

Older Adults' Associative Memory Is Modified by Manner of Presentation at Encoding and Retrieval

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Relative to young adults, older adults typically exhibit a reduced ability to accurately remember associations between stimuli. Prior research has assumed that this age-related memory impairment affects different types of associations similarly. However, research in young adults has suggested that item–item and item–context associations are supported by different underlying neural mechanisms that could be unequally affected by aging. This experiment compared memory across association types in younger and older adults by presenting the same types of stimuli as either item–item or item–context pairs. Manner of presentation during retrieval was also manipulated so that pairs were presented in a manner that was either congruent or incongruent with their presentation during encoding. Older adults showed a particular benefit of encoding–retrieval congruency for item–context associations, supporting the idea that the associative deficit may be reduced by unitization at encoding and reinstatement of this prior stimulus configuration at retrieval.

Keywords: associative memory, manner of presentation, item–item, item–context

The need to form and remember associations is a critical aspect of everyday cognitive functioning, and its impairment contributes to reduced quality of life. A considerable body of prior research has shown that older adults exhibit such a deficit in associative memory performance (e.g., Chalfonte & Johnson, 1996; Kausler & Puckett, 1981; Naveh-Benjamin, 2000; Naveh-Benjamin, Hussain, Guez, & Bar-On, 2003; Spencer & Raz, 1995). It is often assumed that the associative deficit applies in a general way to all types of associations (e.g., Li, Naveh-Benjamin, & Lindenberger, 2005). If so, then older adults are predicted to demonstrate impairments in

memory for item–item associations that are similar to those for item–context associations.

However, neuroimaging studies in younger adults have found that item–item and item–context associations are supported by different subregions of the medial temporal lobe (MTL; Diana, Yonelinas, & Ranganath, 2010, 2012). One framework for defining the roles of these MTL subregions is the binding of item and context model of associative memory (Diana, Yonelinas, & Ranganath, 2007), which suggests that whereas cortical MTL regions support processing of individual items and contexts, the hippocampus is responsible for forming the links between these two aspects of episodes in memory. Additional research in younger adults has shown that the extent to which associative information is integrated (i.e., unitized) can reduce the demand on the binding component of associative memory and shift processing from the hippocampus to the perirhinal cortex (Diana, Yonelinas, & Ranganath, 2008; Haskins, Yonelinas, Quamme, & Ranganath, 2008; Ranganath, 2010; Staresina & Davachi, 2010). It is possible that certain manners of stimulus presentation at encoding and retrieval are more likely to engender unitization than others are. This would be a great benefit to older adults because it would provide a means to encode and retrieve associations without the need to rely on brain structures that show significant age-related degradation (e.g., hippocampus; Raz et al., 2005).

Thus, in light of the neuroimaging research on unitization, and on item–item and item–context processing in the MTL, there is reason to predict that item–item and item–context associations might not be uniformly affected by aging and that unitization might have a different role in memory performance for the two association types. Prior studies of memory in older adults have been unable to directly compare the two association types because

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of the confound that the types of stimuli typically used as items are different from those used as contexts (i.e., items have often been words, faces, or objects, whereas contexts have been scenes, voices, or colors). However, the terms *item* and *context* need not be tied to particular stimulus properties. Rather, those terms reflect different *roles* that can be played by any given piece of information. Contexts typically consist of information that is more peripheral (i.e., less focal) and less temporally variable than item information is (e.g., Murnane, Phelps, & Malmberg, 1999). Thus, stimuli such as scenes are often used as contexts because they can easily be placed in this type of “background” role. However, associative memory experiments that use scenes only as contexts conflate stimulus type with context role. To overcome this critical confound, we conducted two experiments in which we constructed face–scene pairs that could be used in either item–item or item–context encoding conditions. In doing so, we were able to manipulate the manner of presentation at encoding, without confounding stimulus type with association type, by using these pairs of domain-specific stimuli (face and scenes) and inducing those pairs to be processed as either item–item or item–context pairs depending on the manner of presentation.

In addition to factors that influence encoding of associations as item–item and item–context, there may be important retrieval factors related to the two association types as well. Previous research on context reinstatement in older adults has claimed that older adult deficit in binding context is due to impaired retrieval processes (Vakil, Hornik, & Levy, 2008). Additionally, previous research in younger adults has also shown that when unitization takes place at encoding and the retrieval cue matches that unitized ensemble, old–new discrimination is enhanced (e.g., Murnane et al., 1999). Therefore, reinstating the same unitization-supportive presentation manner at retrieval may result in improved associative memory performance, particularly for older adults. Because item–context associations in older adults may be particularly sensitive to the reinstatement of context during retrieval, it was also important to examine whether the association types were affected differently by the degree to which retrieval presentation matched encoding. Thus, we also manipulated manner of presentation during the retrieval phase so that pairs were presented in a manner of presentation that was either congruent or incongruent with their presentation during encoding.

Experiment 1

Method

Participants. Based on prior studies of associative memory (e.g., Naveh-Benjamin, 2000), our goal was a sample size of 30 participants in each age group. Young adults were recruited from introductory psychology courses at Elon University, and older adults were recruited from the local community surrounding Elon University. Data were collected from 32 younger adults, and two were excluded. One was excluded due to a computer malfunction, and the other did not complete the task correctly. Therefore, 30 younger adults were included in the analysis (mean age = 19.50 years, $SD = 1.03$). Data were collected from 35 older adults, and five were excluded because they did not complete the task correctly (during debriefing, participants were asked to describe how they had performed the task, and data were excluded from partic-

ipants who indicated that they had not paid attention to both the faces and scenes or that they had been otherwise confused or inconsistent in following the instructions). Therefore, 30 older adults were included in the analysis (mean age = 72.97 years, $SD = 4.85$; Mini-Mental State Examination [MMSE; Folstein, Folstein, & McHugh, 1975]: $M = 29.30$, $SD = .99$). No participants reported any history of neurological or psychiatric disorders, and all had MMSE scores above 25. All individuals received course credit or financial compensation for their participation. All experimental procedures were approved by Elon University’s Institutional Review Board for the ethical treatment of human participants.

Materials. The face stimuli consisted of both male and female faces, each exhibiting a neutral expression, taken from the following online databases: the Color Facial Recognition Technology (FERET) database (Phillips, Moon, Rizvi, & Rauss, 2000; Phillips, Wechsler, Huang, & Rauss, 1998), the adult face database from Denise Park’s lab (Minear & Park, 2004), the AR face database (Martinez & Benavente, 1998), and the FRI Computer Vision Laboratory Face Database (Solina, Peer, Batageli, Juvan, & Kovac, 2003). The scene stimuli consisted of scenes collected from an Internet image search and did not contain any faces or words.

