment attempts to somewhat remedy this problem by presenting pairs in different colors, thereby decreasing the interference between pairs.

Method

Participants.

Twenty-eight younger adults were recruited from introductory Psychology courses (ages 18-20), and 27 older adults (ages 65-80) were recruited from central Missouri. All participants reported being in good physical and mental health (see Table 1 for additional demographic information). There were no differences in the gender distributions for the two age groups, $t(53)=1.71$, $p>.05$, while older adults averaged one additional year of education than the young (12.64 vs. 13.63, $t(53)=3.00$, $p<.01$).

Table 1.

Demographic Information for Experiments 1-4.

	N	Proportion(male)	Age	Education
		Experiment 1		
Young	28	.39	18.36 (.68)	12.64 (.73)
Old	27	.19	72.52 (3.96)	13.63 (1.57)
		Experiment 2		
Young	28	.32	18.39 (.50)	12.68 (.72)
Old	26	.23	73.27 (4.47)	15.19 (2.88)
		Experiment 3		
Young	24	.29	19.29 (1.52)	13.52 (1.33)
Old	24	.29	71.21 (3.20)	12.85 (1.50)
		Experiment 4		
Young	26	.27	19.08 (1.69)	13.27 (1.44)
Old	25	.48	73.33 (3.84)	14.13 (3.42)

Note. Standard deviations in parentheses.

Design.

This experiment is a 2 (age: young vs. old) x 2 (test: item vs. associative) x 2 (unitization: same color vs. different color) factorial design. Type of test and unitization were manipulated within lists.

Materials.

Four study lists were used (see Appendix A, Section 1, for stimuli). Each study list contained 40 unrelated pairs of high frequency, bisyllabic words. Half of these pairs were unitized and half were non-unitized. Item tests contained 32 items (8 unitized targets, 8 non-unitized targets, and 16 distractors), and associative tests contained 32 pairs (8 unitized intact pairs, 8 non-unitized intact pairs, 8 unitized recombined pairs, and 8 non-unitized recombined pairs).

The colors orange (hue=32, saturation=100, brightness=98) and blue (hue=230, saturation=97, brightness=98) were shown against a gray background (hue=300, saturation=2, brightness=84). The two colors were rotated between subjects such that a given word occurred equally often in orange and blue. Recombined pairs were created by rearranging words from the same color and unitization conditions. For example, a unitized blue-blue study pair could only be recombined with another blue-blue study pair. Likewise, a non-unitized blue-orange study pair could only be recombined with another non-unitized blue-orange study pair. Colors were reinstated for both types of tests. The order of the four study lists was rotated each for participant as well as the order of the two recognition tests. Finally, the allocation of studied words to the various tests was arranged such that each word appeared equally often as an item target, intact pair, and recombined pair at test.

Procedure

Participants began by having their color vision tested ("Isihara Test for Color Blindness," n.d.). Then they were given instructions for each segment of the experiment followed by a practice trial, which included a sample study phase and practice item and associative tests. Next, they were presented with four full-length experimental trials. Pairs in the study list were shown at a 6-second rate, and their directions were to remember the words and the pairings between the words. They were told that they would see different colors, but that they should not pay attention to the colors and only try to learn the words and pairs. After an interpolated activity of one minute, they were given the item and associative tests. In the item test, they were to indicate whether or not they recognized the individual words; in the associative test, they indicated whether or not they recognized the pair. For both tests, they pressed keys that were labeled "yes" and "no." They had 3 seconds to make their response.

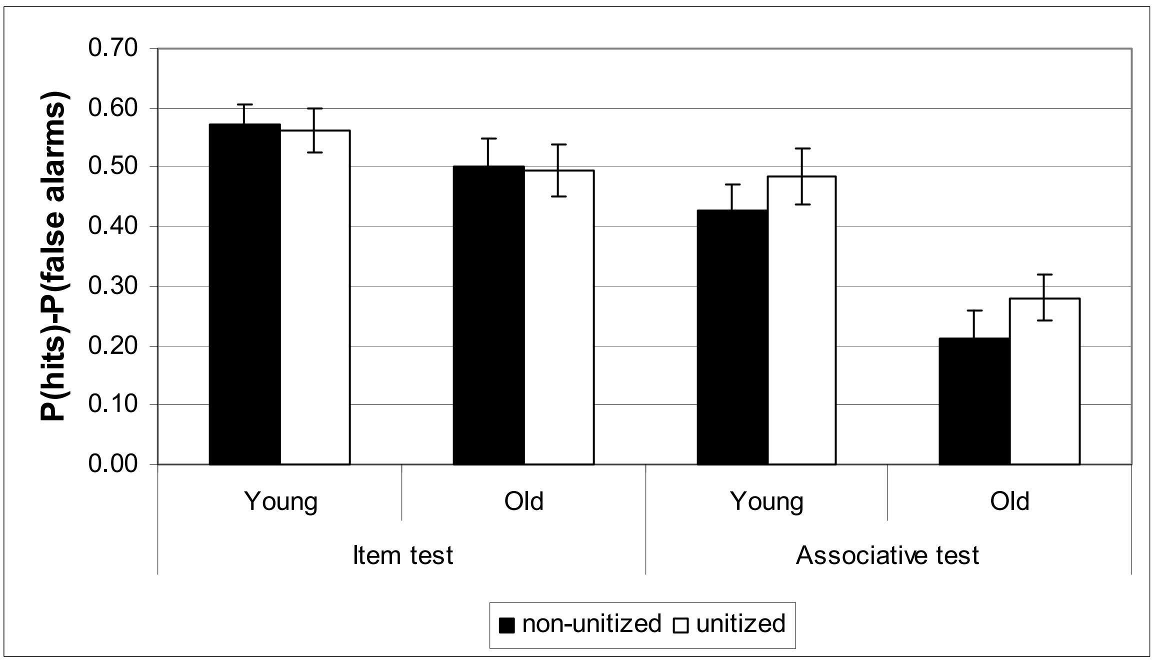
Results

The data were analyzed in a 3-way ANOVA using the variables age, test, and unitization on proportion hits minus proportion false alarms (see Appendix B, Table B1 for descriptive statistics). Main effects were observed for age, test type, and unitization such that younger adults (M=.52, SD=.20) showed superior performance over the old (M=.37, SD=.20), $F(1,53)=7.63$, $p<.01$, the item test (M=.53, SD=.21) elicited higher performance than the associative test (M=.36, SD=.24), $F(1,53)=64.88$, $p<.001$, and there was a marginal benefit for unitized (M=.46, SD=.21) versus non-unitized stimuli (M=.43, SD=.23), $F(1,53)=3.15$, p=.08. An associative deficit was also shown for the older adults. Specifically, there was an interaction of age and test, $F(1,53)=12.46$, p=.001, reflecting large age differences in the associative test (M=.47, SD=.24 for the young and M=.24, SD=.21 for the old), $t(53)=3.75$, $p<.001$, but none in the item test (M=.57, SD=.18 for the young and M=.50, SD=.23 for the old), $t(53)=1.27$, $p>.05$.

The critical question is how unitization may affect associative memory performance. While there was no triple interaction among age, test, and unitization, $F(1,53)<1$, $p>.05$, there was a significant interaction between test and unitization, $F(1,53)=5.15$, $p<.05$, revealing that young and old showed similar advantages of unitization in the associative test (M=.39, SD=.25 for unitized and M=.32, SD=.27 for non-unitized), $t(53)=2.61$, p=.01, but no effect in the item test (M=.53, SD=.22 for both conditions), *t*(53)=.31, *p*>.05 (see Figure 1). No other effects were significant. For further investigation, the data were separated into proportion hits and proportion false alarms and re-analyzed in two separate ANOVAs using each as a dependent variable.

Figure 1.

Mean of Proportion Hits Minus Proportion False Alarms as a Function of Age, Test, and Unitization Condition in Experiment 1 (Error Bars Represent Standard Errors Around The Mean)



When determining the effect of age, test, and unitization on the hit-rate, only the main effect of test was found to be significant (*M*=.74, *SD*=.15 for the item and *M*=.69, *SD*=.15 for the associative), *F*(1,53)=7.91, *p*<.01. All other factors, including age, *F*(1,53)<1, *p*>.05, unitization, *F*(1,53)<1, *p*>.05, the interaction of age and test,

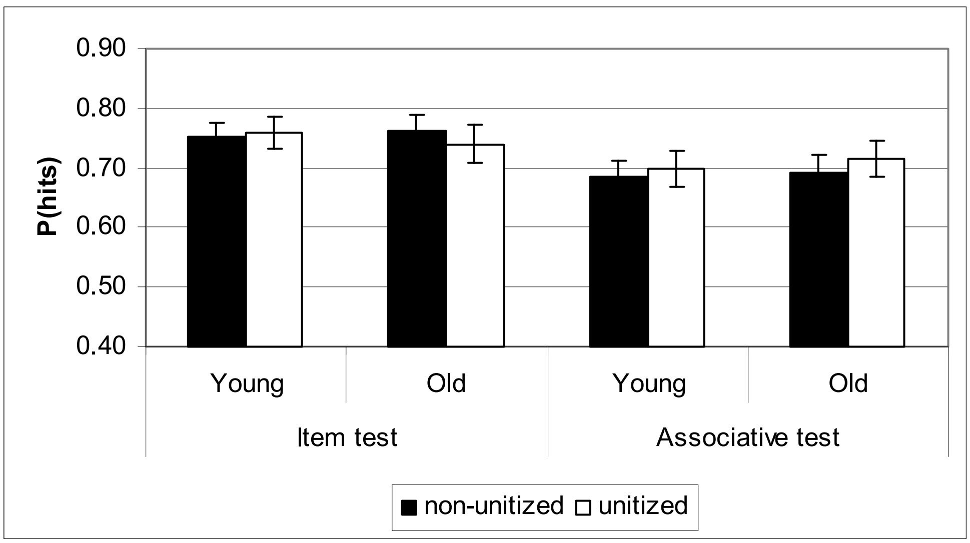
$F(1,53)<1$, $p>.05$, the interaction of age and unitization, $F(1,53)<1$, $p>.05$, and the triple interaction, $F(1,53)<1$, $p>.05$, were nonsignificant (see Figure 2a).

Analyzing the same variables using the false-alarm rate, however, produced very different results. The main effects showed that younger adults (M=.21, SD=.12) made fewer false alarms than the older adults (M=.35, SD=.15), $F(1,53)=14.32$, $p<.001$, the item test (M=.22, SD=.16) elicited fewer false alarms than the associative test (M=.34, SD=.18), $F(1,53)=40.34$, $p<.001$, and fewer were associated with the unitized condition (M=.27, SD=.16) when compared to the non-unitized condition (M=.29, SD=.16), $F(1,53)=4.67$, $p<.05$. Furthermore, there was an interaction of age and test, $F(1,53)=14.31$, $p<.001$, showing that older adults had more false alarms than young in the associative test (M=.45, SD=.16 and M=.24, SD=.13, respectively), $t(53)=5.20$, $p<.001$, yet there were no age differences in the item test (M=.25, SD=.19 for old and M=.19, SD=.12 for young), $t(53)=1.50$, $p>.05$. Most important, though, is how unitization interacted with test. Mimicking the findings from the overall memory score reported earlier, there was an interaction of unitization and test, $F(1,53)=4.71$, $p<.05$, and follow-up tests revealed that this effect was primarily driven by the associative test. That is, unitization reduced false alarms in the associative test (M=.32, SD=.19 vs. M=.37, SD=.20), $t(54)=2.39$, $p<.05$, but not in the item test (M=.22, SD=.16 for both conditions), $t(54)=.13$, $p<.05$ (see Figure 2b). The interaction of age and unitization, $F(1,53)<1$, $p>.05$, and the triple interaction, $F(1,53)<1$, $p>.05$, were nonsignificant.

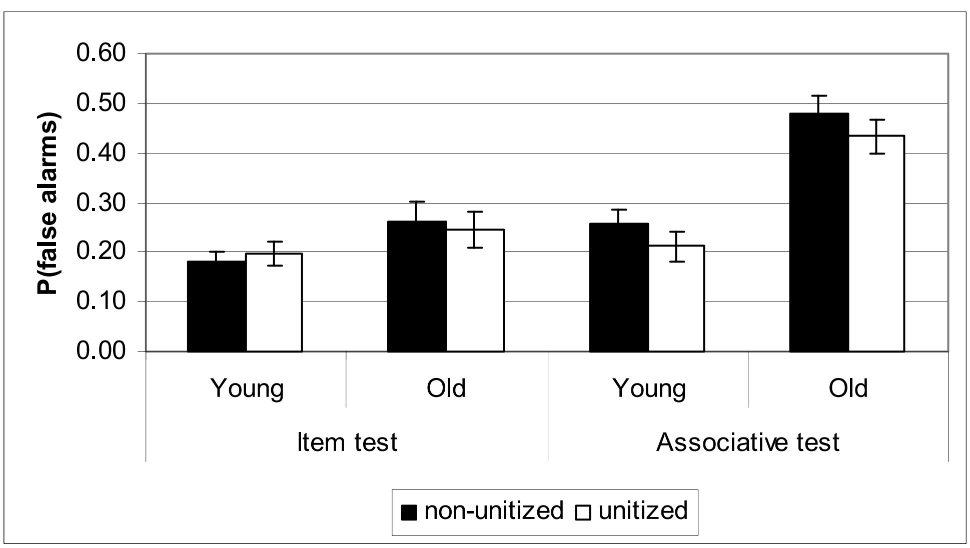
Figure 2.

(A) Mean of Proportion Hits as a Function of Age, Test, and Unitization Condition in Experiment 1, and (B) Mean of Proportion False Alarms as a Function of Age, Test, and Unitization Condition in Experiment 1 (Error Bars Represent Standard Errors Around The Mean)

(A)



(B)



Discussion

The results of Experiment 1 are consistent with previous findings that illustrate a binding deficit in older adults' memory performance (e.g., Naveh-Benjamin, 2000; Naveh-Benjamin et al., 2004; Kilb & Naveh-Benjamin, 2007). Moreover, this particular deficit is manifested as a problem in falsely recognizing recombined pairs despite no difficulty in correctly recognizing previously studied pairs. The pattern described here would be expected if older adults base their recognition mainly on feelings of familiarity – i.e., the familiar items would lead to erroneous beliefs that the new pairings were already seen even though they were not.

Most importantly, unitization had a clear effect on the associative test, and both age groups benefited to the same degree, which is somewhat surprising since other manipulations, like repetition, have shown a stronger advantage for young than old (Light et al., 2004). Given that younger adults already had relatively high performance in the associative test, their benefit in relative terms may not be as large as for the older adults, whose performance increased by 33% (compared to an increase of about 14% for the young).

If unitizing the word pairs at study strengthened their overall encoding, then one would expect increases to both item and associative test performance. However, the fact that no effect was seen in the item test suggests otherwise. Alternatively, it is possible that unitization strengthened the encoding of the pairs at the cost of encoding the individual items. If so, item memory performance should be lower for words shown in the unitized than non-unitized conditions, but again, there was no such difference here.

Furthermore, both of the above possibilities can be tested at the level of individual participants by examining the relationship between the effects of unitization in the item and associative tests. When separate estimates of the unitization effect on associative memory (i.e., unitized associative test performance minus non-unitized associative test performance) and the corresponding effect on item memory were calculated for each participant, there was no correlation between the two unitization effects, $r(53)=.06$, $p>.05$, even when done separately for young, $r(26)=-.03$, $p>.05$, and old, $r(25)=.14$, $p>.05$.

The proposed interpretation is that unitization has its effect primarily at retrieval, making recognition processes more reliable when words of a given pair are shown in the same color. Since the main contribution of unitization was to decrease false recognition of recombined pairs rather than to increase the hit rate of intact pairs, this explanation seems viable. The goal of Experiment 2 was to gain further support for this account.

EXPERIMENT 2:
Testing the Contribution of Familiarity and Recollection to the Effects of Perceptual Unitization

While the purpose of Experiment 1 was to establish whether or not perceptual unitization increases associative memory in both younger and older adults, it does not address the contributions of familiarity and recollection. Experiment 2 allowed for remember/know judgments to be collected in order to determine whether familiarity, recollection, or both mediate the unitization effects on associative memory performance.

The remember/know paradigm has been widely used, as evidenced in a meta-analysis citing nearly 400 experiments (Rotello, Macmillan, & Reeder, 2004). Furthermore, Yonelinas and Jacoby (1995) have shown convergence between estimates of recollection and familiarity using the remember/know paradigm and the well-established process dissociation procedure.

Some recent evidence suggests that benefits of unitization can be captured by know responses. Giovanello, Keane, & Verfaellie (2006) manipulated conceptual unitization by presenting either two unrelated word pairs (e.g., salad business) or two words that combine to form one compound word (e.g., pin wheel). In a later test, pairs were either kept intact (e.g., salad business) or were recombined with other pairs that were previously presented (e.g., pin point). They found that memory performance was higher for the (unitized) compound words than for the unrelated word pairs; more importantly, this advantage was shown in items judged as familiar but not in items that were recollected.

Experiment 2 followed the same procedure as in Experiment 1 except that remember/know responses were collected for endorsed items and pairs. With the additional responses, it is possible to examine two new dependent variables. First, one can look at the degree to which participants rely on familiarity and recollection by examining the number of remember and know responses given. Second, memory accuracy can be observed separately for remember and know responses. Predictions were made for each of these two measures.

Beyond replicating findings from the previous experiment, it was expected that estimates of recollection would be higher for associative tests than item tests (Hockley &

Consoli, 1999), and older adults would rely on recollection less often than younger adults (Jennings & Jacoby, 1993, 1997). In addition, separate patterns were predicted depending on whether unitization is driven by recollection or familiarity. If driven by familiarity, then one would predict that (1) estimates of recollection would decrease, and estimates of familiarity would increase (as measured by response frequency) for unitized compared to non-unitized conditions, and (2) memory benefits of unitization in the associative tests would be seen within the accuracy of know responses. Alternatively, the opposite pattern is expected if unitization is driven by recollection. Specifically, estimates of recollection would increase while familiarity decreases for unitized stimuli, and the effects of unitization should be observed in remember responses. Because remember and know responses are mutually exclusive, which may underestimate familiarity, a correction was implemented (as is suggested by Yonelinas, Kroll, Dobbins, Lazzara, & Knight, 1998), which estimates familiarity only in the absence of recollection and allows for independence between measures of familiarity and recollection.

Method

Participants

Younger and older adults were drawn from the same pools as Experiment 1 (see Table 1 for demographic information). While the older adults completed more education than younger adults, $t(52)=4.47$, $p<.001$, the age groups did not differ in gender, $t(52)=.73$, $p>.05$.

Design & Materials

These were the same as in Experiment 1.

Procedure

The procedure was identical to Experiment 1 with the exception that remember/know/guess responses were collected for each recognized event presented at test. Instructions for these responses were adapted from Gardiner, Ramponi, & Richardson-Klavehn (1998; see Appendix A, Section 2). Slight modifications were added in order to make the directions clearer for the older adults. Specifically, in place of saying "remember," participants were asked to say "context" if recognizing a word in the item test (or a pair in the associative test) triggered a unique thought that occurred when that word was initially seen at study. Instead of saying "know," participants said "familiar" to indicate that they were encountering strong feelings of familiarity without any accompanying contextual information. They also said "guess" when relying on chance alone. For each test, participants were first given 3 seconds to indicate "yes" or "no" to a given probe as in Experiment 1. If they pressed "no", they would immediately be given the next test stimulus. If they pressed "yes", then a new screen would ask whether the response was given because of "context", "familiarity", or a "guess". Participants were given unlimited time in providing this second response.

Results

In the current experiment, participants sometimes did not respond to the recognition tests within the 3-second window; therefore, their responses were not recorded[4]. These missed responses were excluded from subsequent analyses, but see Appendix B for further information regarding when responses were most frequently missed.

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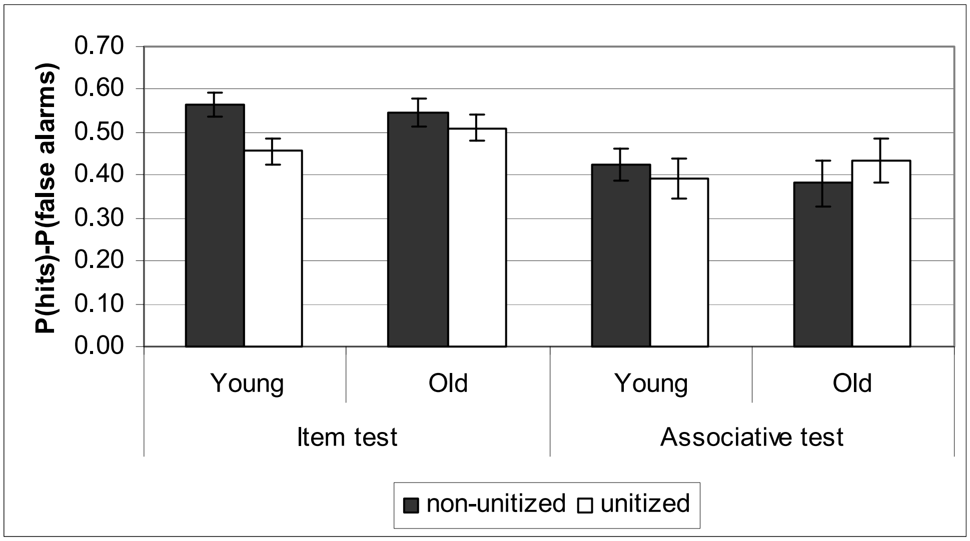
[4] Given this particular finding, the results of Experiment 1 were reanalyzed such that missed responses were ignored; however, this did not change any of the patterns observed.

