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Same face, same place, different memory: manner of presentation modulates the associative deficit in older adults

Amy A. Overman^a, Nancy A. Dennis^b, John M. McCormick-Huhn^b, Abigail B. Steinsiek^a and Luisa B. Cesar^a

^aPsychology Department and Neuroscience Program, Elon University Elon, USA; ^bPsychology Department, The Pennsylvania State University Pennsylvania, USA

ABSTRACT

One of the more severe and consequential memory impairments experienced by older adults is the loss of the ability to form and remember associations. Although the associative deficit is often assumed to be unitary, memory episodes may contain different types of associations (e.g., item-item, item-context). Research in younger adults suggests that these different association types may involve different neural mechanisms. This raises the possibility that different association types are not equally affected by aging. In order to investigate this, the current study directly compared memory across item-item and item-context associations in younger and older adults by manipulating the manner of presentation of the associations. Results indicate that the associative deficit in aging is not uniform and that aging has a greater impact on item-context compared to item-item associations. The results have implications for theories of associative memory, age-related cognitive decline, and the functional organization of the medial temporal lobe in aging.

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Memory; associative deficit; binding; item-item; itemcontext

The need to form and remember associations is a ubiquitous part of everyday life: for example, remembering the name associated with a familiar face or the place you met a friend for lunch. The loss of this ability is one of the more severe and consequential memory impairments experienced by older adults (Chalfonte & Johnson, 1996; Naveh-Benjamin, 2000). Studies of the associative deficit in older adult memory often assume that it is a single general impairment for all association types (e.g., Li, Naveh-Benjamin, & Lindenberger, 2005). However, neuroimaging studies in young adults have suggested that different association types are mediated by different neural mechanisms. For example, the Binding of Items and Contexts (BIC) model (e.g., Diana, Yonelinas, & Ranganath, 2007) of the medial temporal lobe (MTL) posits neural differences in memory for item versus contextual information which affect the ways in which these types of information can be associated. Specifically, BIC proposes that memory for specific items is supported by the perirhinal cortex whereas memory for contextual information is supported by parahippocampal cortex. Consequently, associations among two or more items can be processed within perirhinal cortex

(especially when the items are "unitized," i.e., combined into a new single item), whereas associations between items and contexts must be linked via the hippocampus. The BIC model also uses this division of labor between item and contextual information in the MTL, and the hippocampus's role in linking them, to explain the prominent role of the hippocampus in recollection.

Given that age-related decline affects the hippocampus more than other MTL subregions (Raz, 2005), the BIC model provides a framework for understanding older adults' reduction in recollection-based memory and increased reliance on familiarity (Bastin & Van der Linden, 2003; Ward, Maylor, Poirier, Korko, & Ruud, 2016; Yonelinas, 2002). Similarly, BIC helps to account for older adults' deficit in memory for contextual information (e.g., Bayen, Phelps, & Spaniol, 2000; Johnson, Hashtroudi, & Lindsay, 1993). However, BIC also implies that the associative deficit in aging could be more severe for item–context associations, which depend heavily on the hippocampus, than for item–item associations, which may be processed independently of the hippocampus. Thus, the assumption that the age-related associative memory deficit is unitary overlooks the possibility that some aspects of associative memory may be relatively preserved in older adults, and thus recruited to ameliorate more impaired aspects of associative memory. Indeed, studies that have used encoding conditions that encourage unitization have found reduced associative deficits, in line with BIC (Ahmad, Fernandes, & Hockley, 2015; Bastin et al., 2013; Delhaye & Bastin, 2016).

In order to directly test the BIC model's prediction that item-item and item-context associations are differentially affected in aging, it would be ideal to compare memory across both types of associations, while controlling for any differences between the types of stimuli used to create the associations. Although both types of associations have been investigated in prior studies, direct comparisons are not typically possible, because different types of stimuli/information tend to be used in the roles of "items" versus "contexts" (i.e., "items" are typically words, faces, or objects, whereas "contexts" are often scenes, voices, colors, etc.). A more pure comparison would avoid confounding the role of the stimulus (item versus context) with the type of stimulus (face, voice, object, scene, etc.) by using at least one of the stimulus types in both roles. Doing so requires clearly defining the criteria that distinguish between the roles of item and context.