Procedure. During the encoding phase face–scene pairs were presented in a manner that characterized them either as an item (face) embedded within a context (scene) or as two independent items. To accomplish this, we manipulated both the focality and temporal variability of scenes across the item–context and item–item conditions. Specifically, in the item–context encoding list, scenes were presented as contexts by placing them behind the faces (reduced focality) and blocking scene types together (reduced temporal variability). Figure 1 illustrates the experimental design. Participants were aware that they were completing a memory task and were instructed verbally and with written text at the beginning of the experiment that they should pay attention to both the face and scene in each pairing.

A slide presented at the beginning of each block designated which scene type would be viewed in the upcoming set of trials (e.g., kitchen, restaurant, office, living room). In the item–item encoding list, scenes were presented as items by placing them next to faces and allowing scene type to vary randomly from trial to trial. Below each pairing was the encoding task question “How welcoming?” along with four response options, ranging from 1 (*not at all*) to 4 (*very*). Two encoding lists each contained 40 unique face–scene pairs that were viewed for 4 s each. Participants studied both lists in succession, and list order was counterbalanced. Stimulus pairs were arranged so that each scene type had equal numbers of associations with female and male faces and equal numbers of associations that would subsequently be presented with congruent and incongruent retrieval configuration.

Retrieval occurred immediately after participants completed the second encoding list. During the retrieval phase, the critical manipulation was that face–scene pairs were presented either (a) in a manner that was congruent with the encoding presentation or (b) in an incongruent format (i.e., the opposite presentation format from what was presented at encoding). Below each pairing was the associative memory question “Did this face and scene appear together previously?” along with the response options YES and NO. There were 80 retrieval pairs,

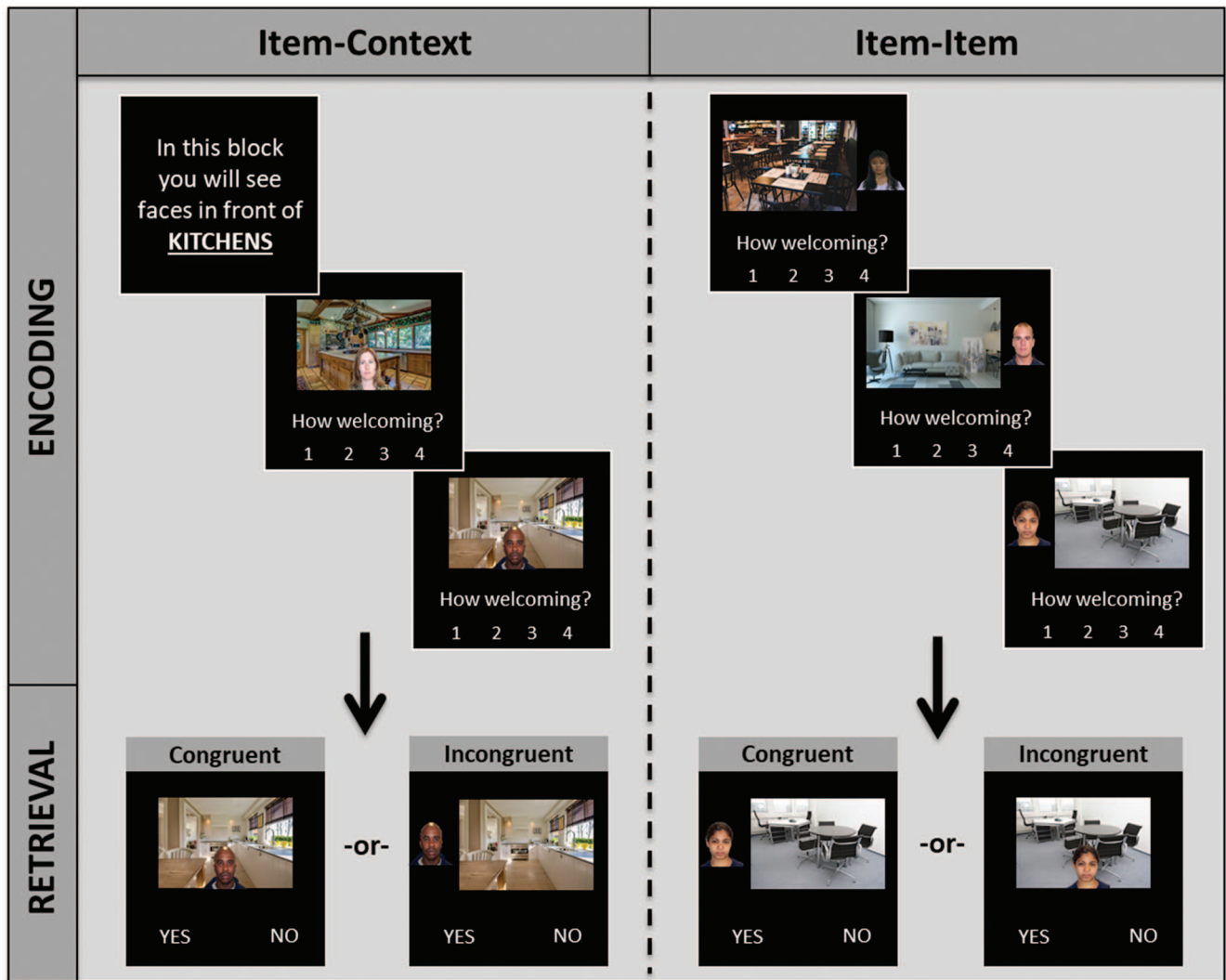


Figure 1. Item–context and item–item encoding conditions in Experiment 1. For the item–item condition, the face and the scene were presented side-by-side and the category of scene changed for each trial. For the item–context condition, the face was presented superimposed on the scene and the scenes were blocked by category (although the particular scene within the category changed on each trial). Encoding conditions were presented in two consecutive lists, with list order counterbalanced across participants. During the retrieval phase, congruent and incongruent test trials were based on whether the face and scene were presented in the same configuration as during encoding. Facial images in this figure are from the Color Facial Recognition Technology (FERET) database (Phillips, Moon, Rizvi, & Rauss, 2000; Phillips, Wechsler, Huang, & Rauss, 1998) or the adult face database from Denise Park’s lab (Minear & Park, 2004). See the online article for the color version of this figure.

evenly divided into intact and rearranged pairs. Intact pairs were exactly the same items and same pairs as during encoding, and rearranged pairs contained items that were previously studied but the pair itself was novel. Rearranged pairs from both encoding conditions were rearranged only within the same scene type (e.g., faces studied with kitchens were tested with only kitchens), so that rearranged pairs could be excluded based on only the specific face and scene and not the scene category, in both item–item and item–context conditions. Both intact and rearranged pairs were divided evenly between congruent and incongruent presentation retrieval. Participants were instructed

to make their judgments based on the co-occurrence of the face and scene and not on the configuration of the display. For both encoding and retrieval, participants were given written instructions and were asked to explain the task instructions to the experimenter before beginning to ensure that they understood how to complete the task.