A 3-way ANOVA was performed using the variables age, test, and unitization on memory performance as measured by proportion hits minus proportion false alarms (see Appendix C, Table C2 for descriptive statistics). Results showed no age difference ($M=.46$, $SD=.16$ for young and $M=.47$, $SD=.18$ for old), $F(1,52)<1$, $p>.05$, while unitized information ($M=.45$, $SD=.18$) was remembered less well than non-unitized information ($M=.48$, $SD=.17$), $F(1,52)=4.85$, $p<.05$, and performance was higher for item tests ($M=.52$, $SD=.14$) than associative tests ($M=.41$, $SD=.23$), $F(1,52)=22.45$, $p<.001$. Surprisingly, there was no interaction between age and test, $F(1,52)<1$, $p>.05$, but the interactions of both age and unitization, $F(1,52)=8.29$, $p<.01$, and test by unitization, $F(1,52)=8.57$, $p<.01$, were significant. Further analysis of the age x unitization interaction revealed that younger adults were impaired by unitization ($M=.50$, $SD=.15$ for non-unitized and $M=.42$, $SD=.18$ for unitized), $t(27)=3.51$, $p<.01$, but older adults were not ($M=.46$, $SD=.19$ for non-unitized and $M=.47$, $SD=.18$ for unitized), $t(25)=.49$, $p>.05$. Also, only the item test was negatively affected by unitization ($M=.55$, $SD=.16$ for non-unitized and $M=.48$, $SD=.16$ for unitized), $t(53)=4.34$, $p<.001$, leaving the associative test unaffected: $M=.40$, $SD=.23$ for non-unitized and $M=.41$, $SD=.24$ for unitized, $t(53)=.37$, $p>.05$. The triple interaction was not significant, $F(1,52)<1$, $p>.05$ (see Figure 3).

Figure 3.

Mean of Proportion Hits Minus Proportion False Alarms as a Function of Age, Test, and Unitization Condition in Experiment 2 (Error Bars Represent Standard Errors Around The Mean)



Given the results of Experiment 1, there was a specific prediction that unitization would increase performance in the associative test. In order to evaluate this prediction, the effect of unitization was examined only within the associative test for both younger and older adults. While the younger adults showed no effect of unitization (M=.43, SD=.20 for non-unitized and M=.39, SD=.25 for unitized), $t(27)$=.97, p>.05, the older adults showed a tendency toward increased performance for unitized (M=.44, SD=.26) over non-unitized pairs (M=.38, SD=.27), $t(25)$=1.89, p=.07, in line with the results of Experiment 1.

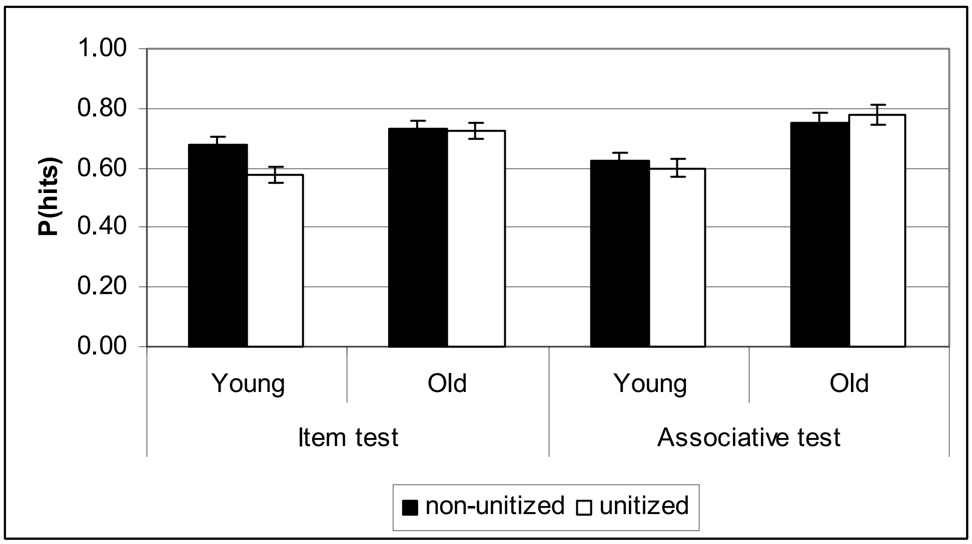
Next, the ANOVA using age, test, and unitization was performed using only the proportion hits. This time, there was an age effect showing increased hits for the old

(M=.67, SD=.17) compared to the younger (M=.62, SD=.12) adults, $F(1,52)=12.73$, $p=.001$, as well as an overall impairment of unitization (M=.68, SD=.17 for non-unitized and M=.65, SD=.18 for unitized), $F(1,52)=5.33$, $p<.05$, but no effect of test, $F(1,52)<1$, $p>.05$. Again, there was no interaction of age and test, $F(1,52)=2.11$, $p>.05$, but there were interactions for age and unitization, $F(1,52)=11.21$, $p<.01$, and test and unitization, $F(1,52)=7.33$, $p<.01$. The patterns mimicked those found for hits minus false alarms such that younger adults were impaired by unitization (M=.65, SD=.12 for non-unitized and M=.59, SD=.13 for unitized), $t(27)=3.63$, $p=.001$, while older adults were not (M=.74, SD=.15 for non-unitized and M=.75, SD=.14 for unitized), $t(25)=.85$, $p>.05$. Meanwhile, only the item test was affected by unitization (M=.70, SD=.14 for non-unitized and M=.65, SD=.16 for unitized), $t(53)=3.48$, $p=.001$, leaving the associative test unchanged (M=.68, SD=.18 for non-unitized and M=.69, SD=.19 for unitized), $t(53)=.13$, $p>.05$. The triple interaction was not significant, $F(1,52)=1.15$, $p>.05$ (see Figure 4a).

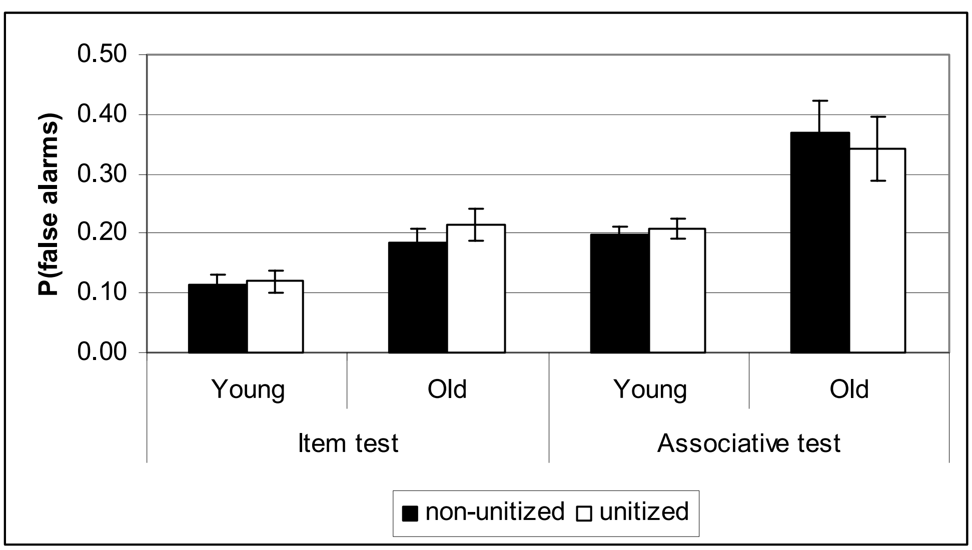
Figure 4.

(A) Mean of Proportion Hits as a Function of Age, Test, and Unitization Condition in Experiment 2, and (B) Mean of Proportion False Alarms as a Function of Age, Test, and Unitization Condition in Experiment 2 (Error Bars Represent Standard Errors Around The Mean)

(A)



(B)



As in the results of proportion hits minus proportion false alarms, younger adults showed no difference in associative memory for unitized (M=.60, SD=.16) vs. non-unitized pairs (M=.62, SD=.16), $t(27)$=.87, p>.05, but older adults showed a marginal advantage for unitized pairs (M=.78, SD=.18) than non-unitized pairs (M=.75, SD=.18) in the associative test, $t(25)$=1.77, p=.09.

These analyses were also performed for proportion false alarms (see Figure 4b). A 3-way ANOVA using age, test, and unitization showed that older adults (M=.28, SD=.18) had more false alarms than younger adults (M=.16, SD=.11), $F(1,52)$=8.37, p<.01. There was no longer an effect of unitization, $F(1,52)$<1, p>.05, yet there were more false alarms in the associative test (M=.27, SD=.22) than the item test (M=.15, SD=.11), $F(1,52)$=31.24, p<.001. None of the interactions were significant (age x test: $F(1,52)$=2.70, p>.05, age x unitization: $F(1,52)$<1, p>.05, test x unitization: $F(1,52)$=1.80, p>.05, age x test x unitization: $F(1,52)$=2.77, p>.05).

When the effect of unitization was examined for the associative test only, neither age group showed a difference between the means: in younger adults, M=.20, SD=.16 for non-unitized and M=.21, SD=.16 for unitized, $t(27)$=.60, p>.05; in older adults, M=.37, SD=.28 for non-unitized and M=.34, SD=.27 for unitized, $t(25)$=1.06, p>.05.

Remember/Know Judgments

The proportion of remember (R), know (K), and guess (G) responses were calculated by taking the total number of a given response per participant and dividing that number by that person's total number of endorsed responses. For example, if someone said "remember" to 3 stimuli, "know" to 5 stimuli, and "guess" to 2 for a total of 10 responses, then the proportion R is .30, proportion K is .50, and proportion G is .20. Since the proportion K is suggested to be an underestimation of familiarity (Yonelinas et al., 1998), a correction was added such that the estimate of familiarity = proportion K/(1-proportion R). The estimate of recollection was simply the proportion of R responses.

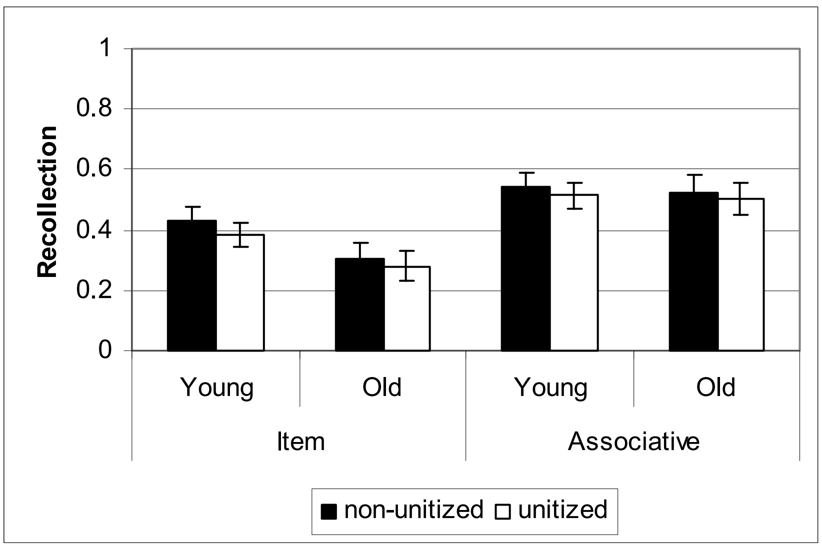
Using frequency of recollection responses as the dependent variable, an ANOVA was performed on age, test, and unitization (see Appendix C, Table C3, for descriptive statistics). There was no main effect of age, $F(1,45)=1.15$, $p>.05$, but there were main effects of both test, $F(1,45)=45.66$, $p<.001$, and unitization, $F(1,45)=5.34$, $p<.05$, such that more recollection-based responses were made in the associative test ($M=.52$, $SD=.25$) than the item test ($M=.35$, $SD=.23$) and more were made for non-unitized ($M=.45$, $SD=.23$) than unitized ($M=.41$, $SD=.23$) stimuli. There was also an interaction of age and test, $F(1,45)=4.50$, $p<.05$, reflecting that younger adults had higher estimates of recollection than old in the item test, $t(52)=1.86$, $p=.07$, despite no age differences in the associative test, $t(45)=.19$, $p>.05$. The interaction of age and unitization, $F(1,45)<1$, $p>.05$, test and unitization, $F(1,52)<1$, $p>.05$, and the triple interaction were nonsignificant, $F(1,45)<1$, $p>.05$ (see Figure 5a).

When frequency of familiarity responses were used in the same 3-way ANOVA as above, the effect of age remained nonsignificant, $F(1,52)<1$, $p>.05$, but the effect of test showed more familiarity-based responses in the item ($M=.79$, $SD=.16$) than the associative test ($M=.64$, $SD=.31$), $F(1,52)=10.83$, $p<.01$. All other effects were nonsignificant: unitization, $F(1,52)<1$, $p>.05$; age x test: $F(1,52)=1.19$, $p>.05$; age x unitization: $F(1,52)=1.06$, $p>.05$; test x unitization: $F(1,52)<1$, $p>.05$; age x test x unitization: $F(1,52)=1.98$, $p>.05$ (see Figure 5b).

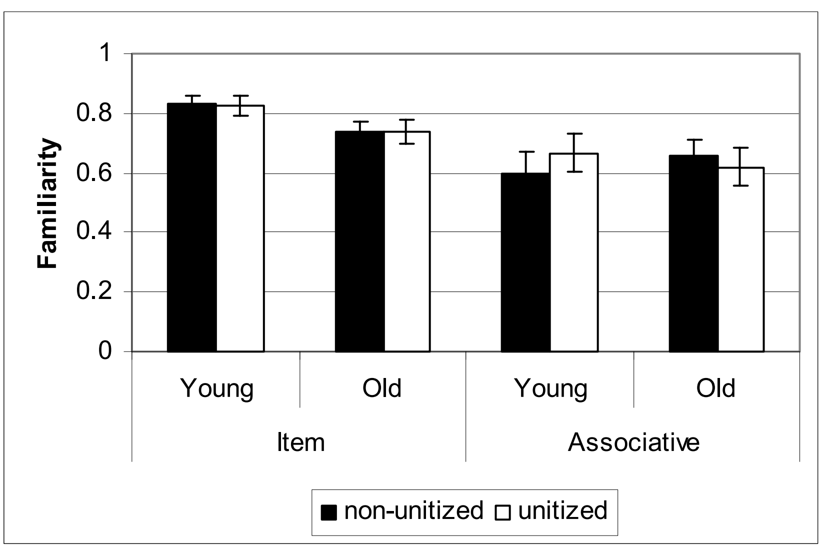
Figure 5.

(A) Mean Frequency of Recollection Responses as a Function of Age, Test, and Unitization in Experiment 2, and (B) Mean Frequency of Familiarity Responses as a Function of Age, Test, and Unitization in Experiment 2 (Error Bars Represent Standard Errors Around The Mean)

(A)



(B)



Memory Performance for Remember Responses Only

Next, accuracy was calculated only for remember responses by taking the proportion correct of all remember responses made (see Appendix C, Table C4, for descriptive statistics). This was the dependent variable used in an ANOVA with age, test, and unitization (see Figure 6a). While the main effect of age did not reach significance, $F(1,41)=3.18$, $p>.05$, participants performed better in the item ($M=.94$, $SD=.08$) than the associative test ($M=.84$, $SD=.16$), $F(1,41)=18.01$, $p<.001$, and performed better for unitized ($M=.92$, $SD=.10$) than non-unitized stimuli ($M=.87$, $SD=.13$), $F(1,41)=17.37$, $p<.001$. There was no interaction of age and test, $F(1,41)=1.73$, $p>.05$, but there was an interaction of age and unitization, $F(1,41)=13.13$, $p=.001$, such that older adults showed increased performance in unitized ($M=.92$, $SD=.08$) compared to non-unitized conditions ($M=.81$, $SD=.13$), $t(23)=4.34$, $p<.001$; however, younger adults showed no effect of unitization ($M=.92$, $SD=.11$ for unitized and $M=.92$, $SD=.11$ for non-unitized), $t(26)=.28$, $p>.05$. The triple interaction was significant as well, $F(1,41)=7.51$, $p<.01$, showing that the interaction of test and unitization was significant within the performance of the old, $F(1,20)=15.00$, $p=.001$, but not the young, $F(1,21)=1.51$, $p>.05$. For older adults, benefits of unitization were limited to the associative test ($M=.67$, $SD=.22$ for non-unitized and $M=.90$, $SD=.11$ for unitized, $t(21)=5.33$, $p<.001$; in the item test, $t(22)=.55$, $p>.05$).

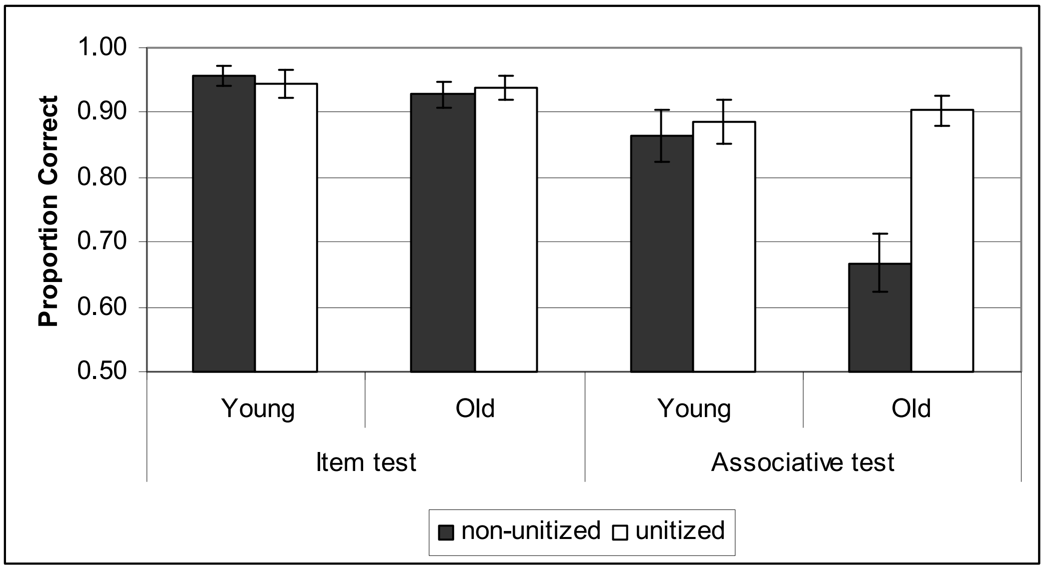
Memory Performance for Know Responses Only

Proportion correct was also calculated only for know responses (see Appendix C, Table C4, for descriptive statistics). In a 2(age) x 2(test) x 2(unitization) ANOVA on accuracy, the only significant effect was of test, $F(1,39)=41.03$, $p<.001$. Specifically, performance in the item test (*M*=.80, *SD*=.11) was higher than that of the associative test (*M*=.63, *SD*=.21). No other effects reached significance: age, $F(1,39)<1$, $p>.05$; unitization, $F(1,39)<1$, $p>.05$; age x test, $F(1,39)<1$, $p>.05$; age x unitization, $F(1,39)<1$, $p>.05$; age x test x unitization, $F(1,39)<1$, $p>.05$ (see Figure 6b).

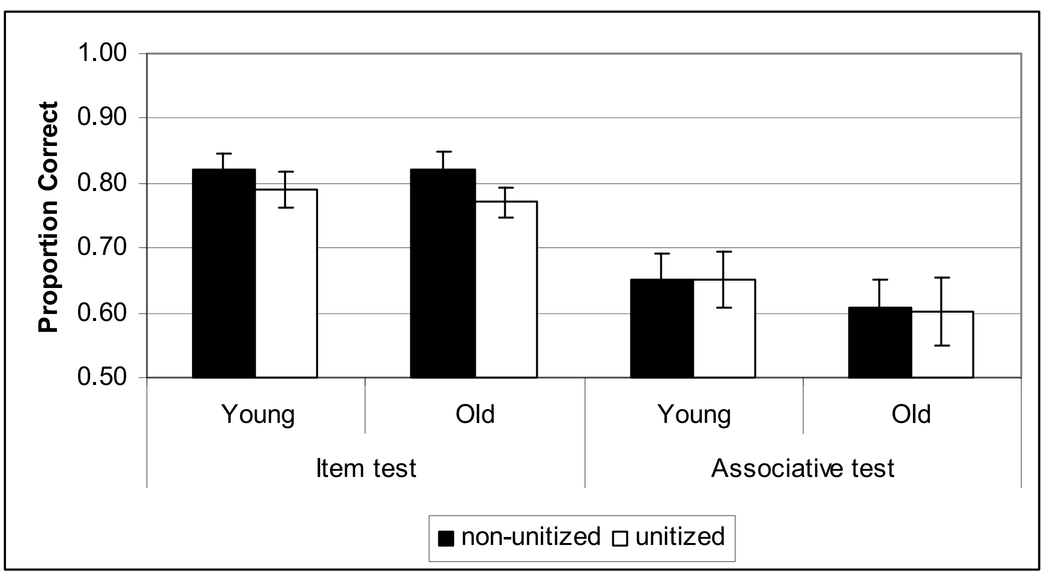
Figure 6.

(A) Mean Proportion Correct for Remember Responses as a Function of Age, Test, and Unitization in Experiment 2, and (B) Mean Proportion Correct for Know Responses as a Function of Age, Test, and Unitization in Experiment 2 (Error Bars Represent Standard Errors Around The Mean)

(A)



(B)



Discussion

Experiment 2 attempted to replicate the patterns observed in Experiment 1 while adding information about the contributions of familiarity and recollection. Surprisingly, an associative deficit was not seen here for older adults. One possibility is the fact that the older adults in the sample had, on average, 2.5 more years of education than the younger adults. Thus, the older adults may have been using more complex strategies than their younger counterparts. To test this notion, 13 older participants who had each completed more than 15 years of education were omitted from the analysis in order to more closely match the older sample with the level of younger adults ($t(39)=.77$, $p>.05$); however, the age x test interaction was still nonsignificant, $F(1,39)<1$, $p>.05$. A second consideration relates to the fact that participants had difficulty responding to each stimulus within the time frame. When the proportions of hits and false alarms were calculated, these missed responses were omitted, which could have inflated older adults' associative memory scores. If this were the case, an associative deficit should be observed when the missed responses are included in the calculations of memory performance, but when those scores were used in a 2(age) x 2(test) x 2(unitization) ANOVA, there was no significant interaction of age and test, $F(1,52)<1$, $p>.05$.