It can be difficult to define precisely the differences between items and contexts; context may refer to incidental features of to-be-remembered stimuli themselves (sometimes referred to as "intrinsic" context, e.g., Mulligan, 2011) or to information occurring in the "background" (as in studies of environmental context; e.g., Hockley, 2008). Two ways of characterizing context across its many forms (cf. Murnane, Phelps, & Malmberg, 1999) is that contextual information tends to be more peripheral (i.e., less focal) than item information, and that context tends to be less temporally variable than item information. The reduced focality of context can be physical in nature (i.e., the context information is literally in the background) or attentional (i.e., the context is whatever information is unattended; note that the attentional aspect of context plays an important role in some theoretical accounts of age differences in context memory such as the DRYAD model; Benjamin, 2010). Reduced temporal variability captures the situational nature of some contextual information: that is, items are more likely to be the things that come and go from one stimulus presentation to the next, whereas context includes 46 👄 A. A. OVERMAN ET AL.

many of the aspects of a situation that frame the individual items and change at a more gradual rate.

Because certain elements of an encoding situation (e.g., a scene) more often play the role of being less focal and less temporally variable than other elements (e.g., objects, faces, etc.), information type is easily confounded with the item/context dichotomy. To overcome this confound, the present study used face-scene pairs both as item-item and item-context pairs by manipulating the manner in which pairs were presented. Specifically, we manipulated the presentation of scene stimuli so that they would be more item-like in some pairs and more context-like in other pairs. We did this across three experiments by manipulating both the focality and the temporal variability of the scene stimuli. Focality was manipulated in the physical sense (by placing the scene in the background, behind the face, versus placing the scene next to the face) and not in the attentional sense (in order to preserve encoding of individual stimuli themselves while altering the relationship between the stimuli). Temporal variability was manipulated by grouping similar scenes together versus allowing scene types to change from trial to trial along with faces. Experiment 1 manipulated both focality and temporal variability of scenes, Experiment 2 manipulated only temporal variability, and Experiment 3 manipulated only focality. Together, these experiments allowed us to examine whether the associative deficit is affected by these aspects of context-ness, and how each individual aspect of context-ness contributes to any such effects on agerelated differences in associative memory.

Method

Participants

Based on prior studies of associative memory (e.g., Naveh-Benjamin, 2000), we aimed to recruit between 25 and 30 participants in each age group, for each version of the experiment. A total of 28 younger adults (mean age = 18.61 years) and 26 older adults (mean age = 74.19 years; MMSE: M = 29.69, SD = .74) participated in Experiment 1.

A total of 30 younger adults (mean age = 19.07 years, SD = 1.28) and 34 older adults participated in Experiment 2; Four older adults from Experiment 2 were excluded from analysis for the following reasons: one was excluded for making the same button response for all trials and three were excluded for having no false alarms and no hits due to not using all response options, for a total of 30 (mean age = 72.97 years; MMSE: M = 29.73, SD = .64).

A total of 30 young adults (mean age = 19.1) and 31 older adults (mean age = 74.52 years; MMSE: M = 29.19, SD = 1.08) participated in Experiment 3. Four older adults from Experiment 3 were excluded from the analysis for the following reasons: one was excluded for scoring a 25 on the MMSE (scores <26 excluded), one was excluded for a high depression score (>5 on the Geriatric Depression Scale, Short Form; Yesavage et al., 1983), and two were removed for not using all response options for a total of 27 (mean age = 74.52 years; MMSE: M = 29.19, SD = 1.08). None of the participants whose data were analyzed reported any history of neurological or psychiatric disorders. All study procedures were approved by the Institutional Review Boards of Elon University and the Pennsylvania State University.

Materials and design

Stimuli consisted of 88 color photographs of faces (Minear & Park, 2004; Phillips, Moon, Rizvi, & Rauss, 2000) and 88 scenes from four categories: kitchens, offices, living rooms, restaurants. Two study lists each contained 40 unique face–scene pairs. Participants studied both lists and list order was counterbalanced.