Results

Figure 2 presents the data in terms of signal-detection measures (i.e., d' and C), as well as hit and false alarm rates, across the four

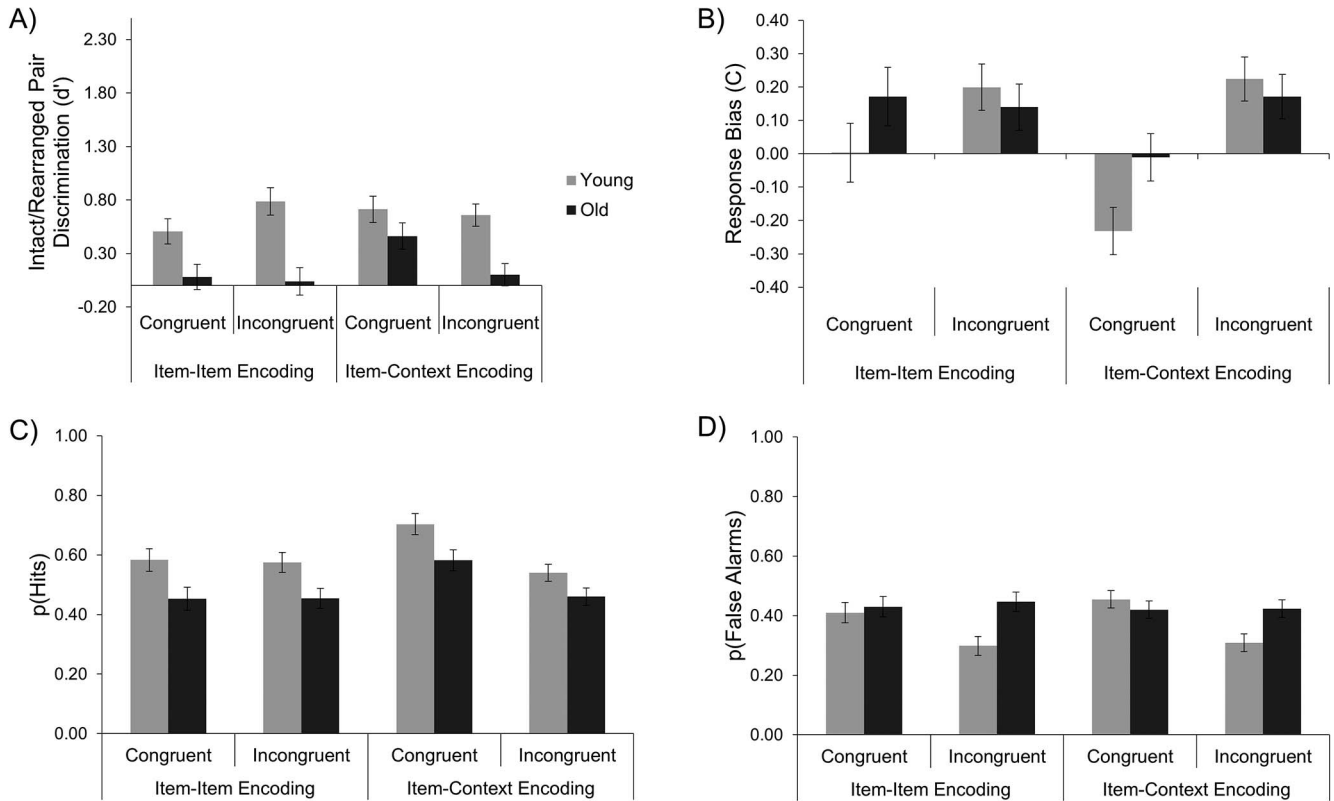


Figure 2. Experiment 1 results. Panel A: Mean d' for young and older adults in each condition. Panel B: Mean response bias (C) for young and older adults in each condition. Panel C: Mean hit rates for young and older adults in each condition. Panel D: Mean false alarm rates for young and older adults in each condition. Error bars represent the standard error of the mean for each panel.

conditions for both age groups. Statistical analyses of these data are reported in the next sections.

Old–new discrimination. To evaluate old–new discrimination in recognition memory, we computed d' for associations based on responses to intact and rearranged pairs from test trials for both congruent and incongruent retrieval configurations. A 2 (encoding presentation: item–item vs. item–context) \times 2 (retrieval presentation: congruent vs. incongruent with encoding) \times 2 (age group: younger vs. older adults) analysis of variance (ANOVA) was used to examine memory performance. There was a significant effect of age, $F(1, 58) = 21.95, p < .001, MSE = 14.74, \eta_p^2 = .275$, such that young adults had higher memory performance compared to older adults. The effect of encoding presentation was not significant, $F(1, 58) = 3.25, p = .077, MSE = 1.03$, nor was the effect of retrieval congruency, $F(1, 58) = .35, p = .554, MSE = .12$. There was a significant retrieval Congruency \times Age Group interaction, $F(1, 58) = 4.61, p = .036, MSE = 1.50, \eta_p^2 = .074$. Follow-up t tests indicated that young adults performed better than older adults did in both the congruent retrieval presentation, $t(58) = 2.64, p = .011$, and the incongruent retrieval presentation, $t(58) = 5.03, p < .001$; the interaction reflects a greater age difference in the incongruent versus congruent retrieval presentations. There was also a significant Encoding Presentation \times Retrieval Congruency interaction, $F(1, 58) = 4.36, p = .041, MSE = 1.62, \eta_p^2 = .07$. Follow-up t tests indicated that for item–context

encoding, retrieval presentation that was congruent with encoding led to better performance than did incongruent retrieval presentation, $t(59) = 2.11, p = .039$. However, for item–item encoding, there was no difference in memory performance depending on retrieval presentation, $t(59) = 1.02, p = .312$. There was no Encoding Presentation \times Age Group interaction, $F(1, 58) = 1.584, p = .213, MSE = .50$, and no three-way interaction, $F(1, 58) = .002, p = .962, MSE = .001$. Together, the observed interactions suggest that congruency between encoding and retrieval benefits older adults more than young adults and benefits item–context associations more than item–item associations. These two effects come together to produce older adults' noticeably better performance for item–context pairs with congruent retrieval presentation relative to other conditions, as seen in Figure 2.