The third, and likeliest, explanation is that the act of giving remember/know responses affected participants' memory performance (note that this was the only methodological distinction between Experiments 1 and 2). Similar findings have been observed in a separate experiment conducted in the same laboratory (Kilb & Naveh-Benjamin, 2008), showing that when participants gave remember/know responses, the associative deficit of older adults was largely eliminated relative to a condition without remember/know responses. One possibility for this "remember/know effect" is that providing these responses encourages the participant to think more critically about the test probe rather than casually responding yes or no. That is, participants may realize that having a recollection is more effective than relying on familiarity (particularly in the associative test); consequently, they may put more effort into remembering the context during retrieval. On a related note, their knowledge about the usefulness of recollection could influence how they try to learn the information during encoding. While the mechanism behind the remember/know effect is unclear, further investigation is currently being carried out.

Turning now to the manipulation of unitization, the results were again somewhat inconsistent with findings from Experiment 1. While there was a slight advantage of unitization for the older adults in the associative test, younger adults actually showed impairment in the item test for unitized words. This particular finding is not necessarily inconsistent with the hypothesis. If unitization sufficiently fuses two items together so that they are perceived as only one unit, then one might expect items from unitized pairs to be less recognized than items from non-unitized pairs when presented in isolation. Thus, this deficit in item memory should be related to a benefit in associative memory for unitized stimuli. To investigate this potential tradeoff, separate estimates of the unitization effect on item memory (i.e., unitized item test performance minus non-unitized item test performance) and the corresponding effect on associative memory were calculated for each participant. As seen in Experiment 1, there was no correlation between the two unitization effects, $r(52)=.07$, $p>.05$, even when done separately for young, $r(26)=-.01$, $p>.05$, and old, $r(24)=-.01$, $p>.05$.

The frequency estimates of recollection and familiarity were consistent with the findings of Hockley & Consoli (1999), showing increased use of recollection for the associative test compared to the item test in younger adults. This supports the notion that associative memory relies more on recollective experience than item memory because one must remember the context in which a specific word appeared. Older adults had lower estimates of recollection than young in the item test, which is consistent with the findings of Jennings and Jacoby (1993, 1997), though there was no age difference in recollection in the associative test.

The focal predictions were to determine whether unitization is driven by familiarity or recollection, and one way of addressing this question is to look at frequency estimations of the two. Results show a significant main effect of unitization, indicating that participants were less likely to experience a recollection for unitized compared to non-unitized stimuli, which is in line with the notion that the unitization effects are driven by familiarity. However, unitization did not change the estimates of familiarity. These results provide partial support that familiarity contributes to unitization effects.

The finding that more remember responses were made for non-unitized than unitized stimuli could be due to increased distinctiveness. That is, presenting a pair in two colors makes each word more distinct, and thus, more likely to be recollected than items in unitized pairs. This possibility is consistent with the findings of Reder and her colleagues (Reder, Donavos, & Erickson, 2002), showing that lists of words presented in a distinctive font were associated with more remember responses than those in a less distinctive font. While this view can explain increased remember responses in the item test for non-unitized than non-unitized words, it may not be able to account for increased remember responses to non-unitized pairs in the associative test.

A second method for examining the reliance on familiarity and recollection is to look at accuracy separately for remember and know responses. When examining only the memory performance within the remember responses, the results are striking. First, there is clear evidence of an associative deficit for older adults in the non-unitized condition, and second, this associative deficit disappears in unitized conditions (see Figure 6a). One reason that younger adults did not also benefit from unitization in their recollection-based responses has to do with ceiling effects. Their accuracy in the associative test is at about 90% for both non-unitized and unitized pairs, so there was little room for unitized scores to improve from non-unitized conditions. Unfortunately, the nature of the remember responses makes it difficult to bring these scores off of the ceiling. Note that the score is tabulated as the number of correct remember responses divided by the total remember responses made. If a participant designated a stimulus with a remember response, it means that she/he could recollect something about the context in which it was originally presented. Provided that the accessible contextual information is correct, it is unlikely that many remember responses will be wrong. Interestingly, older adults' recollection-based memory accuracy is substantially lower than younger adults' for non-unitized pairs in the associative test, showing that even though older adults are giving remember responses, their recollections are not always as useful as that of younger adults. No effects of unitization could be observed within the familiarity-based responses (see Figure 6b).

In summary, the findings of Experiment 2 suggest that benefits of unitization occur because of the contribution of recollection rather than familiarity. However, the competing alternative should not be completely dismissed yet because (1) there is evidence that participants relied less on recollection in unitized than non-unitized conditions, and (2) the fact that older adults did not show an associative deficit in overall memory performance indicates that there may be some methodological limitations of using the remember/know paradigm in examining the current research question.

EXPERIMENT 3:

Manipulating Pair Repetition in Order to Increase Associative Memory

Another possible way to improve older adults' associative memory is to increase the number of presentations for each pair. This method was explored by Light and her colleagues (Light et al., 2004; Light, Chung, Pendergrass, & Van Ocker, 2006) who repeated word pairs within a given study list and gave associative tests consisting of intact pairs, recombined pairs, and pairs of unstudied words. Light et al. (2004) found that repetition increased hit rates for intact pairs in both younger and older adults, but it also impeded memory in older adults by increasing their false alarm rate to recombined pairs, which did not occur in younger adults under unconstrained time conditions. The researchers' overall conclusion, then, was that repetition is not an effective way to boost the associative memory of older adults. At the same time, it is clear that the improvement in older adults' hit rates is much larger than their increase in false alarms. If one calculates an overall assessment of associative memory by taking the proportion hits to intact pairs minus the proportion false alarms to recombined pairs for this dataset, the older adults' score doubles with repetition (.15 vs. .32 in Experiment 1, and .28 vs. .52 in Experiment 2), indicating that repetition could potentially be very useful for improving associative memory in older adults. Moreover, the pattern of performance shown by older adults did not change when a response deadline was used, suggesting that repetition can improve memory even in the absence of recollection.

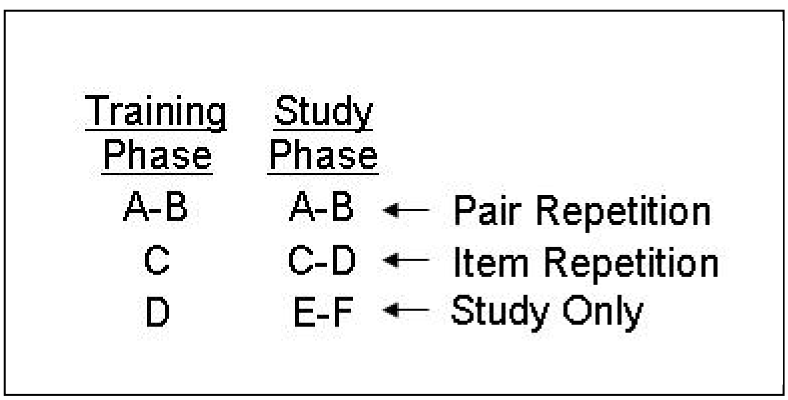
Since repetition of a pair also involves repetition of its constituent items, it can be difficult to tease apart the separate effects of item and pair repetition. This distinction is crucial because item repetition should lead to false alarms to recombined pairs, whereas pair repetition should strengthen the association between the two items. Because Light et al. (2004) only repeated pairs, both item and pair repetition increased, and the degree to which participants were influenced by each is unclear.

Earles & Kersten (2008) increased item repetition independently of pair repetition by presenting younger adults with video clips of person-action pairs. Some video clips were seen several times during study, increasing both item and pair repetition; however, others were recombined such that a given person could be seen performing three different actions in the study list, increasing item repetition without affecting pair repetition. When each type of pair was recombined at test, more false alarms were seen with item repetition than pair repetition, suggesting that repetition of pairs can, to some extent, protect against conjunction errors.

In the current experiment, item and pair repetition were examined by presenting either one singleton (item repetition condition) or one pair (pair repetition condition) at a time during a single training phase in preparation for later trials. The participant's task during each of the four subsequent trials was to learn a study list of picture pairs, each followed by corresponding item and associative recognition tests. These study lists included pictures from the item repetition condition, pairs from the pair repetition condition, and study only pairs (those that were never presented in the training phase; see Figure 7). A similar procedure used by Naveh-Benjamin, Cowan, Kilb, & Saults (2007) determined that pair repetition during such a training phase shown prior to studying word pairs increased cued recall (i.e., an associative test) for both younger and older adults. Importantly, participants' instructions at test in the current task are to base their memorial judgments solely on the study list for the given trial as opposed to the earlier training phase.

Figure 7.

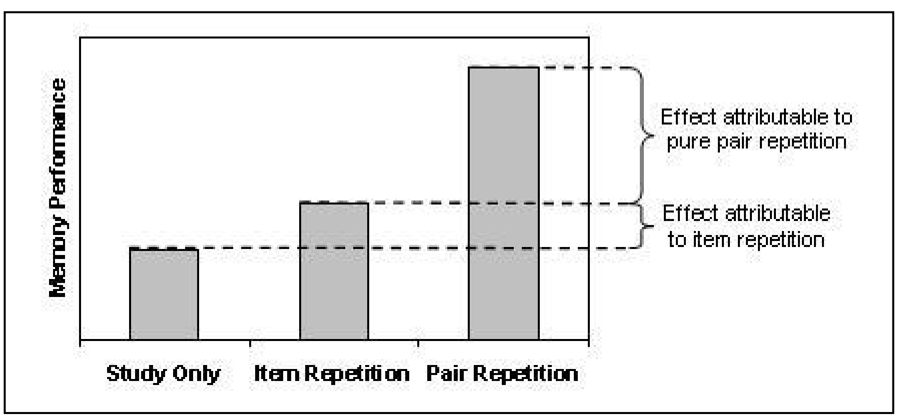
Schematic Diagram of the Training and Study Phases in Experiments 3 and 4.



The advantage of the method used here is three-fold: (1) Because participants should only be trying to consciously retrieve information from the study list during test, any effects of previously presented pictures during the training phase are assumed to be mediated by familiarity (presumed to be an automatic process) and not by recollection, and (2) the amount of information presented during a given time period was held constant for the study only, item repetition, and pair repetition conditions during the study phase. This was not the case at training because participants were given the same amount of time to learn either an item in the item repetition condition or a pair in the pair repetition condition, meaning that they had half as much time to learn each individual item in pair repetition than item repetition. Most importantly, (3) a relatively pure measure of pair repetition can be obtained after controlling for item repetition. Specifically, item repetition can be assessed as any difference in performance between item repetition and study only conditions, and pure pair repetition can be assessed as any difference in performance in pair repetition and item repetition conditions (see Figure 8).

Figure 8.

Schematic Diagram of Calculations for Item and Pure Pair Repetition in Experiments 3 and 4.



If responding is based solely on recollection, there should be no effect of item or pair repetition at test because participants' ability to consciously retrieve information directly from the study list would override any influence of familiarity from the prior training phase. However, if responding is based at all on familiarity, an interaction is expected. Specifically, item repetition but not pure pair repetition should increase performance in item tests, and pure pair repetition but not item repetition should increase performance in the associative tests. In the case of the item tests, one would not expect an effect of pure pair repetition because there is no a priori reason that presenting two words together would increase item memory more than presenting them singly. In fact, the contextual discordance between presenting the items in pairs during learning and as singletons at test could potentially impair memory performance (e.g., see Graf & Ryan, 1990). For the associative tests, item repetition is predicted to weaken performance since it would create an inclination to recognize highly familiar words from training that have been recombined to form new pairings.

Regarding age differences, Light et al. (2004) found that older adults did not benefit from pair repetition as much as younger adults. The claim of the current experiment is that the reason for this shortcoming is that older adults (but not younger adults) are impaired by item repetition, which is inherent to pair repetition. It is predicted that when using the purer measure of pair repetition (i.e., pair repetition minus item repetition), the memory performance of the old should increase at least as much as the younger adults.

As an additional extension of previous work, Experiments 3 and 4 included pictorial stimuli instead of word pairs. Findings have shown that older adults display an associative deficit for unrelated picture pairs compared to younger adults (Naveh-Benjamin et al., 2003), and it was expected that an associative deficit would be observed here in the study only condition. The stimuli consisted of faces paired with different scenes, which is similar to the common real-life situation of trying to remember where a particular person was met, making the current findings more ecologically valid than those of Experiments 1 and 2.

Method

Participants

Twenty-four younger and 24 older adults were taken from the same pools as Experiments 1 and 2. The age groups were matched in gender (7 males and 17 females) and did not differ in years of education, $t(46)=1.63$, $p>.05$ (see Table 1 for demographic information).

Design

This experiment is a 2 (age: young vs. old) x 2 (test: face, scene, associative) x 3 (repetition type: study only, item repetition, pair repetition) design. Additionally, number of repetitions (1 or 3) was manipulated within item and pair repetition conditions. Test, repetition type, and number of repetitions were manipulated within lists.

Materials

Four study lists were used. Each study list included 42 unrelated pairs (14 for each repetition type – study only, item repetition, pair repetition) composed of faces and outdoor scenes. Half of the faces were female, and half were male; within each gender, half of the faces were younger adults, and half were older adults. Scenes were taken from Luo, Sakuta, & Craik (2008)(see Appendix A, Section 3, for sample stimuli). Face tests each contained 12 target and 12 distractor faces, scene tests each contained 12 old and 12 new scenes, and associative tests contained 15 intact and 15 recombined pairs. One-third of each of the targets was taken from each repetition type (i.e., study only, item repetition, pair repetition). The number of repetitions was manipulated within repetition type such that half were shown once at training (1x condition), and half were shown three times at training (3x condition) in a spaced manner. Since the distractors were not shown in either the learning or study phases, they were arbitrarily assigned to the various repetition conditions such that they appeared temporally close to their corresponding targets. For example, the distractors allocated to the 1x condition were intermixed with the targets that were actually presented in the 1x condition.

For training, 168 unique events were shown, all of which were later presented in the study lists. For the 112 singletons, 16 later appeared as targets in the face tests, 16 later appeared as targets in the scene test, 40 later appeared as intact pairs, and 40 later appeared as recombined pairs. For the remaining 56 pairs, 16 later appeared as targets in the item tests (i.e., 16 faces and 16 scenes), 20 later appeared as intact pairs, and 20 later appeared as recombined pairs. Half of the total unique pairs were in the 1x condition, and the remaining half were in the 3x condition for a grand total of 336 events. All stimulus types were intermixed and divided into 3 sets of 112 for presentation during training.

The order of the four study lists was counterbalanced for each participant along with the order of the three recognition tests (between-subjects). Also, the allocation of stimuli to the various repetition conditions was rotated across participants so that a given picture appeared equally often in the study only, item repetition, and pair repetition conditions. Within the repetition conditions, a given stimulus was used equally in the 1x and 3x conditions. Finally, each picture appeared equally often as an item target, an intact pair, and a recombined pair at test.

Procedure

Participants began with the training phase. This phase consisted of 3 sets, and their only instructions were to learn as much information as they could. Each event (consisting of a single item or a pair) was presented for 4 seconds at a time. Between blocks, they were given a 2-minute filler task. After the training phase, they were given further instructions about the four trials to come. Specifically, they were told that they would learn study lists, each followed by a face, scene, and associative test (the nature of which was described). Then they were given a practice trial containing a short study list and the three test types. During the study phase, picture pairs were presented once every 4 seconds, and they were instructed to learn both the items and their pairings. After a 60-second filler task, participants received the three corresponding tests (with instructions to compare the test stimuli against the most recent study list presented). Required test responses were the same as in Experiment 1, but participants were given unlimited time to make each response.

Results

A 2(age) x 3(test) ANOVA for the study only conditions was used to establish that an associative deficit was observed for the current sample (see the left-most portion of Figure 9). Main effects revealed that younger adults (M=.58, SD=.20) performed slightly better than older adults (M=.47, SD=.19), $F(1,46)$=3.61, p=.06, and performance varied among the three recognition tests, $F(2,92)$=48.41, p<.001. Follow-up tests showed that there was a significant difference between the scene test (M=.66, SD=.21) and the associative test ($M=.34$, $SD=.28$), $t(47)=10.13$, $p<.001$. Furthermore, the scene test elicited higher performance than the face test ($M=.58$, $SD=.26$), $t(47)=2.42$, $p<.05$, and performance on the face test, in turn, was better than on the associative test, $t(47)=5.33$, $p<.001$. Finally, there was an interaction of age and test, $F(2,92)=12.26$, $p<.001$, such that younger adults ($M=.49$, $SD=.26$) outperformed the old ($M=.20$, $SD=.21$) in the associative test, $t(46)=4.35$, $p<.001$, but there were no age differences in the face test ($M=.58$, $SD=.23$ for young and $M=.57$, $SD=.29$ for old, $t(46)=.08$, $p>.05$) or the scene test ($M=.67$, $SD=.21$ for young and $M=.65$, $SD=.21$ for old, $t(46)=.30$, $p>.05$). Additional 2-way ANOVAs were performed separately for the hits and false alarms.

Using only the proportion of hits, there was no longer a main effect of age ($M=.69$, $SD=.18$ for young and $M=.67$, $SD=.18$ for old), $F(1,46)<1$, $p>.05$, but there were still different patterns of performance among the three tests, $F(2,92)=6.59$, $p<.01$ (see left-most portion of Figure 10). Specifically, the scenes ($M=.73$, $SD=.18$) were recognized better than both the faces ($M=.67$, $SD=.23$), $t(47)=2.25$, $p<.05$, and the associations ($M=.64$, $SD=.21$), $t(47)=4.23$, $p<.001$, but there was no difference between the faces and the associations, $t(47)=1.05$, $p>.05$. There was no interaction between age and test, $F(2,92)=2.29$, $p>.05$.

Turning now to the proportion of false alarms, another ANOVA was performed on age and test (see left-most portion of Figure 11). Main effects were seen for age, showing that younger adults ($M=.11$, $SD=.07$) had fewer false alarms than older adults ($M=.19$, $SD=.09$), $F(1,46)=12.18$, $p=.001$, and that there were different false alarm rates for the different tests, $F(2,92)=73.47$, $p<.001$. False alarms were more abundant in the associative test ($M=.30$, $SD=.18$) than both the scene test ($M=.07$, $SD=.08$), $t(47)=9.23$, *p*<.001, and the face test (*M*=.09, *SD*=.11), *t*(47)=7.85, *p*<.001, which did not differ from each other, *t*(47)=1.40, *p*>.05. Most importantly, the interaction of age and test was significant, *F*(2,92)=12.66, *p*<.001. As seen before in the initial analysis using hits minus false alarms, there were no age differences in either the face test (*M*=.07, *SD*=.08 for young and *M*=.11, *SD*=.14 for old), *t*(46)=1.16, *p*>.05, or the scene test (*M*=.07, *SD*=.07 for young and *M*=.07, *SD*=.09 for old), *t*(46)=.06, *p*>.05; however, older adults (*M*=.40, *SD*=.18) showed significantly more false alarms than the young (*M*=.20, *SD*=.11) in the associative test, *t*(46)=4.77, *p*<.001.

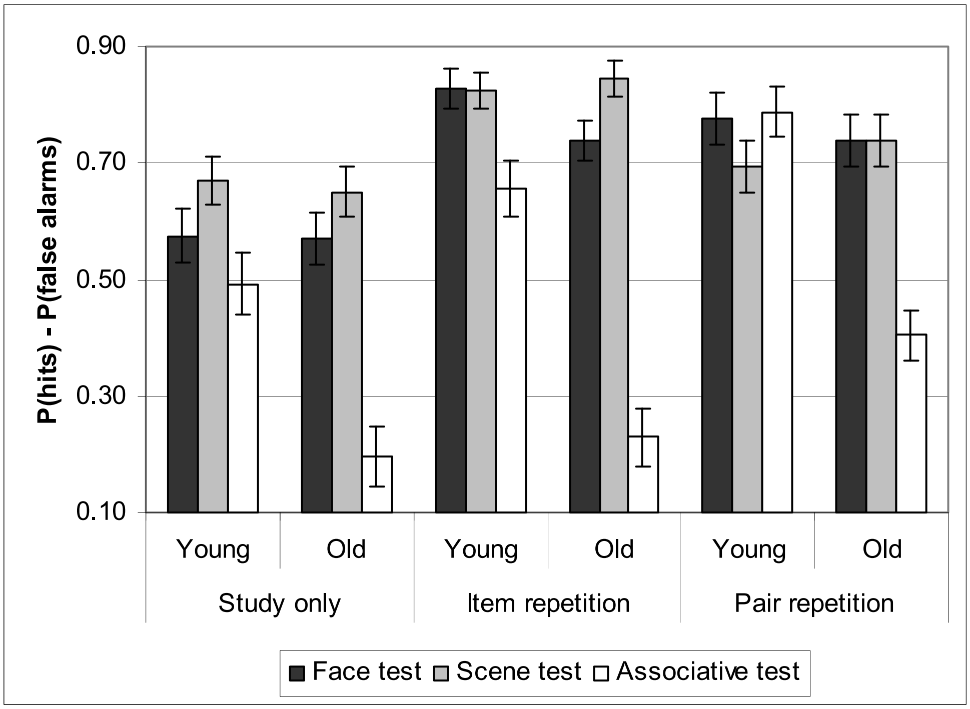
Repetition

For the sake of brevity, discussion of the repetition results is limited to the study only versus 3x conditions as this provided the strongest manipulation of repetition. For ANOVA tables showing all *F*-values for the observed effects as well as descriptive statistics, please see Appendix D. When examining the effect of repetition in the 3x condition, a 2 (age) x 3 (test) x 3 (repetition type: study only, item repetition, pair repetition) ANOVA was performed on proportion hits minus proportion false alarms (see Figure 9; see also Appendix D, Table D2 for *F*-values), and all main effects were significant. The younger adults (*M*=.70, *SD*=.14) outperformed the older adults (*M*=.57, *SD*=.16), and there were differences among the test types and among the repetition types. The test effect showed that associative performance (*M*=.46, *SD*=.28) was lower than performance in both the face test (*M*=.71, *SD*=.18), *t*(47)=6.44, *p*<.001, and the scene test (*M*=.74, *SD*=.15), *t*(47)=7.42, *p*<.001, but the scores in the face and scene tests did not differ, *t*(47)=1.43, *p*>.05. Within repetition, it was found that the study only condition (*M*=.53, *SD*=.20) elicited lower performance than both item repetition (*M*=.69, *SD*=.18),

$t(47)=7.26$, $p<.001$, and pair repetition ($M=.69$, $SD=.18$), $t(47)=8.45$, $p<.001$, while the two repetition types were not statistically different, $t(47)=.14$, $p>.05$. There was an interaction between age and test, revealing that older adults ($M=.28$, $SD=.23$) were impaired in the associative test relative to younger adults ($M=.65$, $SD=.19$), $t(46)=5.95$, $p<.001$, despite no age differences in either the face test ($M=.73$, $SD=.16$ for young and $M=.69$, $SD=.21$ for old), $t(46)=.81$, $p>.05$, or the scene test ($M=.73$, $SD=.15$ for young and $M=.75$, $SD=.14$ for old), $t(46)=.38$, $p>.05$. While the interaction of age and repetition and the triple interaction were nonsignificant, there was an interaction between test and repetition. In the face test, both item ($M=.79$, $SD=.22$), $t(47)=5.85$, $p<.001$, and pair repetition ($M=.76$, $SD=.22$), $t(47)=5.34$, $p<.001$, yielded higher performance than study only ($M=.58$, $SD=.26$), but the two repetition types did not differ, $t(47)=.73$, $p>.05$. In the scene test, the item repetition condition ($M=.84$, $SD=.17$) elicited better performance than pair repetition ($M=.72$, $SD=.19$), $t(47)=3.67$, $p=.001$, and pair repetition elicited better performance than study only ($M=.66$, $SD=.21$), $t(47)=2.34$, $p<.05$ (for item repetition vs. study, $t(47)=5.72$, $p<.001$). In the associative test, pair repetition ($M=.60$, $SD=.34$) produced higher scores than item repetition ($M=.44$, $SD=.34$), $t(47)=3.55$, $p=.001$, which was, in turn, higher than study only ($M=.34$, $SD=.28$), $t(47)=2.78$, $p<.01$ (for pair repetition vs. study only: $t(47)=6.65$, $p<.001$).