The critical manipulation during the study phase, across all experiments, was that face–scene pairs were presented either (a) in a manner that characterized them as an item (face) paired with a context (scene) or (b) in a manner that characterized the face and scene as two independent items of equal status. To accomplish this, in Experiment 1 both the focality and temporal variability of scenes were manipulated 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). 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 type to vary randomly from trial to trial (see Figure 1(a)). The left–right placement of the face and scene also varied randomly from trial to trial in the item–item condition. Faces and scenes were presented at the same size in both conditions in order to avoid changing the visibility of stimulus features in either condition.

Experiments 2 and 3 separated the two contextual factors of focality and temporal variability. Experiment 2 manipulated *only* the temporal variability of scenes across item–context and item–item conditions, while holding focality constant. Thus, the item–context list was blocked by scene type just as in Experiment 1, with a slide identifying the upcoming scene type at the beginning of each block, and the item–item list was randomly ordered. However, for Experiment 2, faces and scenes were presented side-by-side across both encoding lists (see Figure 1(b)). In contrast, Experiment 3 manipulated *only* the focality of scenes across item–context and item–item conditions, while holding temporal variability constant. Thus, the item–context trials presented scenes behind faces and the item–item trials presented faces and scenes side-by-side. All trials in Experiment 3 were presented in random order and were not grouped by scene type (see Figure 1(c)).

For all three versions of the experiment, there was a 96-item test list consisting of stimuli from all 80 studied pairs, and 16 unstudied faces and scenes were used to form new stimuli.

Procedure

Aside from differences in focality and temporal variability during encoding described above, all testing procedures were kept constant across Experiments 1, 2, and 3. During the study phase, participants saw each study pair for five seconds and rated each for how welcoming it was. At test, a two-step recognition task assessed memory separately for individual stimuli, and for associations, within each test trial. In the first step of the test trial, an individual stimulus (face or scene) was presented. For half the trials, this initial recognition cue was a scene, presented above the text "Do you recognize this



Figure 1. Item–context and item–item encoding conditions in Experiments 1, 2, and 3. Experiment 1 defined context-ness as a combination of reduced focality and reduced temporal variability; thus, scenes in the item–context condition were presented in the background and were grouped by scene type. Experiments 2 and 3 manipulated focality and temporal variability separately: Experiment 2 defined context-ness as reduced temporal variability only (thus, the scenes were grouped but not placed in the background for the item–context condition); Experiment 3 defined context-ness as reduced focality only (thus, the scenes were placed in the background for the item–context condition) the background for the item–context condition but were not grouped together by type).

scene?" The participant used the computer mouse to click on a region of the screen labeled "yes" or "no." In the case of a correct "yes" response (i.e., hit), the second step of the test trial then presented the scene again at the top of the screen, and a face below the scene, outlined with a bright green border. On-screen text below the images asked, "Was this the face that went with the scene?" The participant used the computer mouse to click on one of three response options: (1) yes, this is the face that went with the scene; (2) no, but I remember this face; or (3) I do not remember this face. For the other half of trials, in which a face was presented in the first step, the same procedure was followed, with the images and on-screen questions presented accordingly in each step (i.e., "Do you recognize this face?" and "Was this the scene that went with the face?"). Half the face-scene pairs from each study list were intact at test (targets); half were rearranged into alternate pairings within the same scene type (lures). On 16 test trials, the initial recognition cue was a new face/scene, and there was no associative cue even if the participant responded "yes" to the individual stimulus.

Results

In order to evaluate old/new discrimination in recognition memory, d' was computed for individual stimuli based on participants' responses to old and new faces and scenes in the first step of each test trial, and computed for associations based on responses to intact and rearranged pairs from test trials in which the second step was performed. Averages of d' across participants from all three experiments are presented in Figure 2



Figure 2. Memory performance of young adults and older adults for face–scene pairs, individual faces, and individual scenes, in Experiment 1 (A), Experiment 2 (B), and Experiment 3 (C). Error bars represent 95% Cls.