Response bias. To evaluate response bias in recognition memory, we computed C for associations based on responses to intact and rearranged pairs from test trials for both congruent and incongruent retrieval configurations. A 2 (encoding presentation: item–item vs. item–context) \times 2 (retrieval congruency: congruent vs. incongruent with encoding) \times 2 (age group: younger vs. older adults) ANOVA indicated a significant main effect of retrieval congruency, $F(1, 58) = 27.59, p < .001, MSE = 2.41, \eta_p^2 = .322$, such that more conservative bias was present for incongruent retrieval ($M = .18, SE = .04$) compared to congruent retrieval presentation ($M = -.02, SE = .04$). There was a significant

Retrieval Congruency \times Age Group interaction, $F(1, 58) = 10.77$, $p = .002$, $MSE = .94$, $\eta_p^2 = .157$. Follow-up t tests indicated that young adults had a more liberal response bias for congruent retrieval compared to incongruent retrieval presentation, $t(29) = 6.63$, $p < .001$. For older adults, there was no difference in response bias between the two retrieval presentations, $t(29) = 1.29$, $p = .208$. There was also a significant Encoding Presentation \times Retrieval Congruency interaction, $F(1, 58) = 6.62$, $p = .013$, $MSE = .84$, $\eta_p^2 = .102$. Follow-up t tests indicated more liberal response bias for congruent retrieval compared to incongruent retrieval presentation for item–context encoding, $t(59) = 4.75$, $p < .001$, but no difference was found in item–item encoding, $t(59) = 1.49$, $p = .141$. There was no main effect of age, $F(1, 58) = .92$, $p = .34$, $MSE = .29$; no main effect of encoding, $F(1, 58) = 3.55$, $p = .065$, $MSE = .49$; no Encoding Presentation \times Age Group interaction, $F(1, 58) = .10$, $p = .757$, $MSE = .01$; and no three-way interaction, $F(1, 58) = .06$, $p = .80$, $MSE = .01$.

Hits and false alarms. To enable further interpretation of old–new discrimination performance, we analyzed hit and false alarm rates separately. For hits, a 2 (encoding presentation: item–item vs. item–context) \times 2 (retrieval presentation: congruent vs. incongruent with encoding presentation) \times 2 (age group: younger vs. older adults) ANOVA found a significant main effect of age, $F(1, 58) = 16.188$, $p < .001$, $MSE = .77$, $\eta_p^2 = .22$, such that young adults had greater hit rates than older adults did; a significant main effect of encoding presentation, $F(1, 58) = 6.23$, $p = .015$, $MSE = .18$, $\eta_p^2 = .10$, such that hit rates were greater for item–context encoding than for item–item encoding; and a significant main effect of retrieval congruency, $F(1, 58) = 10.56$, $p = .002$, $MSE = .32$, $\eta_p^2 = .15$, such that hit rates were greater for congruent retrieval presentation than for incongruent retrieval presentation. There was also a significant Encoding Presentation \times Retrieval Congruency interaction, $F(1, 58) = 8.30$, $p = .006$, $MSE = .288$, $\eta_p^2 = .13$. Follow-up t tests indicated that hit rates were greater for congruent than for incongruent retrieval with item–context encoding, $t(59) = 2.11$, $p = .039$, but not with item–item encoding, $t(59) = 1.02$, $p = .31$. There was no Encoding Presentation \times Age Group interaction, no Retrieval Congruency \times Age Group interaction, and no three-way interaction (all $F_s < 1$).

For false alarms, a 2 (encoding presentation: item–item vs. item–context) \times 2 (retrieval presentation: congruent vs. incongruent with encoding presentation) \times 2 (age group: younger vs. older adults) ANOVA found a significant main effect of retrieval congruency, $F(1, 58) = 17.34$, $p < .001$, $MSE = .212$, $\eta_p^2 = .23$, such that congruent retrieval presentation had a higher rate of false alarms compared to incongruent retrieval presentation. There was a significant Age Group \times Retrieval Congruency interaction, $F(1, 58) = 23.67$, $p < .001$, $MSE = .29$, $\eta_p^2 = .29$. Follow-up t tests within each age group indicated that for young adults, false alarms were reduced for incongruent retrieval presentation versus congruent retrieval presentation, $t(29) = -6.65$, $p < .001$, but for older adults there was no difference in false alarm rate between the two retrieval presentations, $t(29) = .48$, $p = .637$. The main effect of age group was not significant, $F(1, 58) = 3.51$, $p = .066$, $MSE = .23$; there was no Encoding Presentation \times Age Group interaction, $F(1, 58) = 1.26$, $p = .266$, $MSE = .03$; and there was no main effect of encoding presentation, no Encoding Presentation \times Re-

trieval Congruency interaction, and no three-way interaction (all $F_s < 1$).

Discussion

The results of Experiment 1 suggest that the associative deficit may be reduced for item–context associations when presented at retrieval in the same configuration as at encoding. Older adults' greatest performance was in the condition with item–context encoding and congruent retrieval, whereas their discrimination performance in the other conditions was at or near chance level. This pattern in the older adults resulted from a higher hit rate for the item–context congruent condition, whereas older adults' false alarm rates were similar (and relatively high) across all conditions. Indeed, both age groups had their highest hit rates for item–context congruent pairs, suggesting that intact pairs in that condition provided additional associative support (e.g., ensemble features; [Murnane et al., 1999](#)) for matching to the encoded memory trace. Other differences between young and older adult performance in Experiment 1 are attributable to young adults' lower false alarm rates in the incongruent conditions, whereas older adults were less affected by congruency in false alarms. These false alarm differences were also reflected in the Retrieval Congruency \times Age Group interaction in response bias, such that young adults had a stricter criterion in incongruent conditions, whereas congruency did not significantly affect older adults' response bias. The fact that older adults did not reject incongruent pairs at a higher rate than congruent pairs may reflect a reduced degree of recollection of episodic details relative to young adults (e.g., [Jennings & Jacoby, 1993](#)).

Some caution is warranted in interpreting the age differences in Experiment 1, due to older adults' performance being so poor in several of the conditions. This could have obscured some meaningful differences between the conditions that were near chance level. Thus, to replicate the current results and test these conditions at a higher level of older adult performance, we conducted a second experiment, in which the memory task of Experiment 1 was broken up into several shorter encoding–retrieval sets.

Experiment 2

Experiment 2 modified the design of Experiment 1 to reduce the length of individual encoding and retrieval tasks by breaking the procedure into several shorter sets. An additional modification in Experiment 2 was that we eliminated the blocking by scene type that was used during item–context encoding in Experiment 1. Because Experiment 1 suggested that the combination of encoding configuration and retrieval congruency affected older adults' associative memory, it was important to focus the design more specifically on pair configuration without also confounding pair configuration with temporal blocking. Thus, a completely different set of scenes, which included many different scene types, was used. It was also our aim that the greater variety of scene types would aid in making the task less difficult by reducing the degree of similarity across scenes. This modification also made it possible to mix item–item and item–context pairs within each encoding list, eliminating the need to counterbalance encoding condition order as in Experiment 1.