Figure 9.

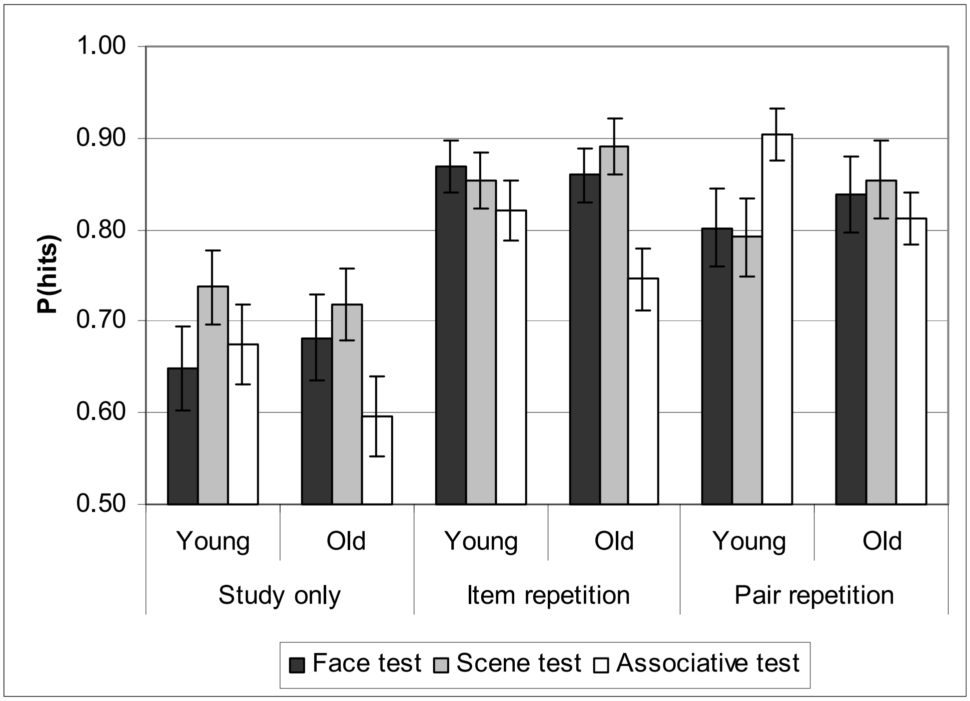
Mean of Proportion Hits Minus Proportion False Alarms as a Function of Age, Test, and Repetition in the Study Only and 3x Conditions in Experiment 3 (Error Bars Represent Standard Errors Around the Mean)



Using the same protocol as above, the data were analyzed separately using proportion hits then again using proportion false alarms. When only hits were measured (see Appendix D, Table D3, for *F*-values), there was no longer a difference between young (M=.79, SD=.14) and old (M=.78, SD=.14), but there were still effects of test and repetition (see Figure 10). Results show that scenes (M=.81, SD=.14) were recognized better than associations (M=.76, SD=.16), $t(47)=2.69$, $p<.05$, but there was no difference between scenes and faces (M=.79, SD=.17), $t(47)=1.62$, $p>.05$, or faces and associations, $t(47)=1.27$, $p>.05$. Also, the study only (M=.68, SD=.18) condition was less recognized than both the item repetition (*M*=.84, *SD*=.14), $t(47)=8.94$, $p<.001$, and associative repetition (*M*=.84, *SD*=.14) conditions, $t(47)=10.20$, $p<.001$, though the repetition conditions did not differ, $t(47)=.37$, $p>.05$. The age x test interaction was also significant such that no age differences were seen in either the face (*M*=.78, *SD*=.16 for young and *M*=.79, *SD*=.18 for old), $t(46)=.40$, $p>.05$, or scene tests (*M*=.80, *SD*=.15 for young and *M*=.82, *SD*=.12 for old), $t(46)=.67$, $p>.05$, but older adults (*M*=.72, *SD*=.17) recognized somewhat fewer associations than younger adults (*M*=.80, *SD*=.14), $t(46)=1.84$, $p=.07$. There was also an interaction of test and repetition. In both item tests, item repetition (*M*=.87, *SD*=.16 for faces and *M*=.87, *SD*=.15 for scenes) was higher than pair repetition (*M*=.82, *SD*=.19 for faces, $t(47)=2.01$, $p=.05$, and *M*=.82, *SD*=.18 for scenes, $t(47)=1.70$, $p=.10$), which was higher than study only conditions (*M*=.67, *SD*=.23 for faces, $t(47)=6.01$, $p<.001$; *M*=.73, *SD*=.18 for scenes, $t(47)=4.20$, $p<.001$; item repetition vs. study only was $t(47)=7.53$, $p<=.001$ and $t(47)=5.70$, $p<.001$ for face and scene tests, respectively). However, in the associative test, pair repetition (*M*=.86, *SD*=.17) was higher than item repetition (*M*=.78, *SD*=.21), $t(47)=2.38$, $p<.05$, which was higher than study only (*M*=.64, *SD*=.21) conditions, $t(47)=4.67$, $p<.001$ (for pair repetition vs. study only, $t(47)=9.00$, $p<.001$. The interaction of age and repetition and the triple interaction were not significant.

Figure 10.

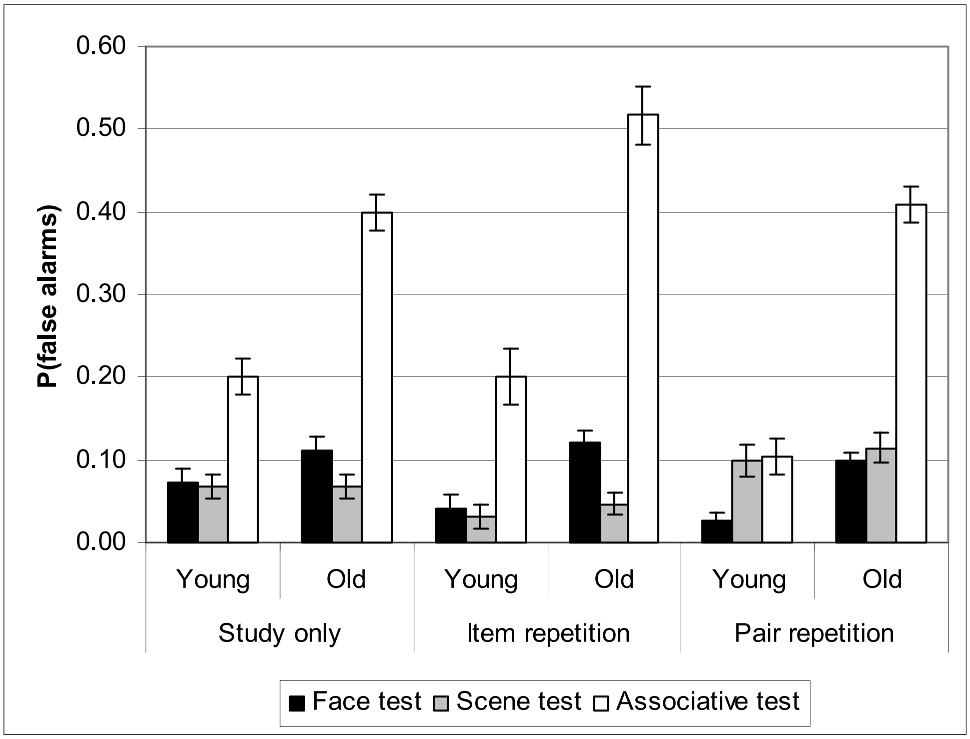
Mean of Proportion Hits as a Function of Age, Test, and Repetition in the Study Only and 3x Conditions in Experiment 3 (Error Bars Represent Standard Errors Around the Mean)



Next, the same analyses were repeated with proportion false alarms (see Appendix D, Table D4, for *F*-values), and the age and test effects were significant (see Figure 11). Older adults (*M*=.21, *SD*=.09) had more false alarms than younger adults (*M*=.09, *SD*=.05), and the associative test (*M*=.30, *SD*=.21) produced more false alarms than either the face (*M*=.08, *SD*=.08), *t*(47)=8.35, *p*<.001, or scene tests (*M*=.07, *SD*=.06), *t*(47)=8.05, *p*<.001 (faces and scenes did not differ, *t*(47)=.59, *p*>.05). Furthermore, the interaction of age and test was significant, reflecting that younger adults had fewer false alarms than older adults in both the face (*M*=.05, *SD*=.05 for young and *M*=.11, *SD*=.09 for old), *t*(46)=3.07, *p*<.01, and associative tests (*M*=.17, *SD*=.08 for young and *M*=.44, *SD*=.21 for old), *t*(46)=6.08, *p*<.001, but not in the scene tests (*M*=.07, *SD*=.06 for young and *M*=.08, *SD*=.07 for old), *t*(46)=.60, *p*>.05. The age x repetition interaction was significant as well, showing that younger adults had significantly fewer false alarms in pair repetition (*M*=.08, *SD*=.06) compared to the study only (*M*=.11, *SD*=.07) condition, *t*(23)=2.74, *p*=.01 (there was no difference between study only and item repetition (*M*=.09, *SD*=.06), *t*(23)=1.65, *p*>.05, or item repetition and pair repetition, *t*(23)=.82, *p*>.05), while the only significant result for older adults was more false alarms in the item repetition (*M*=.23, *SD*=.10) than study only (*M*=.19, *SD*=.09) condition, *t*(23)=2.54, *p*<.05 (there was no difference between study only and pair repetition (*M*=.21, *SD*=.11), *t*(23)=.77, *p*>.05, or item repetition and pair repetition, *t*(23)=1.11, *p*>.05). The interaction of test and repetition was significant, too. In the face test, there were no differences among the repetition conditions (study only: *M*=.09, *SD*=.11; item repetition: *M*=.08, *SD*=.12; pair repetition: *M*=.06, *SD*=.10; study only vs. item repetition: *t*(47)=.58, *p*>.05; study only vs. pair repetition: *t*(47)=1.50, *p*>.05; item vs. pair repetition: *t*(47)=.88, *p*>.05). In the scene test, there were more false alarms in the pair repetition (*M*=.11, *SD*=.09) than study only (*M*=.07, *SD*=.08), *t*(47)=3.35, *p*<.01, which was higher than item repetition (*M*=.04, *SD*=.09), *t*(47)=2.20, *p*<.05 (for pair repetition vs. item repetition, *t*(47)=4.48, *p*<.001). In the associative test, there were more false alarms for item repetition (*M*=.36, *SD*=.27) compared to both study only (*M*=.30, *SD*=.18), *t*(47)=2.09, *p*<.05, and pair repetition (*M*=.26, *SD*=.25), *t*(47)=3.37, *p*<.01, though study only and pair repetition did not differ, *t*(47)=1.58, *p*>.05. The other analyses, including the effect of repetition and the triple interaction were nonsignificant.

Figure 11.

Mean of Proportion False Alarms as a Function of Age, Test, and Repetition in the Study Only and 3x Conditions in Experiment 3 (Error Bars Represent Standard Errors Around the Mean)



Discussion

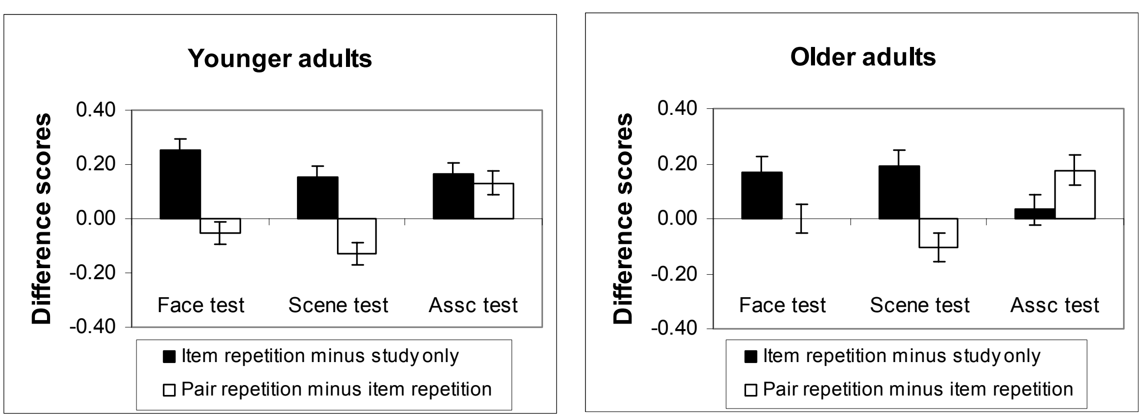
The findings of Experiment 3 show a clear associative deficit for the older adults. In the control condition (study only) in which there was no repetition, older adults were impaired relative to younger adults in the associative test yet there were no age differences in either item test. Furthermore, older adults' impairment was seen primarily within the false alarm scores rather than the hits, suggesting that their binding deficit is mostly due to the erroneous recognition of recombined lures despite relatively spared ability in recognizing previously shown pairings. This pattern is consistent with previous findings (e.g., Naveh-Benjamin, 2000; Kilb & Naveh-Benjamin, 2007) and supports the notion that older adults' deficit stems to a degree from an overreliance on the familiarity of individual items when judging the pairings. The focus of Experiment 3 was in determining whether pure pair repetition can increase the familiarity of associations such that older adults are less likely to false alarm to recombined pairs.

Overall, repetition increased memory accuracy. Analyses show that repeated information was recognized more often than information shown once, though the type of repetition interacted with the different recognition tests, as expected. It was found that hits in the item test were higher in the item than pair repetition condition, whereas hits in the associative test were higher in the pair than item repetition condition. Because distractors in the item tests never appeared at training and were therefore arbitrarily assigned to the various repetition conditions, the patterns of false alarms for the face and scene tests are of little interest and will not be discussed. However, the associative test revealed fewer false alarms in the pair repetition condition compared to item repetition. That is, the highest associative performance was seen in the pair repetition condition, which was a function of both increased hits and decreased false alarms, relative to item repetition. The fact that there were observable effects of repetition from the training phase supports the notion that participants were not relying wholly on recollection. Instead, increased familiarity for previously seen stimuli caused participants to recognize more events at test even though they were instructed to ignore the earlier training phase altogether.

In order to more clearly observe the age differences after calculating the purer measure of pair repetition, see Figure 12. As mentioned previously, pure pair repetition can be measured as performance in pair repetition minus item repetition conditions, whereas the effect of item repetition is simply the difference between item repetition and study only conditions. Upon inspection of the figure, it is evident that younger and older adults display nearly identical patterns of performance. Specifically, both age groups show positive effects of item repetition in the item tests and positive effects of pure pair repetition in the associative test. Furthermore, these effects are about the same size for the two groups. In other words, younger adults no longer show larger effects of pair repetition than older adults when the purer measure is used, which is consistent with evidence that younger and older adults do not differ in their ability to rely on familiarity (Jennings & Jacoby, 1993, 1997).

Figure 12.

Mean Difference Scores Reflecting the Effect of Item Repetition (Performance in Item Repetition Minus Study Only Conditions) and the Effect of Pure Pair Repetition (Performance in Pair Repetition Minus Item Repetition Conditions) as a Function of Age and Test for the 3x Condition in Experiment 3 (Error Bars Represent Standard Errors Around the Mean)



The only visible age difference is in the effect of item repetition on the associative test such that young show increases from item repetition, whereas the older adults do not. While this was not part of the predictions, it could be due to positive transfer between the learning and study phases of the experiment (see also Barnes & Underwood, 1959; Keppel, 1968). In other words, it is possible that originally seeing the items as singletons in the learning phase facilitated the binding between the pictures in the later study phase. It should be noted here that both age groups displayed more hits in item repetition conditions than study only in the associative test; however, the old also showed more false alarms, whereas the young did not. This suggests that any increases to memory performance that the older adults experienced due to earlier presentation were counteracted by their inability to reject the new pairings composed of formerly presented (i.e., familiar) items.

Another unexpected finding is the disadvantage of pure pair repetition in the scene test shown in both age groups. That is, both young and old demonstrated more difficulty in the scene test if the scenes in question were previously shown during the training phase in pairs as opposed to singletons. Although this pattern might be explained by the contextual disparity between presentation and test, it was not seen in the face test. In addition, part of the effect is due to increased false alarms in the pair repetition condition when allocation of distractors to the various repetition conditions was completely arbitrary (i.e., no item test distractors were repeated because they were only shown during test).

One of the purposes of Experiment 4 was to determine whether or not these effects are replicable, including the latter two unexpected findings stated above.

EXPERIMENT 4:

Testing the Contribution of Familiarity and Recollection to the Effects of Pair Repetition

Although efforts were made to ensure that any effect of repetition is driven by familiarity in Experiment 3, it remained possible that the pair repetition effects for both young and old observed in Experiment 3 could also be associated with increased recollection. That is, pair repetition could increase the likelihood that participants recollected a specific pair from the training phase rather than from the study phase. For example, suppose that the pairs A-B and C-D are each shown three times during training and one additional time in a study list. If A-C later appears in the associative test, one could reject it because of a recollection that A was originally presented with B (and/or that C was presented with D). In this situation, there are eight opportunities to use recollection (i.e., three times from the training phase and once from the study phase for A-B and the same for C-D).

The above explanation points to there being two different levels of recollection in this task. At the micro-level, contextual information is needed to remember the corresponding item that appeared with A. At the macro-level, contextual information is needed to remember whether the stimuli were presented at training (to be ignored at test) or at study (to be remembered at test). In other words, it is possible that participants can recollect an original pairing without knowing precisely when it appeared during the experiment. If so, the prediction is that increased associative memory performance for the pair repetition condition would be seen within measures of recollection. Therefore, it cannot be said with certainty that effects of repetition in Experiment 3 are completely driven by familiarity alone.

To rule out the possibility that pair repetition increases recollection, the current experiment extended the findings of Experiment 3 by including remember/know responses. If pure pair repetition increases memory via micro-level recollection, there should be higher estimates of recollection in pair repetition than item repetition, and increases in associative test performance from pair repetition should be seen within the remember responses. Alternatively, if pure pair repetition is supported by familiarity, then pair repetition should elicit more familiarity-based responses than item repetition conditions, and effects of repetition should be observed within the know responses.

Method

Participants

Twenty-six younger (ages 18-25) and 25 older adults (ages 67-82) were drawn from the same pools as Experiments 1-3. Younger and older adults did not differ in either gender, $t(49)=1.56$, $p>.05$, or in years of education, $t(49)=1.29$, $p>.05$ (see Table 1 for demographic information).

Design & Materials

These were the same as in Experiment 3.

Procedure

The procedure was identical to Experiment 3 with the exception that remember/know/guess responses were collected for each event presented at test. As in Experiment 3, participants were given unlimited time to make their initial yes/no response at test. The additional remember/know/guess responses followed the same guidelines as in Experiment 2. Specifically, if an initial “yes” response was given, they had unlimited time to respond with “context”, “familiar”, or “guess”.

Results

For all descriptive statistics, please see Appendix E, Table E1. First, the effects of age and test in the study only condition were analyzed in a 2 x 3 ANOVA on proportion hits minus proportion false alarms to confirm that an associative deficit could be observed for the older adults. It was found that younger adults (M=.62, SD=.17) outperformed older adults (M=.56; SD=.17), F(1,49)=7.88, p<.05. A significant effect of test, F(2,98)=42.54, p<.001, indicated that performance in the scene test (M=.63, SD=.20) was significantly higher than the face test (M=.55, SD=.21), t(50)=2.93, p<.01, which was significantly higher than the associative test (M=.38, SD=.21), t(50)=5.06, p<.001 (scene vs. associative: t(50)=9.88, p<.001). Importantly, the interaction of age and test was significant, F(2,98)=6.27, p<.01, showing a clear impairment for the older adults (M=.26, SD=.19) in the associative test compared to the young (M=.49, SD=.17), t(49)=4.71, p<.001, with no age differences in either the scene test (M=.58, SD=.19 for old and M=.68, SD=.20 for young), t(49)=1.79, p>.05, or the face test (M=.53, SD=.22 for old and M=.56, SD=.20 for young), t(49)=.59, p>.05 (see left-hand portion of Figure 13).