	Experiment 1		Experiment 2			Experiment 3			
Effect or interaction	F	р	η_p^2	F	р	η_p^2	F	р	η_p^2
Associative memory									
Age group	29.02	<.001*	.36	34.11	<.001*	.37	21.12	<.001*	.28
Encoding condition	.08	.77		.25	.62		.03	.86	
Age group \times encoding condition	4.46	.039*	.08	4.53	.037*	.07	1.87	.18	
Face and scene memory									
Age group	28.74	<.001*	.36	6.47	.014*	.10	16.12	<.001*	.23
Encoding condition	2.23	.14		13.20	.001*	.19	.18	.67	
Stimulus type	12.57	.001*	.19	28.02	<.001*	.33	25.93	<.001*	.32
Age group \times encoding condition	.18	.67		.01	.95		1.40	.24	
Age group \times stimulus type	.48	.49		4.13	.047*	.07	.19	.66	
Encoding condition \times stimulus type	1.35	.25		6.38	.014*	.10	11.99	.001*	.18
Age group \times encoding condition \times stimulus type	.001	.98		.02	.90		.75	.39	

Table 1. Summary of ANOVA effects in memory for associations and for individual stimuli (faces and scenes).

The dependent measure for all analyses was d', reflecting intact versus rearranged discrimination for associative memory and old versus new discrimination for item memory. Effect size (η_p^2) is reported only for statistically significant effects.

*p < .05.

for each recognition type, encoding condition, and age group. For the statistical analyses of d' described in the text below, ANOVA results across the three experiments are summarized in Table 1.

Experiment 1

Associative recognition

For the d' measures from responses to intact versus rearranged pairs, performance was analyzed using a 2 (encoding condition: item–item or item–context) × 2 (age group: young or older) repeated-measures ANOVA. The main effect of age group was highly significant, F(1, 52) = 29.02, p < .001, MSE = 16.42, $\eta_p^2 = .36$, indicating worse performance among older adults than young adults. There was a significant two-way interaction between encoding condition and age group, F(1, 52) = 4.46, p = .039, MSE = 2.31, $\eta_p^2 = .08$. This interaction can be seen in Figure 2, as reflected by the larger age difference in the item–context encoding condition than in the item–item encoding condition. There was no significant main effect of encoding condition.

Recognition of faces and scenes

For recognition of single stimuli, performance was analyzed using a 2 (encoding condition) × 2 (stimulus type: face or scene) × 2 (age group) repeated-measures ANOVA. There was a significant main effect of age group, F(1, 52) = 28.74, p < .001, MSE = 19.29, $\eta_p^2 = .36$, such that young adults demonstrated greater recognition performance than older adults, and a significant main effect of stimulus type, F(1, 52) = 12.57, p = .001, MSE = 10.72, $\eta_p^2 = .195$, such that recognition was better for face stimuli compared to scene stimuli. No other main effects or interactions were statistically significant.

Because young and older adults differed in recognition memory performance for individual stimuli, the two-step design of the recognition task had the potential to lead to different numbers of trials across age groups in which the second (associative) step of each trial was reached. To examine this possibility, participants' responses to individual stimuli were further analyzed to determine how many test trials reached the second step. The mean number of associative test trials was compared in a 2 (encoding condition) \times 2 (age group) repeated-measures ANOVA. No main effect of age group was found, F(1, 52) = .81, p = .371, MSE = 41.95, indicating that young and older adults completed the same number of associative trials, on average. Although it may appear inconsistent with older adults' worse old/new discrimination performance for single stimuli, this result reflects similar hit rates across age groups (i.e., the difference in d' was largely due to false alarms, which did not affect the contingency of reaching the associative step in test trials). Neither the main effect of encoding condition nor the interaction was statistically significant. As such, it is unlikely that the critical age group × encoding condition interaction that was found in the associative memory results was caused by differing pools of associative trials across encoding conditions in the two age groups.

Response times

Response times for correct responses were also analyzed, and are summarized in Table 2. Median response time for each participant was found for correct responses within each encoding condition, for both the item memory responses and the associative responses. For item memory, median response times for correct responses were submitted to a 2 (encoding condition: item–item or item–context) \times 2 (age group: young or older) repeated-measures ANOVA. There was a significant effect of age group, F(1, 52) = 63.77, p < .001, MSE = 68,158,765.70, η_p^2 = .551, such that older adults demonstrated longer median response times compared to young adults. There was a significant main effect of encoding condition, F(1, 52) = 4.53, p = .038, MSE = 138,869.34, $\eta_p^2 = .080$, such that faster median response times were measured for item-context encoding compared to the item-item encoding condition. There was no encoding condition \times age group interaction. A similar ANOVA was conducted for associative responses. There was a significant main effect of age group, F(1, 52) = 132.70, p < .001, $MSE = 408,929,856.55, \eta_p^2 = .718$, such that older adults demonstrated longer median response times compared to the young adults. No other result was statistically significant.

