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Older adults can use memory for distinctive objects, but not distinctive scenes, to rescue associative memory deficits

Nichole R. Bouffard[a,b*], Celia Fidalgo[a*], Iva K. Brunec[c], Andy C. H. Lee[a,d] and Morgan D. Barense[a,b]

[a]Department of Psychology, University of Toronto, Toronto, Ontario, Canada; [b]Rotman Research Institute, Baycrest Hospital, Toronto, Ontario, Canada; [c]Department of Psychology, University of Pennsylvania, Philadelphia, Pennsylvania, USA; [d]Department of Psychology, University of Toronto Scarborough, Scarborough, Ontario, Canada

ABSTRACT
Associative memory deficits in aging are frequently characterized by false recognition of novel stimulus associations, particularly when stimuli are similar. Introducing distinctive stimuli, therefore, can help guide item differentiation in memory and can further our understanding of how age-related brain changes impact behavior. How older adults use different types of distinctive information to distinguish overlapping events in memory and to avoid false associative recognition is still unknown. To test this, we manipulated the distinctiveness of items from two stimulus categories, scenes and objects, across three conditions: (1) distinct scenes paired with similar objects, (2) similar scenes paired with distinct objects, and (3) similar scenes paired with similar objects. Young and older adults studied scene-object pairs and then made both remember/know judgments toward single items as well as associative memory judgments to old and novel scene-object pairs ("Were these paired together?"). Older adults showed intact single item recognition of scenes and objects, regardless of whether those objects and scenes were similar or distinct. In contrast, relative to younger adults, older adults showed elevated false recognition for scene-object pairs, even when the scenes were distinct. These age-related associative memory deficits, however, disappeared if the pair contained an object that was visually distinct. In line with neural evidence that hippocampal functioning and scene processing decline with age, these results suggest that older adults can rely on memory for distinct objects, but not for distinct scenes, to distinguish between memories with overlapping features.

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Aging; associative memory; object memory; scene memory; false recognition

Introduction

Hallmarks of healthy memory include both accurate recognition of familiar individual items and intact recall for the relationships between them. Associative memory for inter-item relationships shows marked decline with age and is often characterized by false recognition of associative information (Bastin & Van der Linden, 2005;Castel & Craik, 2003;

CONTACT Nichole R. Bouffard nichole.bouffard@mail.utoronto.ca
*indicates equal contributions.

Chalfonte & Johnson, 1996;Cohn et al., 2008;Gutchess et al., 2007;Kessels et al., 2007; Naveh Benjamin et al., 2004;Naveh Benjamin, 2000;Old & Naveh Benjamin, 2008;Troyer et al., 2011). Associative memory errors are further exacerbated in aging when studied items share visual overlap with each other or with novel test stimuli, resulting in increased false recognition of both novel single items and novel associations (Balota et al., 1999; Bowman & Dennis, 2015;Light et al., 2004;McCabe et al., 2009;Stark & Stark, 2017;Tun et al., 1998;Yeung et al., 2013). Though past work has characterized how interference from highly similar items leads to false recognition, few have directly compared methods that may facilitate older adults' ability to disambiguate highly similar episodes and avoid false recognition of multi-item events. For example, distinctive visual characteristics of events promote their differentiation in memory, but it is as yet unclear what type of distinctive information older adults use to separate similar experiences and to facilitate detailed recall. Thus we asked the following question: Does aging impact the use of distinctive stimuli to remember overlapping episodes?

Common characteristics that characterize real-world episodes include the spatial contexts in which events occur and the objects encountered within those contexts, and the distinctiveness of these spatial contexts or object elements can distinguish memories for these episodes. For example, whereas young adults' long-term memory for individual object and scene images is thought to be high in both capacity (i.e., number of items) and in visual detail (i.e., fidelity of each item), recognition steadily declines as study items and novel lures are drawn from the same semantic category (Konkle et al., 2010a,2010b). In these instances, distinct aspects of an image have a substantial positive impact on young adults' ability to discriminate between studied and unstudied items, even when distinct aspects are irrelevant. For example, recognition accuracy of 400 door images was about 85% when irrelevant but distinctive object information (such as lamp posts, flower pots, name tags, etc.) was present, but dropped by 20% when this irrelevant object information was removed (Vogt & Magnussen, 2007). In a similar vein, distinct spatial contexts also help distinguish events in memory. Imaging studies have shown that as observers learn to associate objects with spatial context information, the neural representations of those objects become less similar (Clarke et al., 2016;Dimsdale-Zucker et al., 2018). Neuroimaging work has shown that hippocampal representations for similar items are differentiated when they are associated with distinct contexts, but are not differentiated when similar items are paired with similar contexts, suggesting that events with similar item and context associations are generalized and represented more similarly in memory (Libby et al., 2019). Moreover, other work has shown that the neural differentiation that occurs when visually similar items are associated with distinct items is correlated with behavioral measures of interference resolution (Favila et al., 2016).