Next, the same 2 x 3 ANOVA was conducted using proportion hits (see Figure 14). This time, there were no longer main effects of age, F(1,49)<1, p>.05, or test, F(2,98)=1.48, p>.05; however, the interaction of age and test remained significant, F(2,98)=3.97, p<.05. Older adults showed impaired performance in the associative test (M=.26, SD=.19) compared to their own scores in both the face (M=.53, SD=.22;

$t(24)=6.49$, $p<.001$) and scene tests ($M=.58$, $SD=.19$; $t(24)=10.79$, $p<.001$), which did not differ from each other, $t(24)=1.24$, $p>.05$. Younger adults, on the other hand, showed increased performance for scenes ($M=.68$, $SD=.20$) relative to faces ($M=.56$, $SD=.20$), $t(25)=3.01$, $p<.01$, and to associations ($M=.49$, $SD=.17$), $t(25)=5.00$, $p<.001$ (faces vs. associations: $t(25)=1.63$, $p>.05$).

Finally, the analysis was performed on proportion false alarms (see Figure 15). Older adults had more false alarms ($M=.09$, $SD=.08$) compared to the young ($M=.04$, $SD=.05$), $F(1,49)=21.87$, $p<.001$, and there were differences among the three recognition tests, $F(2,98)=97.10$, $p<.001$. The most false alarms were made in the associative test ($M=.26$, $SD=.18$), followed by the face test ($M=.08$, $SD=.11$; associations vs. faces: $t(50)=8.55$, $p<.001$), which elicited more false alarms than the scene test ($M=.04$, $SD=.06$), $t(50)=2.92$, $p<.01$ (associations vs. scenes: $t(50)=9.59$, $p<.001$). The interaction of age and test was significant, $F(2,98)=20.10$, $p<.001$, reflecting age differences in the face ($M=.04$, $SD=.06$ for young and $M=.13$, $SD=.13$ for old), $t(49)=3.35$, $p<.01$, and associative tests ($M=.15$, $SD=.12$ for young and $M=.37$, $SD=.17$ for old), $t(49)=5.36$, $p<.001$, but not in the scene test ($M=.04$, $SD=.05$ for young and $M=.05$, $SD=.06$ for old), $t(49)=.64$, $p>.05$.

Repetition

As in Experiment 3, the discussion of the repetition results is focused on the study only versus 3x conditions. For more complete information regarding the *F*-values for all observed effects in both the 1x and 3x conditions, please see Appendix E. Using a 2(age) x 3(test) x 3(repetition: study only, item repetition, pair repetition) ANOVA on proportion hits minus proportion false alarms (see Appendix E, Table E2), older adults

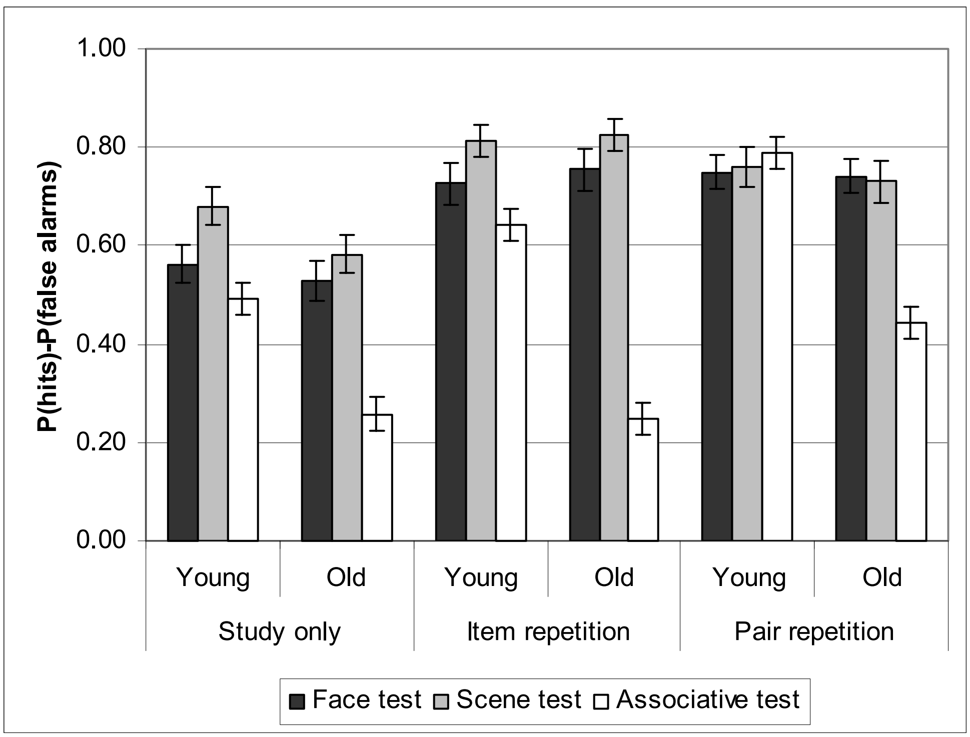
($M=.57$, $SD=.15$) were impaired relative to the young ($M=.69$, $SD=.11$). Performance was superior for the scenes ($M=.73$, $SD=.14$) compared to the faces ($M=.68$, $SD=.16$; $t(50)=3.00$, $p<.01$) and associations ($M=.48$, $SD=.23$; $t(50)=8.71$, $p<.001$), while faces were remembered better than the associations, $t(50)=6.35$, $p<.001$. Regarding the effect of repetition, pictures shown in the study only condition ($M=.52$, $SD=.16$) were not remembered as well as those in either the item repetition ($M=.67$, $SD=.15$; $t(50)=7.83$, $p<.001$) or pair repetition conditions ($M=.71$, $SD=.18$; $t(50)=10.21$, $p<.001$), which did not differ, $t(50)=1.94$, $p>.05$ (see Figure 13).

The interaction of age and test was significant, reflecting age differences in the associative test ($M=.64$, $SD=.12$ for young and $M=.32$, $SD=.21$ for old), $t(49)=6.82$, $p<.001$, but no age differences in either of the item tests (in the face test: $M=.68$, $SD=.14$ for young and $M=.68$, $SD=.18$ for old, $t(49)=.11$, $p>.05$; in the scene test: $M=.75$, $SD=.14$ for young and $M=.71$, $SD=.14$ for old, $t(49)=.97$, $p>.05$). The test x repetition effect was significant as well. In the face test, the study only ($M=.55$, $SD=.21$) condition elicited poorer performance than both item ($M=.74$, $SD=.21$), $t(50)=5.76$, $p<.001$, and pair repetition ($M=.75$, $SD=.19$), $t(50)=7.96$, $p<.001$, which did not differ, $t(50)=.13$, $p>.05$. In the scene test, superior performance was seen in the item repetition condition ($M=.82$, $SD=.18$), followed by pair repetition ($M=.75$, $SD=.20$; item vs. pair repetition: $t(50)=2.59$, $p=.01$), which was, in turn, better than performance in the study only condition ($M=.63$, 20), $t(50)=3.33$, $p<.01$ (item repetition vs. study only: $t(50)=5.82$, $p<.001$). In the associative test, however, scores were highest for pair repetition ($M=.62$, $SD=.31$; pair vs. item repetition: $t(50)=4.61$, $p<.001$; pair repetition vs. study only:

$t(50)=7.61$, $p<.001$), though item repetition ($M=.45$, $SD=.29$) still yielded better performance than study only ($M=.38$, $SD=.21$), $t(50)=2.34$, $p<.05$.

Figure 13.

Mean Proportion Hits Minus Proportion False Alarms as a Function of Age, Test, and Repetition in the Study Only and 3x Conditions in Experiment 4 (Error Bars Represent Standard Errors Around the Mean)

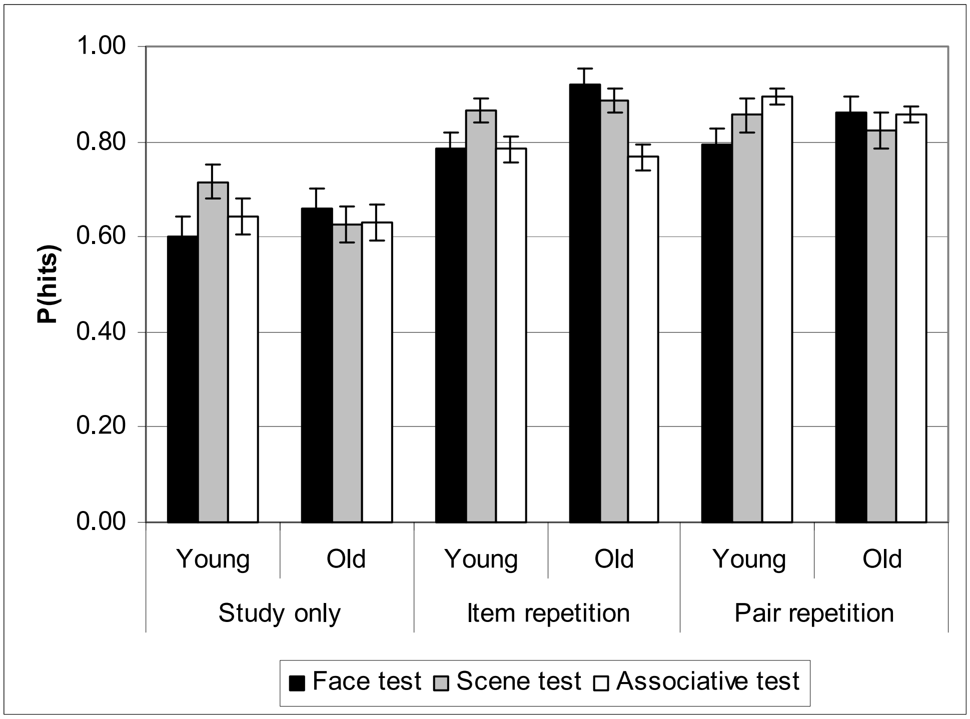


While the interaction of age and repetition was not significant, the triple interaction was. As follow-up tests, 2(age) x 3(repetition) ANOVAs were performed separately for each of the three recognition tests. There was no interaction for the face, $F(2,98)=.57$, $p>.05$, or scene tests, $F(2,98)=1.56$, $p>.05$, but the associative test showed a significant interaction of age and repetition, $F(2,98)=3.21$, $p<.05$. More specifically, both age groups showed the highest performance in the pair repetition condition (*M*=.79, *SD*=.17 for young and *M*=.44, *SD*=.32 for old) compared to study only (in young, $t(25)=7.89$, $p<.001$; in old, $t(24)=3.70$, $p<.001$) and item repetition (in young, $t(25)=3.42$, $p<.01$; in old, $t(24)=3.19$, $p<.01$), but younger adults also demonstrated better performance for item repetition (*M*=.64, *SD*=.17) than study only (*M*=.49, *SD*=.17), $t(25)=3.77$, $p=.001$, while the older adults showed no difference between the two (*M*=.25, *SD*=.25 for item repetition and *M*=.26, *SD*=.19 for study only), $t(24)=.24$, $p>.05$.

A similar 2(age) x 3(test) x 3(repetition) ANOVA was performed on proportion hits (see Appendix E, Table E3). There were no overall age differences in the hit-rates (*M*=.77, *SD*=.12 for young and *M*=.78, *SD*=.12 for old), but scores in the scene test (*M*=.80, *SD*=.13) were higher than the associative test (*M*=.76, *SD*=.13), $t(50)=2.79$, $p<.01$. The face test (*M*=.77, *SD*=.15) did not differ from either the scenes, $t(50)=1.72$, $p>.05$, or the associations, $t(50)=.33$, $p>.05$. Pictures shown in the study only condition (*M*=.65, *SD*=.15) were recognized less often than those in the item (*M*=.83, *SD*=.12), $t(50)=10.67$, $p<.001$, and pair repetition conditions (*M*=.85, *SD*=.13), $t(50)=12.40$, $p<.001$, which did not differ, $t(50)=1.03$, $p>.05$.

Figure 14.

Mean Proportion Hits as a Function of Age, Test, and Repetition in the Study Only and 3x Conditions in Experiment 4 (Error Bars Represent Standard Errors Around the Mean)

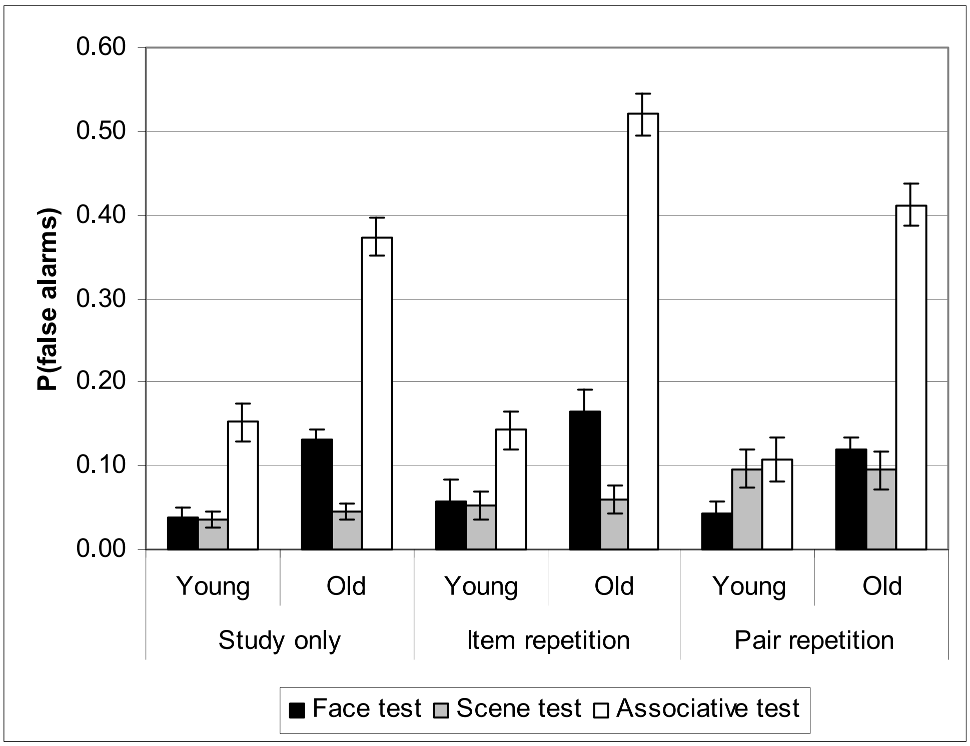


The interaction of age and test was not significant, but the interaction of test and repetition showed different patterns between the item and associative tests. In both item tests, each repetition condition improved performance to about the same degree when compared to study only. For faces, item repetition (M=.85, SD=.17) and pair repetition (M=.83, SD=.18) elicited higher hit-rates than study only (M=.63, SD=.20; $t(50)$=7.18, p<.001 and $t(50)$=9.53, p<.001, respectively), but did not differ from each other, $t(50)$=.96, p>.05. The same pattern could be observed for the scenes (M=.67, SD=.18; M=.88, SD=.13; and M=.84, SD=.18 for study only, item repetition, and pair repetition, respectively; study only vs. item repetition: $t(50)$=7.87, p<.001; study only vs. pair repetition: $t(50)=5.97$, $p<.001$; item vs. pair repetition: $t(50)=1.44$, $p=.16$). Like the item tests, both repetition types ($M=.78$, $SD=.16$ for item and $M=.88$, $SD=.13$ for pair repetition) improved associative memory performance from study only ($M=.64$, $SD=.18$; $t(50)=6.97$, p<.001 and $t(50)=9.50$, $p<.001$, respectively); however, pair repetition yielded a significant advantage over item repetition, $t(50)=4.69$, $p<.001$. The interaction of age and repetition as well as the triple interaction were nonsignificant (see Figure 14).

A 2(age) x 3(test) x 3(repetition) ANOVA was also performed on proportion false alarms (see Appendix E, Table E4). Older adults ($M=.21$, $SD=.09$) were more likely to false alarm than younger adults ($M=.08$, $SD=.06$), and more false alarms were made in the associative test ($M=.28$, $SD=.20$) than the face ($M=.09$, $SD=.11$), $t(50)=8.76$, $p<.001$, and scene tests ($M=.06$, $SD=.07$), $t(50)=7.67$, $p<.001$, which did not differ, $t(50)=1.88$, $p>.05$. Fewer false alarms were made in the study only condition ($M=.13$, $SD=.10$) relative to item repetition ($M=.17$, $SD=.12$), $t(50)=3.46$, $p=.001$, but pair repetition ($M=.15$, $SD=.11$) was not significantly different from either study only, $t(50)=1.50$, $p>.05$, or item repetition, $t(50)=1.91$, $p>.05$.

Figure 15.

Mean Proportion False Alarms as a Function of Age, Test, and Repetition in the Study Only and 3x Conditions in Experiment 4 (Error Bars Represent Standard Errors Around the Mean)



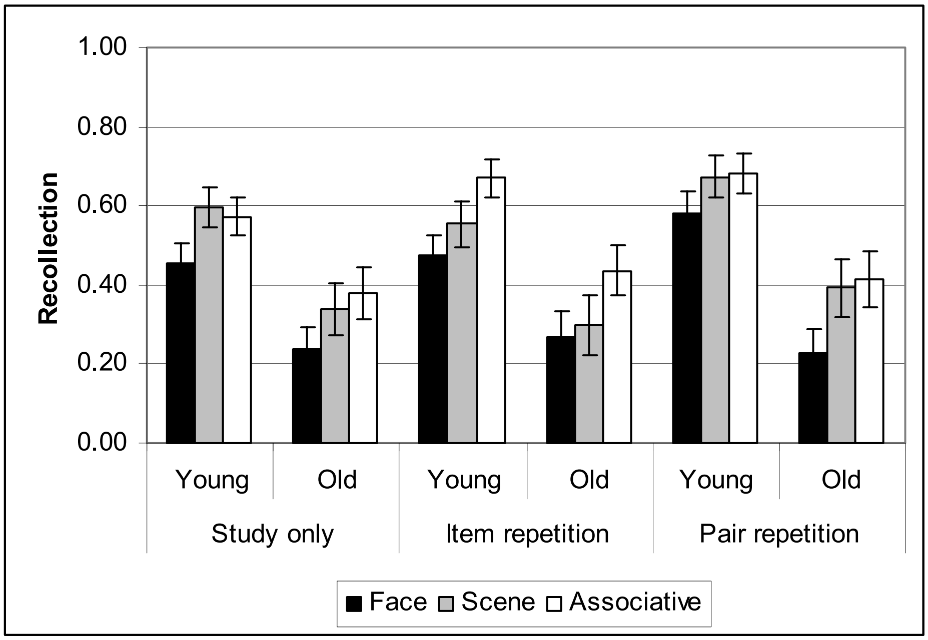
The interaction of age and test was significant as older adults committed more false alarms than young in both the face (*M*=.05, *SD*=.08 for young and *M*=.14, *SD*=.12 for old), *t*(49)=3.44, *p*=.001, and associative tests (*M*=.13, *SD*=.09 for young and *M*=.44, *SD*=.17 for old), *t*(49)=7.88, *p*<.001, but not in the scene test (*M*=.06, *SD*=.07 for young and *M*=.07, *SD*=.07 for old), *t*(49)=.34, *p*>.05. An interaction of age and repetition revealed that only older adults were affected by repetition. They showed the most false alarms in item repetition (*M*=.25, *SD*=.10) compared to study only (*M*=.18, *SD*=.10), *t*(24)=4.12, *p*<.001, and pair repetition (*M*=.21, *SD*=.12), *t*(24)=2.35, *p*<.05, though study only and pair repetition did not differ, $t(24)=1.30$, $p>.05$. In young, there were no significant differences among the three conditions (M=08, SD=.07; M=.08, SD=.08; and M=.08, SD=.07 for study only, item repetition, and pair repetition, respectively; all ts<1). The test x repetition interaction also reached significance. In the face test, there was no effect of repetition (M=.08, SD=.11; M=.11, SD=.16; and M=.08, SD=.11 for study only, item repetition, and pair repetition, respectively; study only vs. item repetition: $t(50)=1.53$, $p>.05$; study only vs. pair repetition: $t(50)=.27$, $p>.05$; item repetition vs. pair repetition: $t(50)=1.47$, $p>.05$). In the scene test, pair repetition (M=.10, SD=.11) elicited more false alarms than study only (M=.04, SD=.06), $t(50)=3.79$, $p<.001$, and item repetition (M=.06, SD=.10), $t(50)=2.77$, $p<.01$, which did not differ, $t(50)=1.22$, $p>.05$. However, in the associative test, item repetition (M=.33, SD=.25) elicited more false alarms than study only (M=.26, SD=.18), $t(50)=2.30$, $p<.05$, and pair repetition (M=.26, SD=.26), $t(50)=2.57$, p=.01, which did not differ, $t(50)=.14$, $p>.05$. The triple interaction was nonsignificant (see Figure 15).

Remember/Know Judgments

Estimates of recollection and familiarity were calculated from the proportion of remember and know responses in the same manner as described in Experiment 2 (see Appendix E, Tables E5 and E6, for descriptive statistics). Using the measure of recollection as the dependent variable, a 2(age) x 3(test) x 3(repetition) ANOVA was executed. As expected, younger adults (M=.58, SD=.21) showed more recollection than the old (M=.33, SD=.30), $F(1,49)=12.18$, p=.001. There were also main effects of test, $F(2,98)=25.34$, $p<.001$, and repetition, $F(2,98)=6.72$, $p<.01$. Follow-up tests revealed that the most recollection was seen in the associative test (M=.53, SD=.29), followed by the scene test (*M*=.48, *SD*=.31), $t(50)=2.32$, $p<.05$, which was higher than in the face test (*M*=.38, *SD*=.29), $t(50)=5.09$, $p<.001$ (associations vs. faces: $t(50)=6.57$, $p<.001$. More recollection could be found in the pair repetition condition (*M*=.50, *SD*=.31) than both item repetition (*M*=.45, *SD*=.29), $t(50)=2.29$, $p<.05$, and study only (*M*=.43, *SD*=.28), $t(50)=3.87$, $p<.001$, which did not differ, $t(50)=1.13$, $p>.05$. The age x test, $F(2,98)<1$, $p>.05$, and age x repetition, $F(2,98)=2.78$, $p>.05$, interactions were nonsignificant, but the test x repetition interaction, $F(4,196)=2.73$, $p<.05$, showed different effects of repetition for each test. In the face test, pair repetition (*M*=.41, *SD*=.34) elicited higher levels of recollection than study only (*M*=.35, *SD*=.30), $t(50)=2.08$, $p<.05$, but item repetition (*M*=.38, *SD*=.31) did not significantly differ from either of the two (item vs. pair repetition: $t(50)=1.02$, $p>.05$; item repetition vs. study only: $t(50)=.97$, $p>.05$). In the scene test, pair repetition (*M*=.54, *SD*=.35) was higher than both item repetition (*M*=.43, *SD*=.36), $t(50)=2.76$, $p<.01$, and study only (*M*=.47, *SD*=.32), $t(50)=2.26$, $p<.05$, which did not differ, $t(50)=1.27$, $p>.05$. In the associative test, study only (*M*=.48, *SD*=.30) was lower than both item (*M*=.56, *SD*=.30), $t(50)=2.88$, $p<.01$, and pair repetition (*M*=.55, *SD*=.33), $t(50)=3.14$, $p<.01$, (item vs. pair repetition: $t(50)=.18$, $p>.05$). The triple interaction was nonsignificant, $F(4,196)=.91$, $p>.05$ (see Figure 16).