	Individual st	timuli	Associations			
Experiment	ltem–ltem	ltem-Context	ltem–ltem	ltem–Context		
Experiment 1						
Young	1706 (412)	1611 (274)	2252 (622)	2035 (445)		
Old	3328 (1117)	3168 (953)	6120 (2248)	5956 (1829)		
Experiment 2						
Young	1714 (519)	1654 (395)	2223 (785)	2217 (1069)		
Old	2995 (758)	2949 (769)	4725 (1405)	4806 (1524)		
Experiment 3						
Young	1841 (440)	1828 (396)	2402 (824)	2653 (1147)		
Old	2763 (574)	2799 (755)	5079 (1882)	4893 (1561)		

Table 2. Average median response times for correct responses.

Standard deviations are presented in parentheses.

Encoding task

For completeness, responses from the encoding task were also analyzed in a 2 (encoding condition) × 2 (age group) repeated-measures ANOVA. The only result that was significant was a two-way interaction between encoding condition and age group, F(1, 52) = 8.05, p = .006, MSE = .56, $\eta_p^2 = .13$. This interaction appeared to reflect a slightly larger age difference in welcomingness ratings in the item–item condition than in the item–context condition, although when examined separately, neither condition had a statistically significant age difference. Overall, the pattern of the age group × encoding interaction observed in associative recognition performance. Thus, it is unlikely that the associative memory differences were induced by any cognitive differences specifically related to welcomingness ratings.

Experiment 2

Associative recognition

For the d' measures from responses to intact versus rearranged pairs, performance was analyzed using a 2 (encoding condition) × 2 (age group) repeated-measures ANOVA. Similar to the results of Experiment 1, there was a significant main effect of age group, *F* (1, 58) = 34.11, *p* < .001, *MSE* = 18.12, η_p^2 = .37, indicating worse performance among older adults than young adults, and a significant interaction between encoding condition and age group, *F*(1, 58) = 4.53, *p* = .037, *MSE* = 1.82, η_p^2 = .07, again reflecting a larger age difference in the item–context condition than in the item–item condition. Also similar to Experiment 1, there was no significant effect of encoding.

Recognition of faces and scenes

For recognition of single stimuli, performance was analyzed using a 2 (encoding condition) \times 2 (stimulus type) \times 2 (age group) repeated-measures ANOVA. There was a main effect of stimulus type, F(1, 58) = 28.02, p < .001, MSE = 24.66, $\eta_p^2 = .33$, such that item recognition was better for face stimuli compared to scene stimuli. There was a significant effect of encoding condition, F(1, 58) = 13.20, p = .001, MSE = 1.97, $\eta_p^2 = .19$, such that memory for items encoded in item-context conditions were better remembered than items encoded in item-item conditions. There was a significant main effect age group, F(1, 58) = 6.47, p = .014, MSE = 4.92, $\eta_p^2 = .10$, such that young adults demonstrated better recognition for single items than older adults. There was also a significant interaction between stimulus type and age group, F(1, 58) = 4.13, p = .047, MSE = 3.64, $\eta_{\rm D}^{2}$ = .07, such that there was a greater age difference in recognition performance for scene stimuli than for face stimuli. Finally, there was a significant interaction between stimulus type and encoding condition, F(1, 58) = 6.38, p = .014, MSE = 1.19, $\eta_n^2 = .10$, such that encoding condition had a greater effect on memory for scenes than on memory for faces. There was no significant interaction between encoding condition and age group, and no significant three-way interaction.