Both distinctive scene contexts and distinctive objects can be used to distinguish similar episodes. However, it is unclear whether these stimulus classes do so to the same degree. One reason to question this assumption is that some theories of episodic memory place special importance on scene contexts in representing past events. Specifically, spatial cognition is considered central to episodic memory (Bird & Burgess, 2008;Gaffan, 1994;Hassabis & Maguire, 2007;Lee et al., 2012;Zeidman et al., 2014) and representations of scene contexts are thought to underlie related functions such as imagination and future thinking (Hassabis, Kumaran, & Maguire, 2007;Hassabis, Kumaran, Vann, et al., 2007;Robin & Moscovitch, 2014). In light of this work, scene contexts may be especially effective mnemonic cues, well-suited to bring to mind associated events. Indeed, recent work has demonstrated that during memory retrieval, young adults recalled spatial contexts before other types of information (e.g., people or objects) and that recall of spatial context first was related to more efficient retrieval overall (Hebscher et al., 2018). In further support of the prominence of scene context in memory, Robin and colleagues (Robin et al., 2015) found that remembered events containing spatial context were remembered more vividly, and in more detail than those remembered without spatial context, and that young adults spontaneously insert spatial contexts into remembered events without instruction to do so, but do not spontaneously insert other types of items (Robin et al., 2015).

An open question is the extent to which the fidelity of scene and object representations is affected by healthy aging, and how this impacts the degree to which these different stimulus classes can serve as associative retrieval cues. For example, declines in spatial memory are among the most prominent memory deficits that occur with aging (Bastin & Van der Linden, 2005;Bruce & Herman, 1983;Iachini et al., 2009;Laurance et al., 2002;Lipman & Caplan, 1992;Park et al., 1983). Spatial memory is thought to be supported by the hippocampus (Bird et al., 2008;Guderian et al., 2015) and hippocampal dysfunction may be responsible for subsequent spatial processing deficits in aging (Antonova et al., 2009;Heo et al., 2009;Wimmer et al., 2012). As a consequence, older adults may rely relatively less on scene information to disambiguate overlapping events or to facilitate retrieval. In addition to spatial processing deficits, object processing regions such as the perirhinal cortex also show dysfunction with healthy aging (Burke et al., 2010,2011). Related work has shown deficits in object perception and memory with healthy aging (Berron et al., 2018;Ryan et al., 2012;Yeung et al., 2013) and greater impairments in object processing relative to spatial processing when the two task types were directly compared (Reagh et al., 2016,2018). Based on this evidence, object processing deficits with healthy aging may impede older adults' ability to effectively use distinct objects to disambiguate events and facilitate associative recall. Together, there are age-related neurocognitive changes that affect both scene and object processing, yet it is unclear how these changes impact memory for object-scene associations as well as the ability to leverage distinctive visual and conceptual information as a retrieval cue.

The main aim of the current study was to elucidate whether the distinctiveness of objects or scenes aided associative memory in older adults, in line with neural changes associated with healthy aging. Specifically, we examined whether instances of associative false recognition could be reduced by introducing distinctive items (scenes or objects) that were intentionally encoded in conjunction with highly overlapping items (objects or scenes, respectively). We reasoned that pairing highly similar items with distinct items during encoding, and subsequently re-presenting both similar and distinct items at test, may aid older adults in overcoming their tendency to false alarm toward novel pairs of items. Most importantly, we aimed to test whether certain types of distinct stimuli (i.e., scenes versus objects) were more powerful associative retrieval cues. We used an associative memory task in which young and older adults studied pairs of scene and object images across three conditions (Figure 1). For two conditions, either the scene or object element in each pair was visually and categorically distinct from other stimuli in its class, whereas the other element was overlapping with other stimuli in its class (i.e., distinct scenes-similar objects and similar scenes-distinct objects). In the third condition, both