Figure 16.

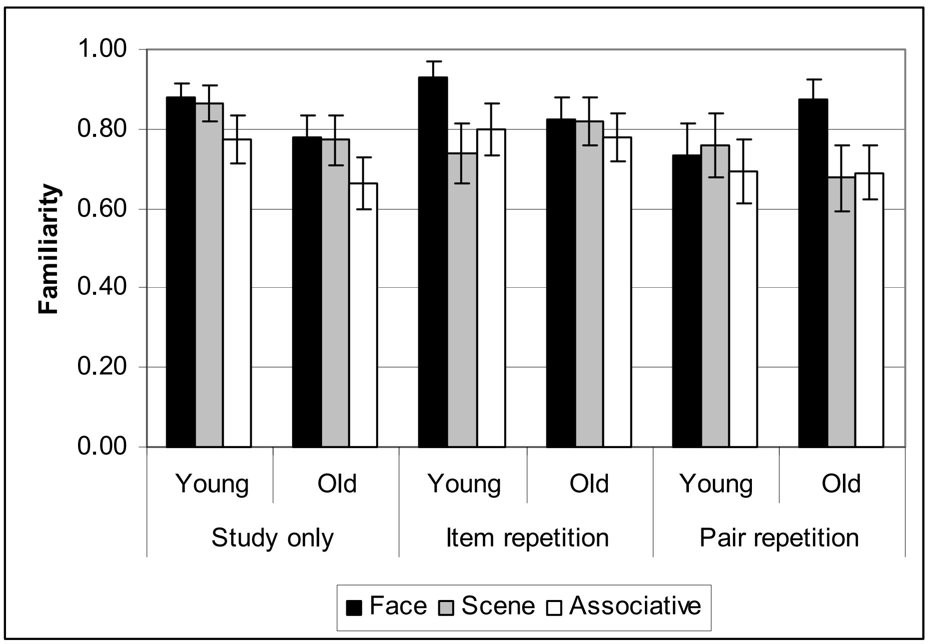
Mean Frequency of Recollection Responses as a Function of Age, Test, and Repetition in the Study Only and 3x Conditions in Experiment 4 (Error Bars Represent Standard Errors Around The Mean)



When the same 3-way ANOVA was performed on frequency of familiarity responses, there was no longer an age difference, $F(1,49)<1$, $p>.05$. The significant effect of test, $F(2,98)=5.28$, $p<.01$, showed that the face test ($M=.84$, $SD=.18$) was associated with more familiarity than both the scene ($M=.77$, $SD=.27$), $t(50)=2.06$, $p<.05$, and associative test ($M=.73$, $SD=.27$), $t(50)=3.33$, $p<.01$, though the two did not differ, $t(50)=1.16$, $p>.05$. Follow-up tests of the effect of repetition, $F(2,98)=3.19$, $p<.05$, showed that item repetition ($M=.82$, $SD=.22$) elicited more familiarity than pair repetition ($M=.74$, $SD=.28$), $t(50)=3.00$, $p<.01$, but no other differences were significant ($M=.79$, $SD=.23$ for study only; item repetition vs. study only: $t(50)=.82$, $p>.05$; pair repetition vs. study only: $t(50)=1.45$, $p>.05$). None of the interactions were significant (age x test, $F(2,98)<1$, $p>.05$; age x repetition, $F(2,98)=1.88$, $p>.05$; test x repetition: $F(4,196)<1$, $p>.05$; age x test x repetition: $F(4,196)=2.23$, $p>.05$)(see Figure 17).

Figure 17.

Mean Frequency of Familiarity Responses as a Function of Age, Test, and Repetition in the Study Only and 3x Conditions in Experiment 4 (Error Bars Represent Standard Errors Around The Mean)



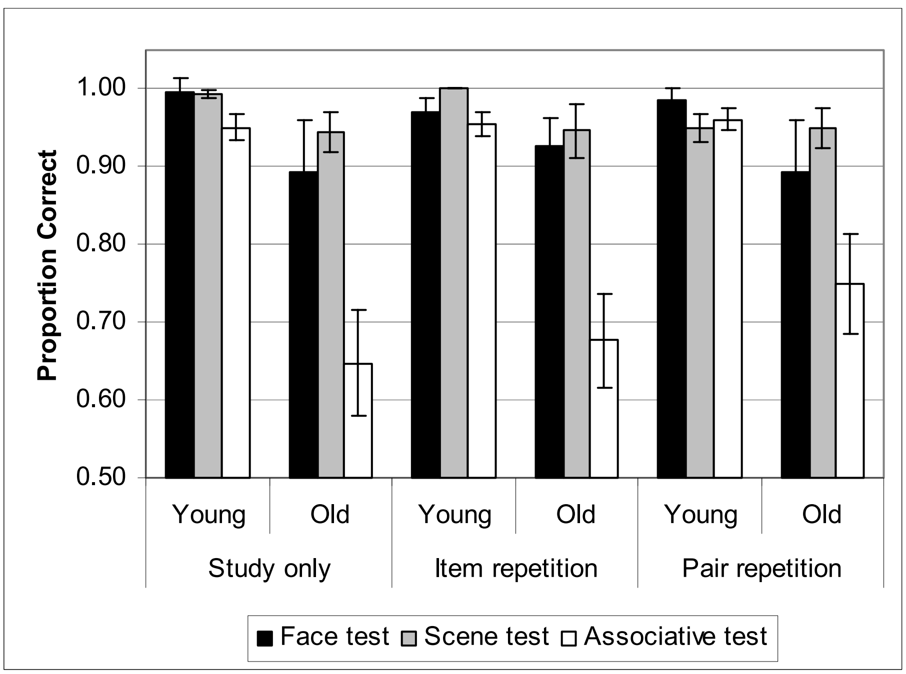
Memory Performance for "Remember" Responses Only

As in Experiment 2, proportion correct was calculated for remember responses only, and these scores were then used in a 2(age) x 3(test) x 3(repetition) ANOVA (see Appendix E, Table E7, for descriptive statistics). Older adults ($M=.81$, $SD=.14$) showed poorer performance than the young ($M=.97$, $SD=.02$), $F(1,29)=19.17$, $p<.001$, and there was a main effect of test, $F(2,58)=16.47$, $p<.001$, reflecting lower accuracy in the associative test ($M=.84$, $SD=.20$) than both the face ($M=.95$, $SD=.13$), $t(43)=3.42$, $p<.001$, and scene tests ($M=.97$, $SD=.07$), $t(45)=4.17$, $p=.001$, which did not differ, $t(43)=.79$, $p>.05$. Furthermore, the age x test interaction, $F(2,58)=8.86$, $p<.001$, showed that greater age differences were observed in the associative test ($M=.96$, $SD=.05$ for young and $M=.69$, $SD=.22$ for old), $t(47)=6.04$, $p<.001$, than the face ($M=.98$, $SD=.04$ for young and $M=.91$, $SD=.18$ for old), $t(42)=1.95$, $p>.05$, and scene tests ($M=.98$, $SD=.03$ for young and $M=.94$, $SD=.09$ for old), $t(44)=2.02$, $p=.05$. There was no main effect of repetition, $F(2,58)=1.81$, $p>.05$, but repetition did interact with age, $F(2,58)=5.49$, $p<.01$, showing somewhat smaller age differences in pair repetition ($M=.97$, $SD=.04$ for young and $M=.86$, $SD=.15$ for old), $t(44)=3.24$, $p<.01$, compared to item repetition ($M=.98$, $SD=.03$ for young and $M=.80$, $SD=.15$ for old), $t(46)=5.64$, $p<.001$, and study only ($M=.98$, $SD=.04$ for young and $M=.80$, $SD=.23$ for old), $t(45)=3.96$, $p<.001$. There was also an interaction between test and repetition, $F(4,116)=2.63$, $p<.05$, demonstrating that the effect of repetition differed according test. In the face test, there was no repetition effect ($M=.96$, $SD=.17$; $M=.94$, $SD=.13$; and $M=.95$, $SD=.17$ for study only, item repetition, and pair repetition, respectively; study only vs. item repetition: $t(35)=.37$, $p>.05$; study only vs. pair repetition: $t(33)=.05$, $p>.05$; item vs. pair repetition: $t(35)=1.48$, $p>.05$). There were marginal effects of repetition in the scene test such that pair repetition ($M=.94$, $SD=.10$) elicited somewhat lower performance than both item repetition ($M=.99$, $SD=.03$), $t(37)=1.72$, $p=.09$, and study only conditions ($M=.97$, $SD=.08$), $t(40)=1.93$, $p=.06$, which did not differ, $t(34)=.10$, $p>.05$.

In the associative test, there was no effect of repetition (*M*=.84, *SD*=.22; *M*=.90, *SD*=.14; and *M*=.86, *SD*=.21 for study only, item repetition, and pair repetition, respectively; study only vs. item repetition: $t(45)=.59$, $p>.05$; study only vs. pair repetition: $t(42)=.32$, $p>.05$; item vs. pair repetition: $t(43)=1.25$, $p>.05$). The triple interaction was not significant, $F(4,116)<1$, $p>.05$ (see Figure 18).

Figure 18.

Mean Proportion Correct for Remember Responses as a Function of Age, Test, and Repetition in the Study Only and 3x Conditions in Experiment 4 (Error Bars Represent Standard Errors Around The Mean)

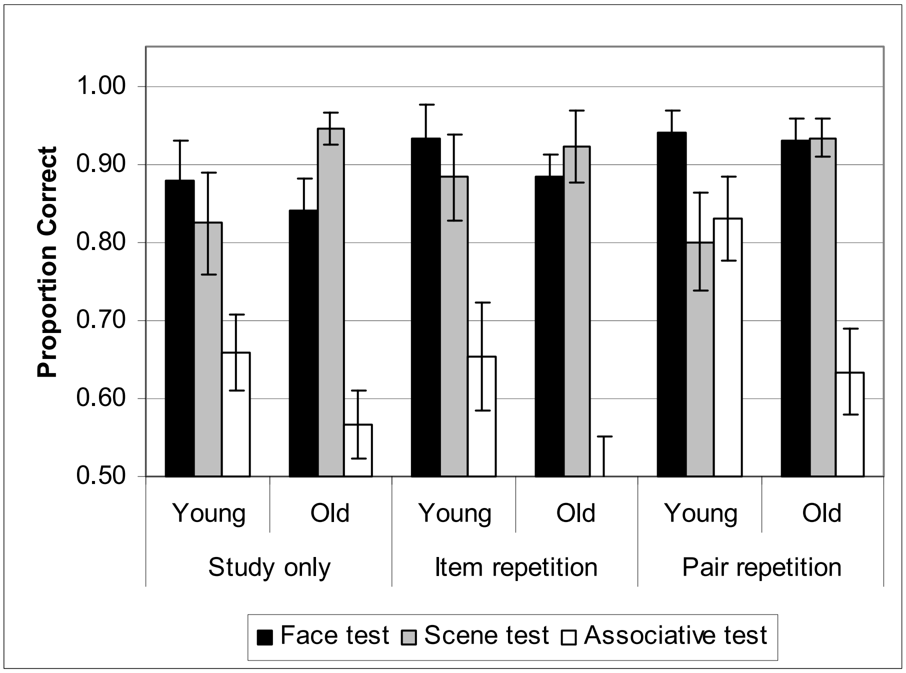


Memory Performance for "Know" Responses Only

Proportion correct was next calculated for know responses only and used in a 2(age) x 3(test) x 3(repetition) ANOVA (see Appendix E, Table E8, for descriptive statistics). This time, there was no main effect of age, $F(1,26)=1.41$, $p>.05$, or repetition, $F(2,52)<1$, $p>.05$, but there was an effect of test, $F(2,52)=36.85$, $p<.001$. As in the remember responses, the associative test ($M=.63$, $SD=.21$) yielded lower performance than both the face ($M=.90$, $SD=.14$), $t(48)=9.90$, $p<.001$, and scene tests ($M=.89$, $SD=.16$), $t(48)=6.98$, $p<.001$, which did not differ, $t(49)=.33$, $p>.05$. The interaction of age and test was significant, too, revealing larger age differences in both the associative ($M=.69$, $SD=.22$ for young and $M=.57$, $SD=.19$ for old), $t(47)=2.02$, $p<.05$, and scene tests ($M=.84$, $SD=.19$ for young and $M=.94$, $SD=.11$ for old), $t(48)=2.18$, $p<.05$, than the face test ($M=.91$, $SD=.16$ for young and $M=.88$, $SD=.12$ for old), $t(48)=.67$, $p>.05$. The test x repetition interaction was also significant, $F(4,104)=3.49$, $p=.01$, to show that the effect of repetition varied by test. In the face test, there was better performance in pair repetition ($M=.93$, $SD=.13$) than study only conditions ($M=.88$, $SD=.21$), $t(43)=2.59$, $p=.01$, but no other differences were significant (for item repetition: $M=.90$, $SD=.18$; study only vs. item repetition: $t(47)=1.08$, $p>.05$; pair vs. item repetition: $t(41)=1.62$, $p>.05$). In the scene test, there was no effect of repetition ($M=.88$, $SD=.24$; $M=.92$, $SD=.20$; and $M=.88$, $SD=.23$ for study only, item repetition, and pair repetition respectively; study only vs. item repetition: $t(40)=.66$, $p>.05$; study only vs. pair repetition: $t(38)=.16$, $p>.05$; item vs. pair repetition: $t(37)=.13$, $p>.05$). In the associative test, higher performance was seen in pair repetition ($M=.76$, $SD=.22$) than both study only ($M=.64$, $SD=.20$), $t(41)=2.32$, $p<.05$, and item repetition ($M=.59$, $SD=.30$), $t(40)=2.41$, $p<.05$, which did not differ, $t(44)=1.16$, $p>.05$. The remaining effects were nonsignificant (repetition: $F(2,52)<1$, $p>.05$; age x repetition: $F(2,52)<1$, $p>.05$; age x test x repetition: $F(4,104)=2.24$, $p>.05$; see Figure 19).

Figure 19.

Mean Proportion Correct for Know Responses as a Function of Age, Test, and Repetition in the Study Only and 3x Conditions in Experiment 4 (Error Bars Represent Standard Errors Around The Mean)

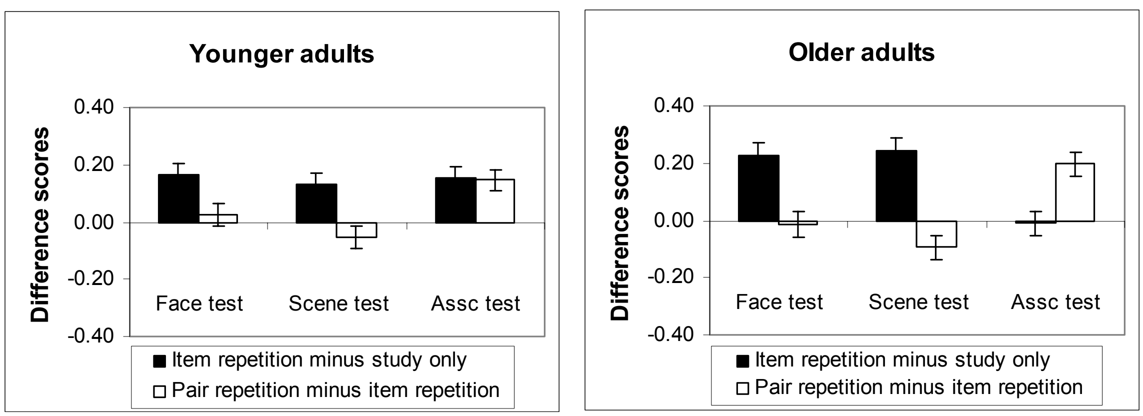


Discussion

Many of the results of Experiment 4 are in agreement with the results of Experiment 3. First of all, older adults showed an associative deficit relative to the young in study only conditions. Second, there was a differential effect of repetition such that item repetition especially increased performance in the item tests, and pair repetition especially increased performance in the associative test (see Figure 20). Third, younger adults displayed positive effects of item repetition in the associative test, but older adults did not. Unlike Experiment 3, evidence shows that older adults had a greater effect of pure pair repetition than the young. Specifically, older adults had fewer false alarms in pair repetition conditions than item repetition, but the young showed no difference in false alarms among any of the repetition conditions. This demonstrates that pair repetition not only increased older adults' associative memory, it also narrowed the gap between younger and older adults.

Figure 20.

Mean Difference Scores Reflecting the Effect of Item Repetition (Performance in Item Repetition Minus Study Only Conditions) and the Effect of Pure Pair Repetition (Performance in Pair Repetition Minus Item Repetition Conditions) as a Function of Age and Test for the 3x Condition in Experiment 4 (Error Bars Represent Standard Errors Around the Mean)

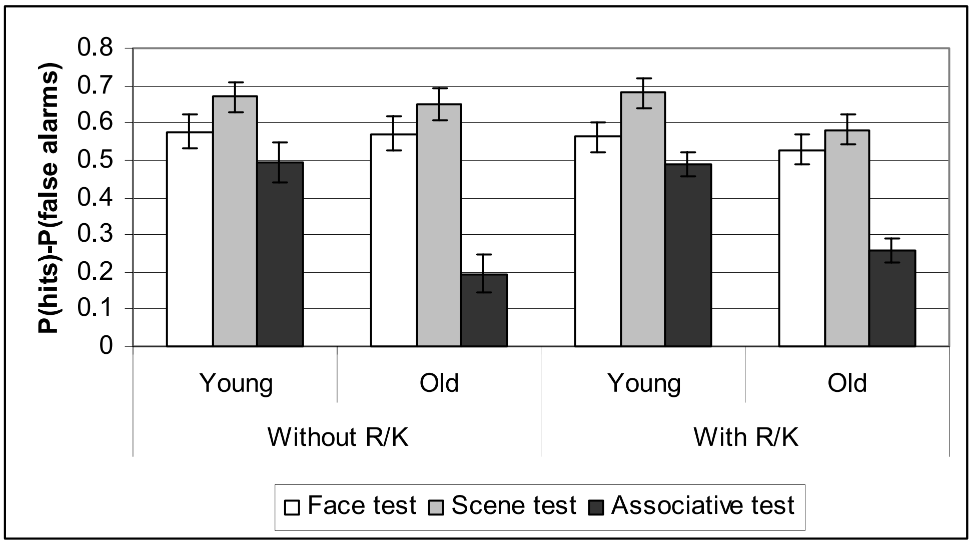


Another similarity between Experiments 3 and 4 is that pair repetition elicited more false alarms than item repetition and study only in the scene test. As previously mentioned in the discussion of Experiment 3, this difference should not have occurred because the distractors, which only appeared at test, were randomly assigned to the repetition conditions. One possibility is that the distractors allocated to the item repetition condition were more distinctive, making them easier to reject than those allocated to the pair repetition condition. However, this explanation can be ruled out because distractors were rotated among the repetition conditions such that a given scene appeared as an item repetition distractor for some participants and as a pair repetition distractor for others. While the cause of this effect remains unclear, a sign test shows that only 20 of the 51 participants in Experiment 4 showed more false alarms in the scene test for pair repetition than item repetition.

One methodological concern from Experiment 2 is that the use of remember/know judgments increases associative memory. If this concern has merit, then the associative deficit should be smaller in Experiment 4 (i.e., with remember/know judgments) than in Experiment 3 (i.e., without remember/know judgments). When a 2(age) x 2(test) x 2(Experiment 3 vs. Experiment 4) ANOVA was performed on proportion hits minus proportion false alarms for study only conditions, the triple interaction was nonsignificant, $F(2,190)=1.41$, $p>.05$. However, the size of the age x test interaction found in Experiment 4 (i.e., with remember/know judgments) was indeed smaller, $F(2,98)=6.27$, $p<.01$, than the age x test interaction found in Experiment 3 (i.e., without remember/know judgments), $F(2,92)=12.26$, $p<.001$ (see Figure 21). It is possible that certain types of stimuli are more sensitive to the effects of remember/know judgments, which could explain why a sizable associative deficit still remained in Experiment 4. For instance, in Experiments 1 and 2 (as well as in the findings of Kilb & Naveh-Benjamin), word pairs were used, but Experiments 3 and 4 contained picture pairs. Perhaps verbal stimuli are especially susceptible to the influence of remember/know judgments compared to pictorial stimuli.

Figure 21.

The Effect of Remember/Know (R/K) Judgments on Proportion Hits Minus Proportion False Alarms as a Function of Age and Test for Study Only Conditions in Experiments 3 and 4 (Error Bars Represent Standard Errors Around the Mean)



The primary goal of Experiment 4 was to determine the degree to which the effects of pair repetition (using the current methodology) are mediated by either recollection or familiarity. Because there were repetition effects despite instructions to ignore the earlier training phase, one might conclude that participants were relying on familiarity to some degree. Alternatively, it is possible that repetition increased the ability to retrieve a micro-level recollection (e.g., A was presented with B) without increasing the ability to retrieve a macro-level recollection (e.g., is A-B remembered from the study or training phase?). If this second alternative is true, then there should be an effect of repetition within measures of recollection. Otherwise, repetition effects should be limited to measures of familiarity.

The findings differed according to the measures used for examining familiarity and recollection. When using frequency estimates, repetition increased the likelihood of a recollection, though pair repetition did not increase recollection more than item repetition in the associative test (see Figure 16). Conversely, repetition had little influence on estimates of familiarity (see Figure 17). These patterns of results suggest that effects of repetition are mediated by recollection rather than familiarity.