As in the analyses for Experiment 1, participants' responses to individual stimuli were further examined to determine how many test trials reached the second step. The mean number of associative test trials was compared in a 2 (encoding condition) \times 2 (age group) repeated-measures ANOVA. The only effect that was significant was a main effect

of encoding condition, F(1, 58) = 12.97, p = .001, MSE = 156.41, $\eta_p^2 = .183$, such that the item–context condition resulted in a greater number of associative trials compared to the item–item condition. Results again suggest that the age group × encoding condition interaction in associative memory performance was not an artifact of differing numbers of associative trials across age groups.

Response times

As in Experiment 1, median response times (see Table 2) for correct item responses were submitted to a 2 (encoding condition: item–item or item–context) × 2 (age group: young or older) repeated-measures ANOVA. There was a significant main effect of age group, *F* (1, 58) = 70.25, *p* < .001, *MSE* = 49,760,592.30, η_p^2 = .548, such that older adults demonstrated longer median response times compared to young adults. The corresponding associative ANOVA identified only a significant main effect of age group, *F*(1, 58) = 78.16, *p* < .001, *MSE* = 194,287,845.68, η_p^2 = .574, such that older adults demonstrated longer median response times compared to young adults.

Encoding task

No significant results were found when examining welcomingness ratings in Experiment 2.

Experiment 3

Associative recognition

For the d' measures from responses to intact versus rearranged pairs, performance was analyzed using a 2 (encoding condition) × 2 (age group) repeated-measures ANOVA. There was a significant main effect of age group, F(1, 55) = 21.12, p < .001, MSE = 13.51, $\eta_p^2 = .28$, such that older adults showed worse performance than young adults. There was no effect of encoding condition, and in contrast to Experiments 1 and 2, the interaction between encoding condition and age group was not significant.

Recognition of faces and scenes

For recognition of single stimuli, performance was analyzed using a 2 (encoding condition) × 2 (stimulus type) × 2 (age group) repeated-measures ANOVA. There was a significant main effect of stimulus type, F(1, 55) = 25.93, p < .001, MSE = 17.23, $\eta_p^2 = .32$, such that recognition for faces was greater than for scenes. There was a main effect of age group, F(1, 55) = 16.12, p < .001, MSE = 14.25, $\eta_p^2 = .23$, such that young adults performed better than older adults. There was a significant interaction between stimulus type and encoding condition, F(1, 55) = 11.99, p = .001, MSE = .90, $\eta_p^2 = .18$, similar to that observed in Experiment 2, such that faces and scenes were differentially affected by encoding condition. No other result was significant.

As in the other experiments, participants' responses to individual stimuli were further analyzed to determine how many test trials reached the second (associative) step. The mean number of associative test trials was compared in a 2 (encoding condition) \times 2 (age group) repeated-measures ANOVA. No results were significant.

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Response times

For item memory, median response times (see Table 2) for correct responses were submitted to a 2 (encoding condition: item–item or item–context) × 2 (age group: young or older) repeated-measures ANOVA. There was a significant main effect of age group, F(1, 55) = 47.80, p < .001, MSE = 25,470,515.09, $\eta_p^2 = .465$, such that older adults demonstrated longer median response times compared to young adults. For associative responses, there was a significant main effect of age group, F(1, 55) = 49.85, p < .001, MSE = 171,776,300.83, $\eta_p^2 = .475$, such that older adults demonstrated longer median response times compared to young adults.

Encoding task

No significant results were found when examining welcomingness ratings in Experiment 3.

Discussion

In contrast to assumptions made in prior research, our results across three experiments demonstrate that the associative deficit in aging is not uniform across itemitem and item-context associations. Our results indicate that older adults' associative memory is more impaired for face-scene associations encoded in an item-context manner than those encoded in an item-item manner. This effect of encoding condition on the age-related difference in *associative* memory was observed even though age differences in memory for *individual* stimuli were not affected by the encoding manipulation.