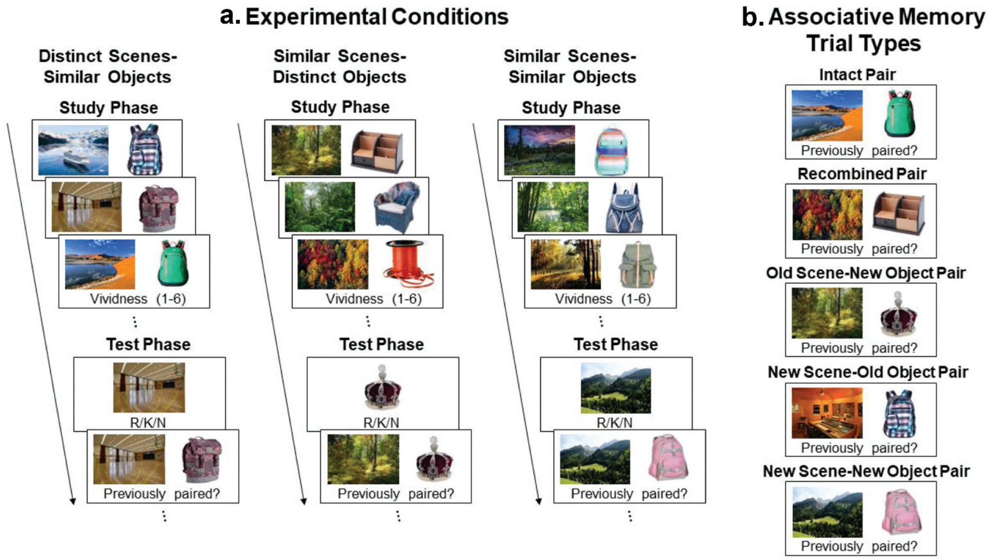

Figure 1. Task schematic demonstrating all three experimental conditions and all five associative memory trial types. a) There were three conditions in total: Distinct Scenes-Similar Objects, Similar Scenes-Distinct Objects, and Similar Scenes-Objects. During the study phase participants imagined a scenario involving the scene-object pairs. For each test trial, participants first made a single R/K/N judgment to either a scene or an object, followed by an associative memory judgment to the scene-object pairs ("Were these images previously paired together?"). All studied images were trial unique. b) Each condition contained all five associative memory trial types: intact pairs, recombined pairs, old scene-new object pairs, new scene-old object pairs, and new scene-new object pairs. [To view this figure in color, please see the online version of this journal].

scenes and objects were visually similar and from the same category as all other scenes and objects, respectively (i.e., similar scenes-similar objects). This condition served as a baseline against which we assessed whether the inclusion of distinct items in the other two conditions aided associative memory. This design allowed us to determine whether distinctive objects or distinctive scenes served as a better associative memory retrieval cue for older adults.

Materials and methods

All stimuli, experiment scripts, data, and analysis scripts have been uploaded to the Open Science Framework (OSF) and can be found here ().

Participants

We recruited 31 young adults from the University of Toronto ($M_{age} = 19.06$, $SD = 1.72$, 18 females) who received either course credit or monetary compensation for their participation. Additionally, 32 older adults ($M_{age} = 69.21$, $SD = 4.04$, 18 females) were recruited through the Adult Volunteer Pool at the University of Toronto St. George Campus. The current sample size was determined based off pilot work that was conducted with

Table 1. MoCA Score breakdown for older adults.