The second way of examining familiarity and recollection is to look at accuracy separately for remember and know responses, and repetition effects were observed within each response type. For cases in which participants gave remember responses, there were smaller age differences in pair repetition relative to item repetition and study only conditions. Inspection of Figure 18 shows that older adults' associative memory performance increased from item repetition to pair repetition, but younger adults had minimal effects of repetition in the associative test. Although this seems to demonstrate that pair repetition reduces age-related memory differences when recollection is used, there are ceiling effects for the young, indicating that there was little room for improvement from even the study only condition. For cases in which participants gave know responses, both younger and older adults displayed higher accuracy for pair repetition than item repetition and study only conditions in the associative test (see Figure 19). Since older adults are at floor in the item repetition condition, it is possible that these data give an underestimation of the pure pair repetition effect in the old.

In summary, these results show that participants were more likely to experience a recollection when information was repeated, and these recollection-based responses led to higher memory accuracy for pair repetition than item repetition and study only conditions, particularly for older adults in the associative test. While participants were no more likely to have familiarity for repeated than nonrepeated stimuli, the familiarity-based responses that they made also provided higher associative memory accuracy for pair repetition than item repetition and study only, as seen for recollection-based responses. Taken together, these data provide evidence that the effects of repetition are driven by both recollection and familiarity.

GENERAL DISCUSSION

Overall, these studies have demonstrated that older adults' deficit in learning and remembering associations can be improved through the use of unitization and pair repetition, and their increased associative memory performance was at least as large as that observed in younger adults. Furthermore, both familiarity and recollection can account for these improvements. Each of the major findings is discussed in more detail below.

The Associative Deficit of Older Adults

Experiments 1-4 produce additional support for the associative deficit hypothesis (Naveh-Benjamin, 2000), showing larger age-related differences in associative tests than item tests using different materials and different manipulations. The one exception was Experiment 2, in which there were no age differences even in the associative test. As mentioned earlier, the likeliest explanation for this is that the addition of remember/know judgments served as a manipulation and increased associative memory performance, similarly to what has been observed elsewhere (Kilb & Naveh-Benjamin, 2008). The results of using pictorial stimuli in Experiments 3 and 4 agree with those of Naveh-Benjamin et al. (2003), which also presented pictures. Because the current stimuli consisted of faces and locations, the conclusions can better translate to real-life situations of trying to recall where a particular person was previously seen.

Manipulations that Increase Associative Memory

Evidence shows that both unitization and pair repetition increased associative memory. Experiment 1 demonstrated that color unitization selectively improves associative and not item memory performance, which occurred to the same degree in younger and older adults. If unitization strengthened the encoding of associations, then one would expect that it either (1) also strengthened the encoding of the individual items or (2) decreased the strength of encoding the individual items because their fusion made them less recognizable when shown separately. Since there was no effect of unitization in the item test, it is concluded that unitization acts mostly at retrieval, such that it is easier to recognize a pair based on its color information. That is not to say that this is merely a context effect from the colors being reinstated at test because the colors were reinstated for both unitized and non-unitized pairs. Rather, having both words of a pair in the same color aided participants' ability to reject recombined pairs.

Unexpectedly, having participants provide remember/know responses increased older adults' associative memory in Experiment 2, thereby eliminating the associative deficit in some cases. While this procedure was not predicted to affect participants' memory performance, the increase is consistent with at least one known body of research (Kilb & Naveh-Benjamin, 2008). Given that the boost in performance is largely reduced when using pictorial stimuli in Experiment 4, it is possible that the mechanism behind the effect involves some kind of strategy that is less effective for pictures. That is, providing remember/know responses could make the participants more aware that it is optimal to retrieve the context in which an event was seen. Consequently, older adults may be more likely to engage in conscious verbal strategies that are less effective for face-scene pairs, which are more difficult to verbalize. For the means across Experiments 1-4, irrespective of the unitization and repetition manipulations, please see Appendix F, Table F1.

Experiment 3 showed increases in item test performance from the effect of item repetition and increases in associative test performance from the effect of pure pair repetition. Importantly, while item repetition led to higher associative memory performance in younger adults, it did not increase associative memory for older adults. Meanwhile, older adults' increases in associative memory from pure pair repetition were at least as large as younger adults', which extends the findings of Light et al. (2004), whose manipulation of repetition confounded pair repetition with item repetition. Consistent with Light et al., younger adults showed a larger reduction in false alarms in pair repetition compared to study only conditions relative to older adults who showed no reduction between these two conditions. However, comparisons between pair repetition and the new item repetition condition showed that older adults displayed at least as large of a reduction in false alarms for pair repetition as younger adults. These data suggest that the effects of item repetition are especially problematic for older adults and controlling for these negative effects eliminates the superior advantage of repetition in younger adults over the old.

The use of the word "advantage" may be somewhat misleading because the instructions in Experiment 3 were to ignore the training phase. In a sense, showing an increase in performance for repeated information should not be labeled as an advantage because it signifies an inability to properly inhibit repetitions from training. Considering that this is at least partially due to a failure of source memory, this strengthens the claim that a sizable portion of the effects of repetition observed here are due to effects of familiarity.

Estimates of Familiarity and Recollection

The overall patterns of use for recollection and familiarity were consistent with previous research. Experiments 2 and 4 showed that participants were more likely to use recollection for associative tests than item tests and were more reliant on familiarity for item tests than associative tests (Hockley & Consoli, 1999). Both Experiments demonstrated no age differences in the use of familiarity, but younger adults used more recollection than older adults, which is in line with the findings of Jennings and Jacoby (1993, 1997).

More remember responses were made in Experiment 2 for non-unitized than unitized stimuli, which was expected if unitization is driven by familiarity. However, the accompanying prediction that more know responses would be made for unitized than non-unitized stimuli was unsupported. In fact, no effects of unitization could be observed in the amount of familiarity-based responses. These combined findings provide only partial evidence that unitization acts via familiarity.

In Experiment 4, more recollection-based responses were made for repeated stimuli compared to stimuli that were presented only once, though participants were no more likely to give a remember response in pair repetition than item repetition conditions. Given that there was also no difference in the amount of familiarity-based responses given to repeated versus nonrepeated items, no final conclusions concerning the mechanism behind pure pair repetition can be made based on frequency estimates alone for familiarity and recollection.

Accuracy of Familiarity and Recollection

When looking separately at accuracy for remember and know responses, it became evident that the effect of unitization was limited to remember responses only, which supports the notion that unitization is driven by recollection rather than familiarity. It is unclear why Experiment 2 shows that unitization is supported by recollection when past experiments have shown it to be supported by familiarity (Parks & Yonelinas, 2008; Rhodes & Donaldson, 2007; Weyerts, Tendolkar, Smid, & Heinze, 1997). Although the remember/know paradigm has not often been used in the study of unitization, at least one study (Giovanello, Keane, & Verfaellie, 2006) found that benefits of unitization were seen within know rather than remember responses, concluding that the effect is driven by familiarity. Another methodological difference between the current study and others is that the unitization manipulation used here is perceptual in nature, whereas the others are mainly conceptual. Evidence from one study shows that simultaneous rather than sequential presentation of fractals paired with nonsense sounds increases associative memory through familiarity (Parks & Yonelinas, 2008), but the current investigation is the first reported case in which meaningful information (i.e., words) is unitized perceptually.

Repetition effects (the effect of pure pair repetition in particular) were shown in the memory accuracy of both remember and know responses, suggesting that both recollection and familiarity mediate the effects of repetition. The fact that recollection is associated with repetition effects is interesting because when giving a remember response at test, the participant is saying that she/he recalls the earlier context in which the stimulus was presented. However, participants were told to base their responses on the study list alone, which contained only one presentation of each stimulus. In other words, a true recollection of the study list should not be influenced by repetition. It is possible that there is a difference here between micro-level recollection and macro-level recollection such that a micro-level recollection includes information about the specific items of an original pair, and a macro-level recollection includes information about the source (i.e., the training phase vs. the study phase). Consequently, participants could be experiencing a micro-level recollection (in which they can recall the original pair) in the absence of a macro-level recollection (in which they can differentiate between training and study).

The finding that repetition was supported by recollection is in contrast to numerous other findings (e.g., Jennings & Jacoby, 1993, 1997; Light et al., 2004), though the others did not examine "pure" effects of pair repetition as was the case here. Assuming that the current data are replicable, pair repetition offers a way of reducing age differences between younger and older adults because much evidence shows that older adults' main episodic memory deficit is in remembering specific associative information

(Chalfonte & Johnson, 1996; Jennings & Jacoby, 1993, 1997; Naveh-Benjamin, 2000; Naveh-Benjamin et al., 2004; Kilb & Naveh-Benjamin, 2007).

Evidence from Experiment 4 also shows that pair repetition is supported by familiarity. This means that it is possible to boost older adults' associative memory with minimal effort on their part. Although studies show that older adults benefit from the use of strategies (e.g., see Naveh-Benjamin, Brav, & Levy, 2007), it can also be observed that strategies require more attentional resources in old when compared to younger adults (Naveh-Benjamin, Craik, Guez, & Kreuger, 2005), suggesting that in real life, older adults may choose to use a less taxing option for improving their memory performance if available. Furthermore, the manipulation of pair repetition can be used by an observer. That is, if one wants an older adult to remember something, one can repeat information again and again.

Future Directions

Little is currently known about the influence of remember/know judgments on memory performance. Since these judgments produced quite a large benefit to older adults' associative memory, future research should investigate the mechanism behind the effect to determine if it can be translated into a useful strategy for older adults to use in their daily lives.

Because of concern that the use of remember/know responses affects associative memory performance, other methods should be implemented for measuring the contributions of familiarity and recollection in the effects of unitization and pair repetition. Options include using the process dissociation procedure (see Jennings & Jacoby, 1993), restructuring the testing format so that ROC curves can be created (see Yonelinas, 2002), or using a response deadline to prevent recollection (see Light et al., 2004).

In terms of unitization, future research needs to be conducted to determine whether the benefit to associative memory can still occur when the specific colors are not reinstated. For instance, if a pair is non-unitized (e.g., orange-blue) at study but becomes unitized (e.g., blue-blue) at test, will there still be a unitization effect? As another example, if a pair is unitized via a certain color at study (e.g., orange-orange) but unitized via a different color at test (e.g., blue-blue), what will then happen to the effect of unitization? Answers to these questions will provide further insight as to whether the unitization acts at encoding or retrieval. Moreover, the unitization effect could be made more robust by manipulating other dimensions of the context. For example, only color was manipulated in the current project so that a non-unitized pair contained one orange word and one blue word, but one could also present a pair in which one word is orange, italicized, and underlined with another word that is blue, shown in bold, and not underlined. In the latter example, the two items of the non-unitized pair differ in three aspects rather than just color.

Regarding pair repetition, it is possible that the increases to associative memory will be even larger if participants are told at test to retrieve information from either the study or the training phase. If so, it would suggest that participants in Experiments 3 and 4 are using recollection to some degree to inhibit information from the training phase. Finally, future work should incorporate the manipulations of both unitization and pair repetition to determine if the effects are additive. For instance, is pair repetition even more effective if the pairs are also unitized?

Conclusions

Both manipulations of unitization and pair repetition were successful in increasing the associative memory performance of younger and older adults, though the effect of unitization was only supported by recollection, whereas the effect of pair repetition was supported by both recollection and familiarity.

Appendix A: Stimuli and Instructions for Experiments 1-4

Section 1: Word Lists Presented in Experiments 1 and 2

LIST 1

Study list

license	walnut
thunder	baker
mansion	charcoal
carriage	algae
engine	laundry
transit	cabbage
station	bottle
blossom	toothbrush
body	canteen
summit	breakfast
ballet	ocean
bucket	feather
pistol	relish
infant	garage
district	hamper
blanket	jury
author	garden
fever	servant
father	banner
machine	bouquet
turkey	flashlight
ointment	forest
wardrobe	cartridge
canvas	ferry
fiber	cherry
rainbow	grenade
fragment	target
novel	clover
tourist	sewage
people	blizzard
dancer	chestnut
summer	cartoon
figure	cracker
design	harvest
goddess	traffic
landscape	candy
orange	teller
franchise	ceiling
textile	widow
province	essay

Item test

license
thunder
ballet
bucket
walnut
baker
ocean
feather
turkey
ointment
dancer
summer
flashlight
forest
chestnut
cartoon
service*
rabbit*
witness*
tribute*
award*
nephew*
sandwich*
speaker*
metal*
lily*
shepherd*
country*
question*
flavor*
hammock*
amount*

Associative test

mansion	charcoal
carriage	algae
engine	laundry
transit	cabbage
pistol	relish
infant	garage
district	hamper
blanket	jury
wardrobe	cartridge
canvas	ferry
fiber	cherry
rainbow	grenade
figure	cracker
design	harvest
goddess	traffic
landscape	candy
station	breakfast*
blossom	canteen*
body	toothbrush*
summit	bottle*
author	servant*
fever	garden*
father	bouquet*
machine	banner*
fragment	clover*
novel	target*
tourist	blizzard*
people	sewage*
orange	essay*
franchise	widow*
textile	ceiling*
province	teller*

tes. Order of stimuli within each list was randomized, and allocation of words to unitization nditions and tests was rotated between subjects. Asterisks denote distractors.

LIST 2

Study list		Item test	Associative test	
dentist	doorway	dentist	lecture	market
public	fender	public	husband	pattern
lecture	market	culture	wedding	weapon
husband	pattern	evening	ankle	christian
wedding	weapon	doorway	crystal	patron
ankle	christian	fender	mileage	acid
newborn	pencil	shadow	disease	income
canoe	union	fellow	anchor	gesture
radar	welcome	basement	mailbox	heaven
elbow	atlas	debate	issue	daylight
culture	shadow	today	measure	shoulder
evening	fellow	concept	doctor	bacon
crystal	patron	volume	cover	poet
mileage	acid	lagoon	presence	regard
disease	income	flower	office	minor
anchor	gesture	marine	structure	razor
council	technique	bubble*	newborn	union*
hamlet	glitter	island*	canoe	pencil*
message	picnic	kitchen*	radar	atlas*
tower	offspring	excess*	elbow	welcome*
basement	volume	career*	council	glitter*
debate	lagoon	mischief*	hamlet	technique*
mailbox	heaven	jungle*	message	offspring*
issue	daylight	pony*	tower	picnic*
measure	shoulder	city*	morning	audience*
doctor	bacon	bedroom*	trouble	present*
morning	present	training*	index	function*
trouble	audience	journal*	conduct	attempt*
index	attempt	slipper*	exchange	offer*
conduct	function	cashew*	period	safety*
today	flower	boundary*	billion	aircraft*
concept	marine	accord*	battle	outside*
cover	poet			
presence	regard			
office	minor			
structure	razor			
exchange	outside			
period	aircraft			
billion	safety			
battle	offer			

LIST 3

Study list		Item test	Associative test	
writer	opening	writer	setting	process
respect	action	respect	quarter	handle
setting	process	supply	demand	area
quarter	handle	control	item	balance
demand	area	opening	female	trial
item	balance	action	anger	portion
honor	contrast	instance	budget	contact
conflict	soda	surprise	statement	china
glory	welfare	tissue	movement	advice
album	hour	weather	address	struggle
supply	instance	title	danger	fashion
control	surprise	progress	notice	cannon
female	trial	result	appeal	minute
anger	portion	thousand	expense	secret
budget	contact	prison	report	brother
statement	china	pelvis	freedom	command
support	excuse	ribbon*	honor	welfare*
nature	devil	story*	conflict	hour*
sample	middle	writing*	glory	contrast*
data	boulder	sugar*	album	soda*
tissue	result	basin*	support	devil*
weather	thousand	chamber*	nature	excuse*
movement	advice	letter*	sample	boulder*
address	struggle	castle*	data	middle*
danger	fashion	clothesline*	fire	session*
notice	cannon	shelter*	entrance	response*
fire	order	offense*	dozen	brilliance*
entrance	brilliance	tunnel*	idea	order*
dozen	response	business*	concern	tension*
idea	session	kleenex*	purpose	bathroom*
title	prison	tennis*	advance	moral*
progress	pelvis	athlete*	signal	crisis*
appeal	minute			
expense	secret			
report	brother			
freedom	command			
concern	bathroom			
purpose	tension			
advance	crisis			
signal	moral			

LIST 4

Study list

alcove	banker
lilac	permit
actor	lightning
airplane	lobby
practice	ruler
saucer	concrete
chicken	asphalt
melon	display
railway	sunshine
arcade	midnight
symbol	lobster
tugboat	ladle
livestock	mango
kayak	anthrax
bandage	casket
catfish	household
mustard	armpit
bagel	circus
cheetah	snowstorm
toaster	cradle
dolphin	carton
cardboard	blister
patient	antler
baggage	camel
whiskey	buckle
bookcase	apron
biscuit	cactus
carrot	bookstore
missile	almond
mallet	checkbook
capsule	oboe
rowboat	trumpet
murder	bonnet
drugstore	axle
birthmark	chopstick
freighter	grapefruit
mixer	trombone
pheasant	filter
chlorine	bullet
bullfight	cymbals

Item test

alcove
lilac
symbol
tugboat
banker
permit
lobster
ladle
dolphin
cardboard
capsule
rowboat
carton
blister
oboe
trumpet
program*
armor*
silence*
cotton*
barrel*
congress*
grassland*
survey*
marriage*
circuit*
sister*
angel*
football*
hotdog*
theater*
scatter*

Associative test

actor	lightning
airplane	lobby
practice	ruler
saucer	concrete
livestock	mango
kayak	anthrax
bandage	casket
catfish	household
patient	antler
baggage	camel
whiskey	buckle
bookcase	apron
murder	bonnet
drugstore	axle
birthmark	chopstick
freighter	grapefruit
chicken	display*
melon	asphalt*
railway	midnight*
arcade	sunshine*
mustard	circus*
bagel	armpit*
cheetah	cradle*
toaster	snowstorm*
biscuit	checkbook*
carrot	almond*
missile	bookstore*
mallet	cactus*
mixer	bullet*
pheasant	cymbals*
chlorine	trombone*
bullfight	filter*

Section 2: Remember/know instructions used in Experiments 2 and 4

Recognition memory is associated with two different kinds of awareness: recollection and familiarity. Quite often, recognition can trigger the recollection of thoughts or events that accompany what is actually being recognized; other times, recognition is driven by a feeling of familiarity.

- ***Example 1***: When you recognize someone's face, you might *recollect the context* in which you spoke to this person at a party the previous night.
- ***Example 2***: When you recognize someone's face, you might not be able to remember the context. However, you are very confident in your recognition and have a very strong feeling of *familiarity*.

The same kinds of awareness can be associated with recognizing words in the current study. Sometimes recognizing a word or pair or words might cause you to remember something you were thinking about when it was originally studied. In this case, you are *recollecting the context* that you experienced at the time of study. Other times, you might recognize a word/pair without remembering the context surrounding it. Instead, the word or pair will seem *familiar*, and you may feel confident that you studied it, but you will not recollect anything specific that you experienced during its earlier presentation.

Test instructions

For each word or pair that you recognize during test, you will need to reveal whether you are recollecting the *context*, if it is simply *familiar*, of if you are *guessing*.

When the computer screen says "How do you recognize it?", you can respond by saying one of the following:

- **Context** – seeing the word or pair triggers a unique memory that occurred during study
- **Familiar** – you are confident that you saw the word or pair, but you are not sure why
- **Guess** – you believe there is a 50/50 change that you are correct
    - If you are leaning towards an answer at all, please do not respond by saying *guess*!

Also, please note that these are not confidence ratings. That is, using *"context"* as a response does not necessarily mean that you are more confident than when using a "*familiar"* response—*"context"* simply means that another thought has been triggered by the word or pair.

Section 3: Sample Face-Scene Pairs Presented in Experiments 3 and 4

Appendix B: Table of Memory Performance in Experiment 1

Table B1.

Memory Performance as a Function of Age, Test, and Unitization Condition in Experiment 1.

		Item Test						Associative Test					
		Non-unitized			Unitized			Non-unitized			Unitized		
		H	FA	H-FA	H	FA	H-FA	H	FA	H-FA	H	FA	H-FA
Young													
	Mean	0.75	0.18	0.57	0.76	0.20	0.56	0.69	0.26	0.43	0.70	0.21	0.48
	SD	0.13	0.11	0.19	0.14	0.12	0.20	0.13	0.14	0.24	0.16	0.16	0.25
Old													
	Mean	0.76	0.26	0.50	0.74	0.25	0.49	0.69	0.48	0.21	0.72	0.43	0.28
	SD	0.14	0.20	0.25	0.17	0.19	0.23	0.16	0.19	0.25	0.16	0.18	0.21

Note. SD=standard deviation

Appendix C: Proportion Missed Responses and Table of Memory Performance in Experiment 2

Proportion of Missed Responses in Experiment 2

The proportion of missed responses was entered into a 4-way ANOVA using the variables age, test, unitization, and probe type (i.e., targets vs. distractors)(see Table C1, for descriptive statistics). Results showed that older adults (M=.12, SD=.08) had more missed responses than younger adults (M=.04, SD=.05), $F(1,52)=18.58$, $p<.001$, there were more missed responses in the associative test (M=.13, SD=.13) than in the item test (M=.03, SD=.05), $F(1,52)=43.57$, $p<.001$, and more missed responses occurred for distractors (M=.09, SD=.09) than targets (M=.07, SD=.07), $F(1,52)=40.64$, $p<.001$. The interaction of age and test was also significant, $F(1,52)=9.27$, $p<.01$. While both age groups missed more responses in the associative test, the effect was larger for the old (M=.05, SD=.06 for items and M=.19, SD=.13 for associations), $t(25)=5.79$, $p<.001$, than the young (M=.01, SD=.02 for items and M=.07, SD=.09 for associations), $t(27)=3.09$, p=.01. There was also an interaction of age and probe type, $F(1,52)=19.49$, $p<.001$, showing that older adults had a larger effect of test probe (M=.10, SD=.07 for targets and M=.14, SD=.09 for distractors), $t(25)=5.64$, $p<.001$, than the younger adults (M=.037, SD=.047 for targets and M=.044, SD=.053 for distractors), $t(27)=2.61$, p=.01. The triple interaction of age, test, and probe type reached significance, too, $F(1,52)=7.05$, p=.01. Follow-up analyses showed no interaction of test and probe type for younger adults, $F(1,27)<1$, $p>.05$, but a significant interaction for older adults, $F(1,25)=11.69$, $p<.01$, reflecting a larger effect of probe in the associative test (M=.16, SD=.13 for targets and *M*=.22, *SD*=.15 for distractors), $t(25)=5.18$, $p<.001$, than in the item test (*M*=.04, *SD*=.05 for targets and *M*=.06, *SD*=.07 for distractors), $t(25)=2.26$, $p<.05$.