In Experiment 1, we manipulated both the focality and temporal variability of scenes during encoding in order to present them as either an item or context in conjunction with a second item, a face. Results demonstrate that, despite the similar content across both item-item and item-context conditions, a larger associative memory age difference was observed in the item-context condition. We further investigated whether either of the factors used to induce item-item and item-context processing (i.e., focality and temporal variability) was more influential in the results of Experiment 1. Both Experiment 2 and Experiment 3 yielded qualitatively similar patterns of results to Experiment 1, with a larger age difference observed in the item-context condition than in the item-item condition. In Experiment 2 (manipulation of temporal variability), this pattern yielded a significant age group \times encoding condition interaction, whereas the interaction was not significant in Experiment 3 (manipulation of focality). Thus, it may be the case that the manipulation of temporal variability contributed more to the interaction observed in Experiment 1 than the manipulation of focality. Nonetheless, the qualitative similarity of the findings from Experiment 3 suggest that focality also contributes to the age group \times encoding interaction observed in Experiment 1. However, future research is needed to fully examine the independent effects of each encoding effect on associative memory. An additional goal for further research is to identify the relative contributions of recollection and familiarity to memory for item-item and item-context associations. Analyses of response time data in the present experiments did not yield any clear differences in the speed of successful recognition to suggest varying degrees of recollection across encoding conditions. However, alternate testing formats (e.g., Bastin & Van der Linden, 2003) could provide insights regarding potential retrieval processing differences between association types.

Overall, the findings align with the framework for associative memory outlined in the BIC model of MTL function (Diana et al., 2007). The BIC model proposes that itemcontext associations depend more heavily on the hippocampus, whereas item-item associations can be encoded within the perirhinal cortex. It has been demonstrated that perirhinal cortex is relatively spared with aging, compared to the hippocampus (Raz et al., 2005). Thus, our current results are consistent with the hypothesis that older adults may take advantage of relatively intact perirhinal function for item-item associations whereas relatively impaired hippocampal function has a greater impact on item-context associations.

Although the present results agree with the predictions of the BIC model, they appear to conflict with the findings of a recent fMRI study of associative memory reported by Memel and Ryan (2017). In that study, young and older adults studied pairs of objects and scenes that were either presented side-by-side or with the object superimposed on the scene. Thus, the encoding manipulation used by Memel and Ryan closely resembled the focality manipulation used in the present experiments. However, in contrast to the present results, Memel and Ryan found that both young and older adults had *better* memory performance in the superimposed condition than in the side-by-side condition, and that the superimposed condition. They interpreted their findings as evidence that associative memory in both age groups benefits similarly from visual integration of stimuli.

One key difference between the Memel and Ryan (2017) design and that of the current study is that Memel and Ryan tested recognition of object-scene pairs using test pairs that presented stimuli in the same configuration in which they had been encoded. That is, objects and scenes that were encoded in the side-by-side configuration were used to create intact and rearranged pairs that were also presented side-by-side in the retrieval phase (and likewise for stimuli that were encoded in the superimposed configuration). In the present study, the associative recognition prompt during the retrieval phase presented intact and rearranged pairs from both the item-item and item-context encoding conditions in a top/bottom arrangement that did not match either encoding configuration. This difference raises that possibility that older adults' ability to benefit from visual integration of stimuli at encoding is dependent upon the reinstatement of the visually integrated configuration at retrieval. Thus, to the extent that superimposing stimuli might encourage unitization, older adults' subsequent recognition of such pairs might be disrupted by changing their configuration at test. This interpretation also aligns with prior findings of a benefit to older adults of context reinstatement (e.g., Ward et al., 2016).

Thus, while the present study focused on encoding manipulations with the retrieval task held constant, an additional consideration for further research is whether these association types in young and older adults are differentially affected by the degree to which encoding configurations are reinstated at retrieval. Future studies should specifically manipulate whether item–item and item–context associations are tested in the same versus different configurations to those in which they were studied. A related issue for further research is how such manipulations might interact with other retrieval test

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formats such as a forced-choice recognition, which has been shown to reduce agerelated deficits (Ahmad et al., 2015; Bastin & Van der Linden, 2003).

In summary, the present results contribute to our understanding of age-related cognitive changes and inform us about the possible functional organization of the MTL in young and older adults. Our findings suggest that the age-related associative memory deficit may be reduced by recruiting item-item associative processes that are less impaired in aging than item-context processes. Furthermore, the results contribute to general theories of associative memory (e.g., item, associated context, and ensemble (ICE) theory; Murnane et al., 1999), by demonstrating how the encoding of associations can be influenced by the manner in which stimuli are presented. Further research should continue to identify means of ameliorating the associative deficit through the manner in which multiple pieces of information are presented.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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