Method

Participants. Young adults were recruited from introductory psychology courses at the Pennsylvania State University, and older adults were recruited from the local community surrounding Elon University. Data were collected from 30 younger adults (mean age = 19.57 years, $SD = 1.36$). Data were collected from 30 older adults, but one was excluded because of a computer malfunction when recording the data. Therefore, 29 older adults were included in the analysis (mean age = 74.07 years, $SD = 4.60$; MMSE: $M = 29.31$, $SD = .89$). No participants reported any history of neurological or psychiatric disorders, and all had MMSE scores above 25. All individuals received course credit or financial compensation for their participation. All experimental procedures were approved by the Pennsylvania State University's Institutional Review Board for the ethical treatment of human participants.

Materials. The face stimuli were selected from the same databases as in Experiment 1. Fifty-six additional faces were added to the stimulus set to bring the total number of faces to 136. A new set of 136 scene stimuli was drawn from the scenes used by Dennis, Turney, Webb, and Overman (2015). These images included a broad variety of indoor and outdoor scenes that were not organized into any particular subcategories.

Procedure. Participants completed four encoding–retrieval sets, each consisting of 34 encoding trials and 34 test trials. As in Experiment 1, encoding lists presented each face–scene pair as either an item (face) embedded within a context (scene) or as two independent items, by manipulating the focality of the scenes. In item–context encoding trials, scenes were placed behind faces (reduced focality), and in the item–item encoding trials, scenes were presented placed next to faces. There was no temporal blocking of scene type as in Experiment 1. Instead, equal numbers (i.e., 17 each) of item–item and item–context trials were randomly intermixed within each encoding list. Below each pairing was the encoding task question “How welcoming are the scene and face?” along with four response options, ranging from 1 (*not at all*) to 4 (*very*). As in Experiment 1, participants were instructed to pay attention to both the faces and scenes during encoding. Each face–scene pair was viewed for 4 s each. Figure 3 illustrates the experimental design.

Each retrieval phase occurred immediately following each encoding phase. As in Experiment 1, the critical manipulation was that pairs were presented in a manner that was either congruent or incongruent with the encoding presentation that had been used for the stimuli in the pair. Below each pairing was the associative memory question “Did this face and scene appear together previously?” along with the response options YES and NO. For each encoding phase, there were 34 retrieval pairs, divided into 18 intact pairs (nine each from item–item and item–context encoding conditions) and 16 rearranged pairs (eight each from item–item and item–context encoding conditions). Intact pairs were exactly the same items and same pair as during encoding, and rearranged pairs contained items that were previously studied but the pair itself was novel. Pairs were rearranged only with the same encoding condition, so that the face and scene within any test pair had always been studied in the same type of pair as each other. Because of the uneven number of intact pairs in each test list, the number of congruent and incongruent trials varied slightly across test lists: Specifically, in the first and third retrieval phases, five congruent

and four incongruent retrieval trials were presented for intact pairs in each of the encoding conditions. In the second and fourth retrieval phases, four congruent and five incongruent retrieval trials were presented for intact pairs in each of the encoding conditions (For rearranged pairs, there were always four congruent and four incongruent pairs from each encoding condition.) As in Experiment 1, participants were instructed to make their judgments based on the co-occurrence of the face and scene and not base their judgments on the configuration of the display. For both encoding and retrieval, participants were given written instructions and were asked to explain the task instructions to the experimenter before beginning to ensure that they understood task objectives.

Results

Figure 4 presents the data in terms of signal-detection measures (d' and C), as well as hit and false alarm rates, across the four conditions for both age groups. Statistical analyses of these data are reported in the next sections.

Old–new discrimination. As in Experiment 1, d' was computed for associations based on responses to intact and rearranged pairs from test trials for both congruent and incongruent retrieval configurations. A 2 (encoding presentation: item–item vs. item–context) \times 2 (retrieval presentation: congruent vs. incongruent with encoding) \times 2 (age group: younger vs. older adults) ANOVA was used to examine memory performance. There was a significant effect of age, $F(1, 57) = 14.56$, $p < .001$, $MSE = 29.06$, $\eta_p^2 = .203$, such that young adults had higher memory performance compared to older adults; a significant main effect of encoding presentation, $F(1, 57) = 4.98$, $p = .030$, $MSE = 1.13$, $\eta_p^2 = .080$, such that memory performance was greater for item–context encoding; and a significant main effect of retrieval congruency, $F(1, 57) = 8.06$, $p = .006$, $MSE = 2.02$, $\eta_p^2 = .124$, such that memory performance was greater for congruent retrieval presentation than for incongruent retrieval presentation. There was also a significant Encoding Presentation \times Age Group interaction, $F(1, 57) = 9.47$, $p = .003$, $MSE = 2.14$, $\eta_p^2 = .142$. Follow-up t tests indicated that older adults performed better when pairs were encoded in the item–context presentation format than in the item–item presentation, $t(28) = 3.59$, $p = .001$. However, for young adults, there was no difference in memory performance depending on encoding presentation, $t(29) = .63$, $p = .536$. There was no Retrieval Congruency \times Age Group interaction, no Encoding Presentation \times Retrieval Congruency interaction, and no three-way interaction (all F s < 1).

Response bias. To evaluate response bias in recognition memory, we computed C for associations based on responses to intact and rearranged pairs from test trials for both congruent and incongruent retrieval configurations. A 2 (encoding presentation: item–item vs. item–context) \times 2 (retrieval presentation: congruent vs. incongruent with encoding) \times 2 (age group: younger vs. older adults) ANOVA indicated a significant main effect of retrieval congruency, $F(1, 57) = 112.53$, $p < .001$, $MSE = 4.40$, $\eta_p^2 = .664$, such that more conservative bias was found for incongruent retrieval presentations ($M = .29$) compared to congruent retrieval presentations ($M = .01$). There was a significant Retrieval Congruency \times Age Group interaction, $F(1, 57) = 4.34$, $p = .042$, $MSE = .17$, $\eta_p^2 = .071$. Follow-up t tests revealed more conservative response bias in incongruent retrieval presentations com-