Table C1.

Proportion Missed Responses as a Function of Age, Test, Unitization Condition, and Probe Type.

		Item Test				Associative Test			
		Non-unitized		Unitized		Non-unitized		Unitized	
		T	D	T	D	T	D	T	D
Young									
	Mean	0.01	0.02	0.01	0.02	0.06	0.08	0.06	0.07
	SD	0.02	0.02	0.02	0.03	0.09	0.1	0.09	0.1
Old									
	Mean	0.03	0.06	0.04	0.05	0.16	0.22	0.16	0.23
	SD	0.06	0.08	0.05	0.07	0.14	0.15	0.13	0.15

Note. T=targets, D=distractors, SD=standard deviation.

Table C2.

Memory Performance as a Function of Age, Test, and Unitization Condition in Experiment 2.

		Item Test						Associative Test					
		Non-unitized			Unitized			Non-unitized			Unitized		
		H	FA	H-FA	H	FA	H-FA	H	FA	H-FA	H	FA	H-FA
Young													
	Mean	0.68	0.12	0.56	0.57	0.12	0.46	0.62	0.20	0.43	0.60	0.21	0.39
	SD	0.13	0.08	0.14	0.14	0.09	0.15	0.16	0.16	0.19	0.16	0.16	0.25
Old													
	Mean	0.73	0.18	0.55	0.72	0.21	0.51	0.75	0.37	0.38	0.78	0.34	0.44
	SD	0.15	0.12	0.16	0.13	0.14	0.15	0.18	0.28	0.27	0.18	0.27	0.26

Note. SD=standard deviation

Table C3.

Mean Frequency of Recollection and Familiarity Responses as a Function of Age, Test, and Unitization Condition in Experiment 2.

		Item test		Associative test	
		Non-unitized	Unitized	Non-unitized	Unitized
		Recollection			
Young					
	Mean	0.43	0.38	0.54	0.52
	SD	0.22	0.22	0.25	0.23
Old					
	Mean	0.31	0.28	0.52	0.50
	SD	0.26	0.25	0.30	0.27
		Familiarity			
Young					
	Mean	0.83	0.83	0.60	0.67
	SD	0.14	0.18	0.39	0.34
Old					
	Mean	0.74	0.74	0.66	0.62
	SD	0.18	0.22	0.29	0.32

Note. SD=standard deviation.

Table C4.

Mean Proportion Correct as a Function of Age, Test, Unitization Condition, and Response Type in Experiment 2.

		Item test		Associative test	
		Non-unitized	Unitized	Non-unitized	Unitized
		Remember responses only			
Young					
	Mean	0.96	0.94	0.86	0.89
	SD	0.07	0.11	0.20	0.17
Old					
	Mean	0.93	0.94	0.67	0.90
	SD	0.10	0.09	0.21	0.11
		Know responses only			
Young					
	Mean	0.82	0.79	0.65	0.65
	SD	0.13	0.14	0.20	0.21
Old					
	Mean	0.82	0.77	0.61	0.60
	SD	0.14	0.12	0.22	0.26

Note. SD=standard deviation.

Appendix D: Tables of Mean Performance and Additional Analyses in Experiment 3

Table D1.

Memory Performance as a Function of Age, Test, and Repetition Condition in Experiment 3.

		1x									3x					
		Study Only			Item Repetition			Pair Repetition			Item Repetition			Pair Repetition		
		H	FA	H-FA	H	FA	H-FA	H	FA	H-FA	H	FA	H-FA	H	FA	H-FA
Face Test																
Young																
	Mean	0.65	0.07	0.58	0.76	0.13	0.63	0.76	0.11	0.65	0.87	0.04	0.83	0.80	0.03	0.78
	SD	0.23	0.08	0.23	0.20	0.15	0.27	0.20	0.13	0.18	0.14	0.08	0.17	0.20	0.05	0.22
Old																
	Mean	0.68	0.11	0.57	0.77	0.14	0.63	0.78	0.19	0.59	0.86	0.12	0.74	0.84	0.10	0.74
	SD	0.25	0.14	0.29	0.24	0.13	0.26	0.23	0.17	0.27	0.18	0.14	0.26	0.17	0.12	0.23
Scene Test																
Young																
	Mean	0.74	0.07	0.67	0.77	0.02	0.76	0.76	0.02	0.74	0.85	0.03	0.82	0.79	0.10	0.69
	SD	0.19	0.07	0.20	0.18	0.04	0.19	0.24	0.04	0.25	0.15	0.07	0.15	0.21	0.09	0.22
Old																
	Mean	0.72	0.07	0.65	0.78	0.08	0.70	0.69	0.04	0.65	0.89	0.05	0.84	0.85	0.11	0.74
	SD	0.17	0.09	0.21	0.17	0.10	0.19	0.26	0.11	0.28	0.15	0.10	0.19	0.15	0.08	0.15
Associative Test																
Young																
	Mean	0.68	0.20	0.49	0.73	0.18	0.59	0.78	0.21	0.56	0.82	0.20	0.66	0.90	0.10	0.79
	SD	0.21	0.11	0.26	0.19	0.14	0.27	0.18	0.15	0.25	0.16	0.17	0.24	0.14	0.10	0.21
Old																
	Mean	0.60	0.40	0.20	0.70	0.40	0.30	0.73	0.52	0.21	0.75	0.52	0.23	0.81	0.41	0.40
	SD	0.20	0.18	0.21	0.20	0.26	0.28	0.20	0.22	0.30	0.25	0.26	0.30	0.19	0.27	0.34

Note. SD=standard deviations

Table D2.

Analyses of Variance for the Effects of Age, Test, and Repetition Type (Study Only, Item Repetition, Pair Repetition) on Proportion Hits Minus False Alarms in the 1x and 3x Conditions in Experiment 3

Source	*df*	*F*	η_p^2	*p*
		Between subjects (1x)		
Age (A)	1	6.64**	.13	.01
Error	49	(.28)		
		Within subjects (1x)		
Test (T)	2	68.41**	.60	<.001
A x T	2	17.15**	.27	<.001
Error (T)	98	(.05)		
Repetition (R)	2	7.25**	.14	.001
A x R	2	1.51	.03	.23
Error (R)	98	(.03)		
T x R	4	.37	.008	.83
A x T x R	4	.06	.001	.99
Error (T x R)	196	(.03)		
		Between subjects (3x)		
Age (A)	1	8.98**	.16	.004
Error	49	(.21)		
		Within subjects (3x)		
Test (T)	2	68.97**	.60	<.001
A x T	2	32.22**	.41	<.001
Error (T)	98	(.05)		
Repetition (R)	2	36.21**	.44	<.001
A x R	2	.92	.02	.40
Error (R)	98	(.04)		
T x R	4	9.84**	.18	<.001
A x T x R	4	1.04	.02	.39
Error (T x R)	196	(.03)		

Note. Values enclosed in parentheses represent mean square errors.
*$p \leq .05$. **$p \leq .01$.

Table D3.

Analyses of Variance for the Effects of Age, Test, and Repetition Type (Study Only, Item Repetition, Pair Repetition) on Proportion Hits in the 1x and 3x Conditions in Experiment 3

Source	*df*	*F*	η_p^2	*p*
		Between subjects (1x)		
Age (A)	1	.17	.004	.68
Error	49	(.23)		
		Within subjects (1x)		
Test (T)	2	2.43	.05	.09
A x T	2	1.65	.03	.20
Error (T)	98	(.03)		
Repetition (R)	2	14.92**	.24	<.001
A x R	2	.53	.01	.59
Error (R)	98	(.02)		
T x R	4	3.41**	.07	.01
A x T x R	4	.67	.01	.62
Error (T x R)	196	(.02)		
		Between subjects (3x)		
Age (A)	1	.09	.002	.78
Error	49	(.17)		
		Within subjects (3x)		
Test (T)	2	4.24*	.08	.02
A x T	2	6.09**	.12	.003
Error (T)	98	(.02)		
Repetition (R)	2	59.92**	.57	<.001
A x R	2	.27	.006	.76
Error (R)	98	(.02)		
T x R	4	5.09**	.10	.001
A x T x R	4	.78	.02	.54
Error (T x R)	196	(.02)		

Note. Values enclosed in parentheses represent mean square errors.
$^*p \leq .05$. $^{**}p \leq .01$.

Table D4.

Analyses of Variance for the Effects of Age, Test, and Repetition Type (Study Only, Item Repetition, Pair Repetition) on Proportion False Alarms in the 1x and 3x Conditions in Experiment 3

Source	*df*	*F*	η_p^2	*p*
		Between subjects (1x)		
Age (A)	1	25.65**	.36	<.001
Error	49	(.05)		
		Within subjects (1x)		
Test (T)	2	109.60**	.70	<.001
A x T	2	20.51**	.31	<.001
Error (T)	98	(.03)		
Repetition (R)	2	3.59*	.07	.03
A x R	2	3.27*	.07	.04
Error (R)	98	(.01)		
T x R	4	4.04**	.08	.004
A x T x R	4	1.20	.03	.31
Error (T x R)	196	(.01)		
		Between subjects (3x)		
Age (A)	1	31.36**	.41	<.001
Error	49	(.05)		
		Within subjects (3x)		
Test (T)	2	92.97**	.67	<.001
A x T	2	25.69**	.36	<.001
Error (T)	98	(.03)		
Repetition (R)	2	1.11	.02	.32
A x R	2	3.84*	.08	.03
Error (R)	98	(.009)		
T x R	4	7.79**	.14	<.001
A x T x R	4	.85	.02	.50
Error (T x R)	196	(.01)		

Note. Values enclosed in parentheses represent mean square errors.
$^*p \leq .05$. $^{**}p \leq .01$.

Appendix E: Tables of Mean Performance and Additional Analyses in Experiment 4

Table E1.

Memory Performance as a Function of Age, Test, and Repetition Condition in Experiment 4.

					1x						3x					
		Study Only			Item Repetition			Pair Repetition			Item Repetition			Pair Repetition		
		H	FA	H-FA	H	FA	H-FA	H	FA	H-FA	H	FA	H-FA	H	FA	H-FA
Face Test																
Young																
	Mean	0.60	0.04	0.56	0.76	0.07	0.69	0.68	0.05	0.63	0.78	0.06	0.73	0.79	0.04	0.75
	SD	0.22	0.06	0.20	0.13	0.10	0.16	0.16	0.06	0.17	0.18	0.13	0.21	0.18	0.07	0.17
Old																
	Mean	0.66	0.13	0.53	0.81	0.15	0.66	0.82	0.17	0.65	0.92	0.17	0.76	0.86	0.12	0.74
	SD	0.19	0.13	0.22	0.19	0.16	0.27	0.17	0.14	0.20	0.13	0.17	0.21	0.17	0.13	0.22
Scene Test																
Young																
	Mean	0.72	0.04	0.68	0.78	0.04	0.74	0.82	0.04	0.78	0.87	0.05	0.81	0.86	0.10	0.76
	SD	0.19	0.05	0.20	0.20	0.07	0.20	0.18	0.09	0.19	0.13	0.09	0.17	0.19	0.11	0.21
Old																
	Mean	0.63	0.05	0.58	0.79	0.08	0.72	0.73	0.05	0.68	0.89	0.06	0.83	0.83	0.10	0.73
	SD	0.17	0.06	0.19	0.17	0.07	0.18	0.20	0.08	0.24	0.14	0.10	0.19	0.18	0.10	0.19
Associative Test																
Young																
	Mean	0.64	0.15	0.49	0.69	0.14	0.55	0.79	0.14	0.65	0.78	0.14	0.64	0.90	0.11	0.79
	SD	0.19	0.12	0.17	0.18	0.12	0.22	0.13	0.12	0.19	0.14	0.12	0.17	0.09	0.13	0.17
Old																
	Mean	0.63	0.37	0.26	0.71	0.43	0.28	0.74	0.47	0.28	0.77	0.52	0.25	0.86	0.41	0.44
	SD	0.18	0.17	0.19	0.17	0.22	0.26	0.18	0.23	0.23	0.17	0.20	0.25	0.16	0.27	0.32

Note. SD=standard deviations

Table E2.

Analyses of Variance for the Effects of Age, Test, and Repetition Type (Study Only, Item Repetition, Pair Repetition) on Proportion Hits Minus False Alarms in the 1x and 3x Conditions in Experiment 4

Source	*df*	*F*	η_p^2	*p*
		Between subjects (1x)		
Age (A)	1	12.74**	.63	.001
Error	49	(.14)		
		Within subjects (1x)		
Test (T)	2	74.88**	.60	<.001
A x T	2	18.21**	.27	<.001
Error (T)	98	(.04)		
Repetition (R)	2	16.20**	.25	<.001
A x R	2	.65	.01	.52
Error (R)	98	(.03)		
T x R	4	1.44	.03	.22
A x T x R	4	1.79	.04	.13
Error (T x R)	196	(.02)		
		Between subjects (3x)		
Age (A)	1	10.63**	.18	.002
Error	49	(.16)		
		Within subjects (3x)		
Test (T)	2	86.62**	.64	<.001
A x T	2	36.78**	.43	<.001
Error (T)	98	(.03)		
Repetition (R)	2	56.97**	.54	<.001
A x R	2	.05	<.001	.96
Error (R)	98	(,03)		
T x R	4	8.48**	.15	<.001
A x T x R	4	2.80*	.05	.03
Error (T x R)	196	(.03)		

Note. Values enclosed in parentheses represent mean square errors.
*$p \leq .05$. **$p \leq .01$.

Table E3.

Analyses of Variance for the Effects of Age, Test, and Repetition Type (Study Only, Item Repetition, Pair Repetition) on Proportion Hits in the 1x and 3x Conditions in Experiment 4

Source	*df*	*F*	η_p^2	*p*
		Between subjects (1x)		
Age (A)	1	.03	<.001	.88
Error	49	(.13)		
		Within subjects (1x)		
Test (T)	2	2.67	.05	.07
A x T	2	6.58**	.12	.002
Error (T)	98	(.03)		
Repetition (R)	2	32.53**	.40	<.001
A x R	2	.67	.01	.51
Error (R)	98	(.02)		
T x R	4	3.07*	.06	.02
A x T x R	4	2.78*	.05	.03
Error (T x R)	196	(.02)		
		Between subjects (3x)		
Age (A)	1	.12	.002	.73
Error	49	(.13)		
		Within subjects (3x)		
Test (T)	2	2.99	.06	.06
A x T	2	10.79**	.18	<.001
Error (T)	98	(.02)		
Repetition (R)	2	103.05**	.68	<.001
A x R	2	2.03	.04	.14
Error (R)	98	(.02)		
T x R	4	5.35**	.10	<.001
A x T x R	4	.92	.02	.46
Error (T x R)	196	(.01)		

Note. Values enclosed in parentheses represent mean square errors.
$^*p \leq .05$. $^{**}p \leq .01$.

Table E4.

Analyses of Variance for the Effects of Age, Test, and Repetition Type (Study Only, Item Repetition, Pair Repetition) on Proportion False Alarms in the 1x and 3x Conditions in Experiment 4

Source	*df*	*F*	η_p^2	*p*
		Between subjects (1x)		
Age (A)	1	40.25**	.45	<.001
Error	49	(.05)		
		Within subjects (1x)		
Test (T)	2	119.18**	.71	<.001
A x T	2	33.79**	.41	<.001
Error (T)	98	(.02)		
Repetition (R)	2	3.16*	.06	.05
A x R	2	2.45	.05	.09
Error (R)	98	(.008)		
T x R	4	.57	.01	.69
A x T x R	4	1.34	.03	.26
Error (T x R)	196	(.01)		
		Between subjects (3x)		
Age (A)	1	36.01**	.42	<.001
Error	49	(.06)		
		Within subjects (3x)		
Test (T)	2	105.48**	.68	<.001
A x T	2	42.38**	.46	<.001
Error (T)	98	(.88)		
Repetition (R)	2	6.39**	.12	.002
A x R	2	3.82*	.07	.03
Error (R)	98	(.01)		
T x R	4	3.70**	.07	.01
A x T x R	4	2.12	.04	.08
Error (T x R)	196	(.01)		

Note. Values enclosed in parentheses represent mean square errors.
*$p \leq .05$. **$p \leq .01$.

Table E5.

Mean Frequency of Recollection as a Function of Age, Test, Repetition in Conditions 1x and 3x in Experiment 4.

			1x		3x	
		Study only	Item repetition	Pair repetition	Item repetition	Pair repetition
				Face test		
Young						
	Mean	0.45	0.55	0.44	0.48	0.58
	SD	0.27	0.33	0.27	0.25	0.27
Old						
	Mean	0.24	0.24	0.19	0.27	0.23
	SD	0.29	0.30	0.31	0.32	0.31
				Scene test		
Young						
	Mean	0.60	0.53	0.55	0.55	0.67
	SD	0.25	0.30	0.30	0.30	0.28
Old						
	Mean	0.34	0.33	0.37	0.30	0.39
	SD	0.33	0.36	0.37	0.38	0.36
				Associative test		
Young						
	Mean	0.57	0.63	0.63	0.67	0.68
	SD	0.25	0.28	0.28	0.24	0.26
Old						
	Mean	0.38	0.40	0.38	0.44	0.42
	SD	0.33	0.33	0.35	0.32	0.35

Note. SD=standard deviation.

Table E6.

Mean Frequency of Familiarity as a Function of Age, Test, Repetition in Conditions 1x and 3x in Experiment 4.

			1x		3x	
		Study only	Item repetition	Pair repetition	Item repetition	Pair repetition
				Face test		
Young						
	Mean	0.88	0.77	0.88	0.93	0.73
	SD	0.18	0.41	0.26	0.21	0.42
Old						
	Mean	0.78	0.86	0.81	0.82	0.87
	SD	0.27	0.23	0.29	0.28	0.24
				Scene test		
Young						
	Mean	0.86	0.86	0.78	0.74	0.76
	SD	0.23	0.33	0.36	0.39	0.40
Old						
	Mean	0.77	0.76	0.69	0.82	0.68
	SD	0.32	0.35	0.42	0.30	0.42
				Associative test		
Young						
	Mean	0.77	0.69	0.78	0.80	0.70
	SD	0.30	0.38	0.36	0.34	0.41
Old						
	Mean	0.66	0.69	0.67	0.78	0.69
	SD	0.33	0.30	0.37	0.30	0.34

Note. SD=standard deviation.

Table E7.

Mean Proportion Correct for Remember Responses as a Function of Age, Test, Repetition in Conditions 1x and 3x in Experiment 4.

			1x		3x	
		Study only	Item repetition	Pair repetition	Item repetition	Pair repetition
				Face test		
Young						
	Mean	1.00	0.95	1.00	0.97	0.99
	SD	0.02	0.11	0.00	0.09	0.07
Old						
	Mean	0.89	0.98	0.74	0.93	0.89
	SD	0.27	0.05	0.31	0.15	0.28
				Scene test		
Young						
	Mean	0.99	1.00	1.00	1.00	0.95
	SD	0.03	0.00	0.00	0.00	0.09
Old						
	Mean	0.95	0.97	0.92	0.95	0.95
	SD	0.11	0.06	0.13	0.15	0.10
				Associative test		
Young						
	Mean	0.95	0.89	0.95	0.96	0.96
	SD	0.08	0.21	0.08	0.07	0.07
Old						
	Mean	0.65	0.76	0.72	0.68	0.75
	SD	0.28	0.19	0.21	0.25	0.26

Note. SD=standard deviation.

Table E8.

Mean Proportion Correct for Know Responses as a Function of Age, Test, Repetition in Conditions 1x and 3x in Experiment 4.

			1x		3x	
		Study only	Item repetition	Pair repetition	Item repetition	Pair repetition
				Face test		
Young						
	Mean	0.88	0.87	0.92	0.93	0.94
	SD	0.24	0.20	0.13	0.21	0.13
Old						
	Mean	0.84	0.83	0.91	0.88	0.93
	SD	0.19	0.23	0.12	0.14	0.12
				Scene test		
Young						
	Mean	0.82	0.91	0.93	0.88	0.80
	SD	0.31	0.15	0.15	0.26	0.30
Old						
	Mean	0.95	0.79	0.98	0.92	0.93
	SD	0.10	0.35	0.05	0.22	0.12
				Associative test		
Young						
	Mean	0.66	0.71	0.75	0.65	0.83
	SD	0.23	0.40	0.26	0.33	0.25
Old						
	Mean	0.57	0.59	0.58	0.49	0.63
	SD	0.21	0.29	0.27	0.29	0.26

Note. SD=standard deviation.

Appendix F: Tables of Memory Performance Across Experiments

Table F1.

Mean Proportion Hits Minus Proportion False Alarms as a Function of Age and Test in Experiments 1-4.

Test	Young	Old	Age Difference
		Experiment 1	
Item	.57 (.18)	.50 (.23)	.07
Associative	.46 (.23)	.25 (.21)	.21
		Experiment 2	
Item	.51 (.14)	.53 (.14)	-.02
Associative	.41 (.20)	.41 (.25)	.00
		Experiment 3	
Item	.62 (.18)	.61 (.21)	.01
Associative	.49 (.26)	.20 (.21)	.29
		Experiment 4	
Item	.62 (.17)	.56 (.17)	.06
Associative	.49 (.17)	.26 (.19)	.23

Notes. Standard deviations shown in parentheses. In Experiments 1 and 2, scores were averaged across unitized and non-unitized conditions. In Experiments 3 and 4, scores were taken from the study only condition, and the item score represents the averages of the faces and scenes and taken from the study only condition. The age difference was calculated

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