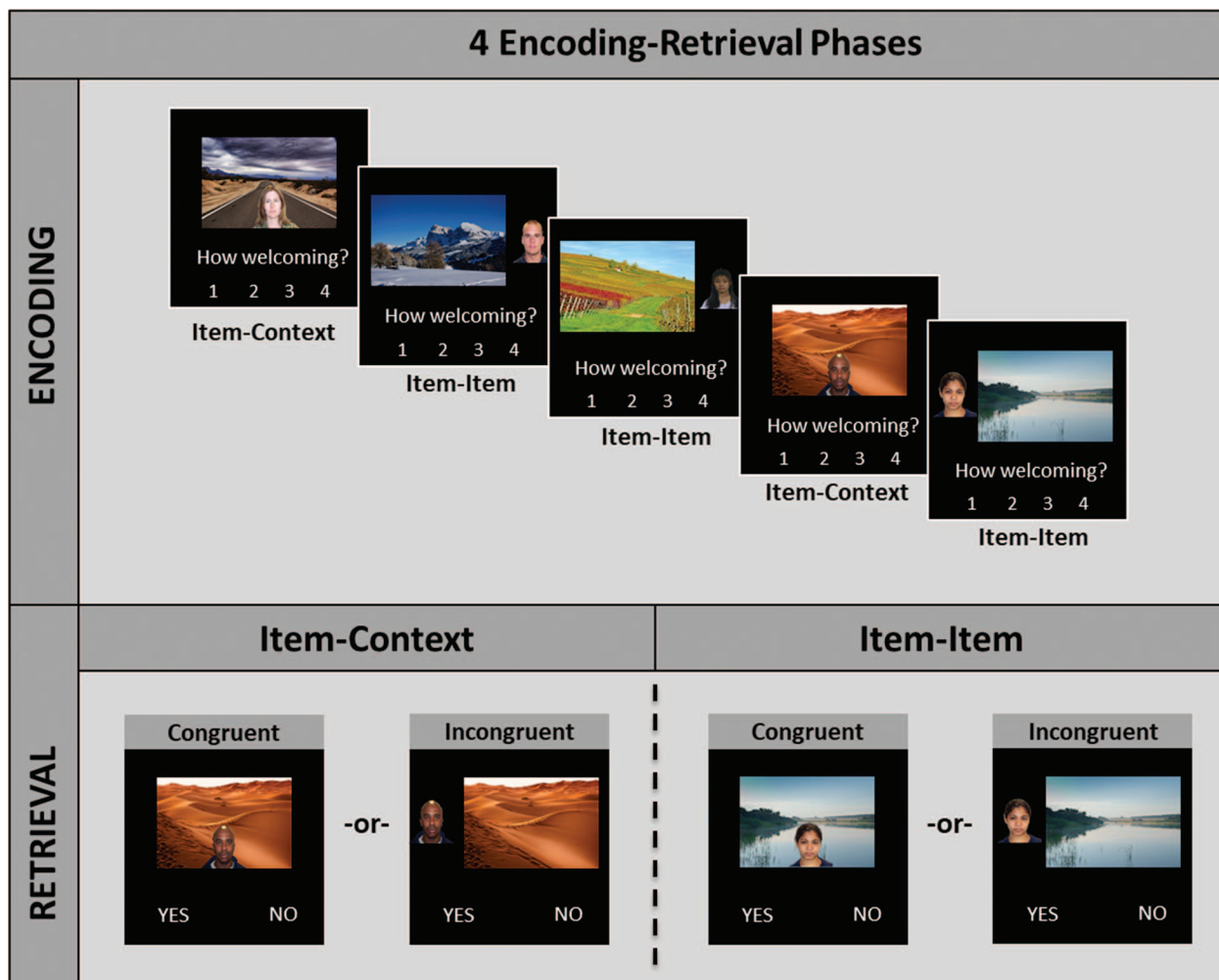


Figure 3. Item–context and item–item encoding conditions in Experiment 2. The blocking aspect of the design was removed so that item–context and item–item trials were intermixed in a single encoding list. As in Experiment 1, congruent and incongruent test trials were based on whether the face and scene were presented in the same configuration as during encoding. Facial images in this figure are from the Color Facial Recognition Technology (FERET) database (Phillips, Moon, Rizvi, & Rauss, 2000; Phillips, Wechsler, Huang, & Rauss, 1998) or the adult face database from Denise Park’s lab (Minear & Park, 2004). See the online article for the color version of this figure.

pared to congruent retrieval presentations in both young adults, $t(29) = 7.13, p < .001$, and older adults, $t(28) = 7.86, p < .001$. There was a significant Encoding Presentation \times Retrieval Congruency interaction, $F(1, 57) = 26.14, p < .001, MSE = 2.20, \eta_p^2 = .314$. Follow-up t tests indicated more conservative bias for incongruent retrieval compared to congruent retrieval with item–context encoding, $t(58) = 9.67, p < .001$, but no difference with item–item encoding, $t(58) = 1.80, p = .077$. There was no main effect of age, $F(1, 57) = 1.61, p = .21, MSE = .53$; no main effect of encoding, $F(1, 57) = 3.30, p = .074, MSE = .23$; no Encoding Presentation \times Age Group interaction, $F(1, 57) = .01, p = .912, MSE = .001$; and no three-way interaction, $F(1, 57) = 1.70, p = .198, MSE = .14$.

Hits and false alarms. To enable further interpretation of old–new discrimination performance, we analyzed hit and false

alarm rates separately. For hits, a 2 (encoding presentation: item–item vs. item–context) \times 2 (retrieval presentation: congruent vs. incongruent with encoding presentation) \times 2 (age group: younger vs. older adults) ANOVA found a significant main effect of age, $F(1, 57) = 17.74, p < .001, MSE = 1.07, \eta_p^2 = .24$, such that young adults had greater hit rates than older adults did; a significant main effect of encoding presentation, $F(1, 57) = 8.39, p = .005, MSE = .08, \eta_p^2 = .128$, such that hit rates were greater for item–context encoding than for item–item encoding; and a significant main effect of retrieval congruency, $F(1, 57) = 88.47, p < .001, MSE = .66, \eta_p^2 = .61$, such that hit rates were greater for congruent retrieval presentation than for incongruent retrieval presentation. There was also a significant Encoding Presentation \times Age interaction, $F(1, 57) = 4.83, p = .032, MSE = .04, \eta_p^2 = .08$. Follow-up t tests indicated that older adults had higher hit rates for

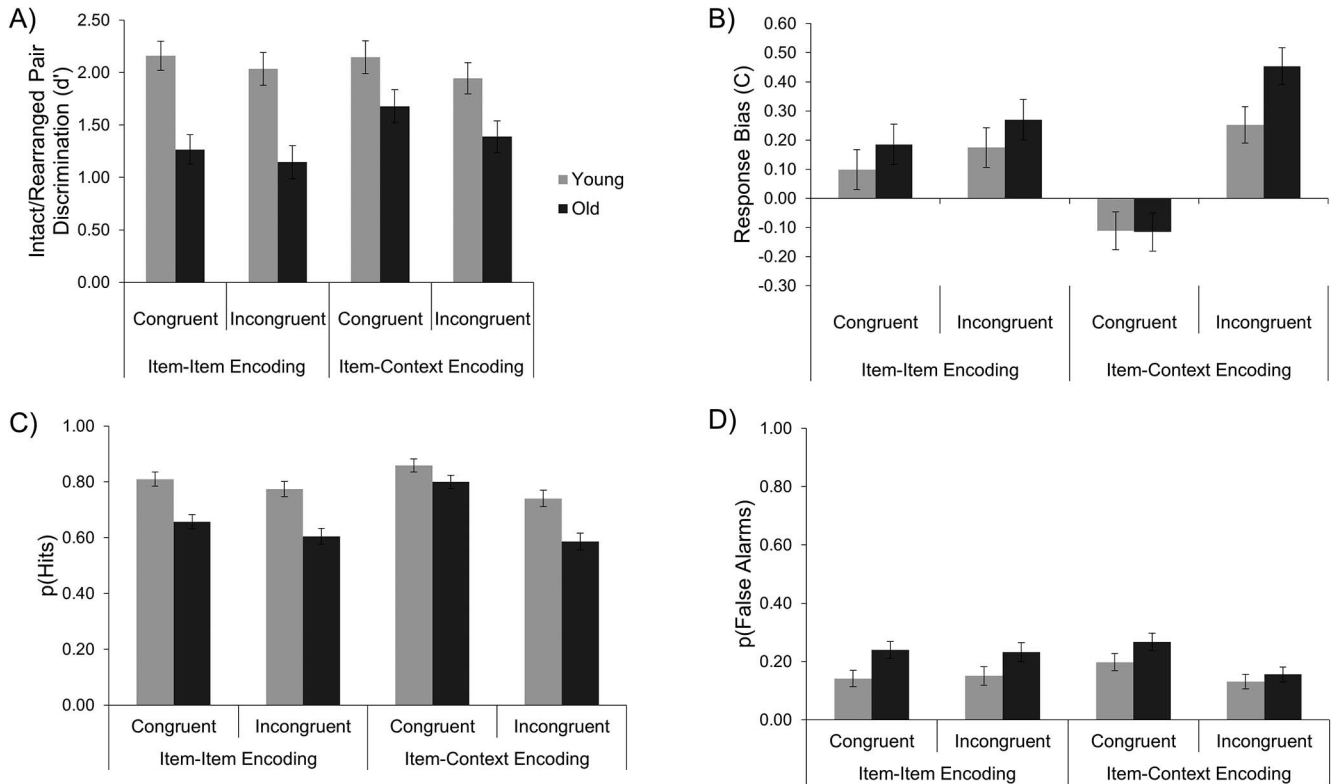


Figure 4. Experiment 2 results. Panel A: Mean d' for young and older adults in each condition. Panel B: Mean response bias (C) for young and older adults in each condition. Panel C: Mean hit rates for young and older adults in each condition. Panel D: Mean false alarm rates for young and older adults in each condition. Error bars represent the standard error of the mean for each panel.

item–context encoding compared to item–item encoding, $t(28) = 4.01$, $p < .001$, but young adults showed no difference between the two encoding conditions, $t(29) = .45$, $p = .653$. There was also a significant Retrieval Congruency \times Age Group interaction, $F(1, 57) = 6.07$, $p = .017$, $MSE = .05$, $\eta_p^2 = .10$. Follow-up t tests indicated that hit rates were greater for congruent retrieval presentation compared to incongruent presentation in both the young adults, $t(29) = 5.74$, $p < .001$, and the older adults, $t(28) = 7.40$, $p < .001$; the interaction indicates that this effect was greater for older adults. There was also a significant Encoding Presentation \times Retrieval Congruency interaction, $F(1, 57) = 24.79$, $p < .001$, $MSE = .22$, $\eta_p^2 = .30$. Follow-up t tests indicated that hit rates were greater for item–context compared to item–item encoding for congruent retrieval presentation, $t(58) = 5.52$, $p < .001$, but not with incongruent retrieval presentation, $t(58) = 1.44$, $p = .156$. The three-way interaction was not significant, $F(1, 57) = 2.50$, $p = .119$, $MSE = .02$.

For false alarms, a 2 (encoding presentation: item–item vs. item–context) \times 2 (retrieval presentation: congruent vs. incongruent with encoding presentation) \times 2 (age group: younger vs. older adults) ANOVA found a significant main effect of retrieval congruency, $F(1, 57) = 13.47$, $p = .001$, $MSE = .12$, $\eta_p^2 = .191$, such that false alarm rates were higher in congruent retrieval presentations compared to incongruent retrieval presentations. There was a significant Encoding Presentation \times Retrieval Congruency interaction, $F(1, 57) = 9.70$, $p = .003$, $MSE = .12$, $\eta_p^2 = .145$.

Follow-up t tests indicated that false alarm rates were greater for congruent retrieval compared to incongruent retrieval with item–context encoding, $t(58) = 4.76$, $p < .001$, but not with item–item encoding. There was no main effect of age group, $F(1, 57) = 3.93$, $p = .052$, $MSE = .28$; no main effect of encoding presentation, $F(1, 57) = .06$, $p = .805$, $MSE = .000$; no Encoding Presentation \times Age Group interaction, $F(1, 57) = 3.47$, $p = .068$, $MSE = .027$; no Retrieval Congruency \times Age Group interaction, $F(1, 57) = 1.69$, $p = .199$, $MSE = .02$; and no three-way interaction, $F(1, 57) = .228$, $p = .635$, $MSE = .003$.

Discussion

Experiment 2 succeeded in improving the performance of older adults above the chance-level discrimination performance seen in some of the conditions in Experiment 1. What is particularly noticeable in the pattern of older adult performance in Experiment 2 is that older adults' discrimination of intact versus rearranged face–scene pairs was qualitatively similar across conditions to their performance in Experiment 1. Specifically, older adults' performance was best for pairs that were studied in item–context configuration and tested in the same (congruent) configuration.

Although older adults' pattern of performance across conditions was similar across experiments, young adults exhibited a somewhat different pattern of performance in Experiment 2 than in Experiment 1. For example, young adults had slightly lower per-

formance in both of the incongruent conditions relative to the congruent conditions in Experiment 2, whereas in Experiment 1, young adults' performance was highest in the item-item incongruent condition. Because of the young adult differences between experiments, the age group differences observed in Experiment 2 did not entirely match those found in Experiment 1. In Experiment 1, it was clear that the smallest age group difference in discrimination performance occurred specifically for item-context pairs with congruent retrieval. In Experiment 2, age group differences were reduced for item-context versus item-item pairs but not substantially more so for congruent versus incongruent retrieval presentations.

Examining the data more closely, we deduced that some of the differences in young adult performance between experiments may be attributable to their patterns of false alarm rates. In Experiment 2, both age groups showed a modest main effect of congruency on false alarms, whereas in Experiment 1, younger adults showed a more pronounced difference in false alarm rates based on congruency (and an age interaction resulting from the lack of any effect of congruency on older adults' false alarms; we further interpret these false alarm patterns in the General Discussion section). Similarly, the response bias measures were more similar across age groups in Experiment 2 than in Experiment 1. Also worth noting is that the pattern of hit rates was quite similar for both age groups across experiments, such that the item-context congruent condition had the highest hit rate. Again, this suggests that both age groups were able to make use of extra associative information for matching intact pairs to previously studied pairs in that condition.

General Discussion

This study investigated whether age groups differ in memory for item-item versus item-context associations and the extent to which memory for these different types of associations depends on congruency between encoding and retrieval presentation. It is important to note that we used a novel paradigm in which the stimuli that constituted item-item and item-context pairs were exactly the same (faces and scenes). It was only the manner of presentation of stimuli that induced processing of the pairs either as two items or as an item and a context.

With respect to discrimination of intact versus rearranged pairs (d'), Experiment 1 showed a reduced age-related deficit for item-context associations when stimulus presentation at retrieval was congruent with its encoding presentation. Older adults did not benefit nearly as much from encoding-retrieval presentation congruency for item-item associations as they did for item-context associations. Experiment 2 corroborated the finding that older adults' performance was best for item-context pairs with congruent retrieval; additionally, there was a smaller age difference for item-context associations compared to memory for item-item associations. Taken together, it is safe to conclude that encoding presentation can modulate the associative deficit. The findings regarding retrieval congruency are more nuanced: Although retrieval congruency affects associative memory in both age groups, its impact on the associative deficit may be conditional on task difficulty. In the present study, retrieval congruency modulated the age-related associative deficit in the more demanding version of the memory task (Experiment 1) but not in the easier version (Experiment 2). Further research is needed to resolve the degree to

which the associative deficit is modulated by congruency between encoding and retrieval presentation.

The fact that older adults' best performance was seen for item-context associations with congruent presentation at retrieval supports the idea that older adults' associative memory may particularly benefit from conditions that support unitization. One key difference between the item-item and item-context conditions in the present experiments was the visual integration of the face and scene in the item-context condition. That is, by our superimposing the two associative elements, the item-context presentation may have lent itself to being encoded as a blended or unitized representation. Past work by Moses and Ryan (2006) has suggested that blended or unitized representations do not allow for individual components of the association to be extracted from the whole. Rather, they are processed as a single unit. Building on this framework, the current findings suggest that the item-context presentation allowed for integration of the face and the scene in such a way that the two representations blended into a single unitized representation. When that unitized representation was reinstated at retrieval, older adults demonstrated enhanced memory performance.

Follow-up analyses investigating the effect of presentation and congruency on hits indicated that both age groups benefited in the item-context congruent condition in terms of an enhanced associative hit rate. This further suggests that unitization provided additional associative features to enable intact pair recognition in this condition. In line with this interpretation is neuroimaging evidence that unitization is less dependent on the hippocampus than are other associative encoding processes (e.g., Haskins et al., 2008), which could explain why older adults displayed a hit rate advantage in the item-context congruent condition despite likely age-related hippocampal decline (Raz et al., 2005). The similarity in the pattern of hit rates also argues against an interpretation that young and older adults were extracting visual information from the different pair types in any fundamentally different way, although an interesting question for further research is whether age groups exhibit any systematic differences in their patterns of visual engagement and neural processing associated with side-by-side versus superimposed stimuli.

In contrast to the similar patterns of hit rates across the two experiments, the pattern of false alarm rates differed somewhat, in ways that affected the overall age differences observed in old-new pair discrimination. Specifically, congruency had a pronounced effect on young adults' false alarms but not on older adults' false alarms in Experiment 1, whereas there was a modest overall effect of congruency on false alarms across both age groups in Experiment 2. In general, effects of congruency on false alarms could reflect use of a recall-to-reject strategy, such that some rearranged pairs in the incongruent condition are rejected because recollection of the encoding configuration associated with the face or scene reveals a mismatch. To the extent that there is also a configuration mismatch for intact incongruent pairs, this type of strategy could be manifested as a stricter response bias in incongruent conditions. This was indeed found in Experiment 1, in which there was an interaction such that young adults had a stricter criterion for incongruent than for congruent pairs, whereas this difference was not significant among older adults. This is in line with findings that older adults do not use recall-to-reject as often as young adults do (Gallo, Bell, Beier, & Schacter, 2006). In Experiment 2, there was greater similarity in the pattern of false alarms (and correspondingly, response bias) between age groups. This

suggests that the greater task difficulty in Experiment 1 increased the tendency for young adults, but not older adults, to reject pairs with incongruent retrieval presentation. It could be the case that participants resorted to this use of congruency when intact and rearranged pairs were hard to discriminate based on the stimuli themselves. However, because doing so would depend on accurate recollection of the encoding configuration of the stimuli, older adults might not be able to resort to congruency in a difficult task in the same way that young adults can.

Overall, the present results suggest that manipulating manner of presentation can induce different processing of the same stimuli as either item–item or item–context, which is a novel finding in itself, given that memory studies tend to use different stimulus types for item–item and item–context associations. When considering how the present experiments relate to prior studies, it should be noted that additional factors that may play a role in context processing were not considered here. For example, in the present experiments, participants were instructed to attend to both stimuli regardless of configuration, whereas in other studies context may include information that is less attended than item information is. Such attentional differences have been used to explain why older adults often exhibit reduced memory for context information. For example, in the DRYAD model of age-related memory impairment (Benjamin, 2010), deficits in context memory are explained as resulting from an overall reduction in encoding fidelity, which disproportionately affects unattended information. Within the present study, the ability of older adults to unitize item–context pairings to a greater extent than item–item pairings might not have been as readily observed if contexts were less attended than items were. A related consideration is that the welcomingness judgment used to orient participants to pairs in the present experiment may have encouraged some degree of depth of processing (Craig & Lockhart, 1972); an interesting question for further study is whether similar results can be found with a more superficial encoding task.

Regarding the associative deficit, our current findings provide evidence that older adults' memory for associations is particularly sensitive to both the type of association and whether the association is tested in a manner that is congruent with its encoding configuration. Future research should further investigate the role of unitization in increased memory performance for item–context pairs with congruent encoding and retrieval presentation and how this may relate to functional organization of the MTL. Given significant age-related decline in the hippocampus (Raz et al., 2005), the possibility of using manner of presentation to shift associative processing to regions that do not decline in aging would be a critical step in supporting memory performance in older adults.

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