	Raw Scores (SD)
Overall Score (/30)	27.07 (1.35)
Visuospatial/Executive (/5)	4.22 (0.67)
Naming (/3)	2.91 (0.28)
Attention (/6)	5.87 (0.33)
Language (/3)	2.62 (0.57)
Abstraction (/2)	1.80 (0.38)
Delayed Recall (/5)	3.17 (1.19)
Orientation (/6)	5.88 (0.33)

Standard deviations are indicated in parentheses.

a previous version of this study. Due to technical difficulties that occurred during data collection, four participants were unable to complete the entire task. The data presented here is therefore from 28 participants. All older adult participants had been administered the Montreal Cognitive Assessment (MoCA) within six months of the experiment and all scored at least 26 or higher, indicating they were not at risk of cognitive decline (Nasreddine et al., 2005;Table 1). Participants were not included if they indicated they were colorblind on our laboratory demographics form. Older adults were paid $18 per hour for their participation. All participants provided informed consent and were screened for a history of psychological illness, traumatic brain injury, and current use of neuroleptic medications. Participants all had normal or corrected-to-normal vision. This study was approved by the University of Toronto Ethics Review Board.

Stimuli

This study used 396 scene images (132 distinct scene categories and 264 similar scenes) and 396 object images (132 distinct object categories and 264 similar objects). All scene images were collected from Google Image Search. Scenes could either be distinct from or similar to the other scenes in the set. Distinct scenes were 50% outdoor and 50% indoor, and depicted various categories (e.g., kitchens, beaches, etc.) to reduce conceptual and visual confusability between them. Similar scenes were all images of forests, with limited visual and conceptual variability between them. We selected forest images that were conceptually similar to one another while maintaining a certain amount of visual similarity. There was a certain degree of variance among the features of the images (color, photo angle, etc.), yet the general visual and conceptual similarity was constant. Examples of variability included the time of year, viewpoint, the presence of bodies of water, and so forth. As for scenes, objects could either be distinct from or similar to the other objects in the set. Distinct objects depicted various object categories (e.g., clock, bell, etc.) with minimal conceptual or perceptual overlap between them. There was a mix of objects that could be found indoors and outdoors but this was not controlled to be 50% indoor and 50% outdoor like the scenes. Similar object images all depicted backpacks with limited visual and conceptual variation between them. Examples of variability included viewpoint (but main features were always present with no aerial or backside views), colors, textures, and style (e.g., one shoulder backpacks, camping backpacks, etc.). None of the distinct scenes were forests and none of the distinct objects were backpacks. Stimuli were randomly assigned to each condition and to each associative memory trial type (Figure 1).

Procedure

The experiment was run using MATLAB (MathWorks, Natick, MA) with the Psychophysics Toolbox (Brainard, 1997;Kleiner et al., 2007;Pelli, 1997). The experiment was divided into six study-test blocks, with two blocks of each of the three conditions (i.e., distinct scenes-similar objects, similar scenes-distinct objects, and similar scenes-similar objects); stimuli were always trial unique, were randomly assigned to associative memory conditions, and block order was counterbalanced across participants (more information provided below). For each block, there were 34 trials in the study phase and 54 trials in the test phase.

Study phase

Each block contained a study phase in which participants were presented with a sequence of 34 scene-object pairs, occurring side-by-side (Figure 1). As participants viewed each scene-object pair, they were instructed to imagine a scenario involving the object within the scene (e.g., a backpack swinging through the trees) as vividly and elaborately as possible. They provided key presses to rate how vivid their imagined scenario had been on a scale from 1 to 6 (where 1 was "not elaborate" and 6 was "very elaborate"). Each pair of images was displayed for 8000 ms and then disappeared. If the participant made a response during the 8000 ms period, the images stayed on the screen until 8000 ms had passed. Participants had to make a response in order to progress to the next trial. If the participant did not respond during the 8000 ms period when the images were on the screen, the images would disappear, leaving just a white screen, and the participant would have to make their response to progress to the next trial. This was to ensure that all participants studied the image pairs for the same amount of time. After each trial a brief window appeared asking the participants to "Press any key to continue to view the next pair." The participant had to press any key to progress to the next trial.

Test phase

After all 34 study pairs of a condition block were viewed, the test phase of that block began. Each test block had 54 trials. Each test trial had two phases: first an assessment of single item recognition, followed by an associative memory judgment.

Single item recognition

For each trial, participants first viewed a single image, either a scene or an object, and made a remember/know/new (R/K/N) judgment about the image (Gardiner, 1988;Tulving, 1985). The single item recognition test trials were self-paced and participants took as long as they needed to respond. The presentation of either a scene or object was randomized within blocks such that 50% of test trials contained a scene R/K/N judgment and 50% contained an object R/K/N judgment. R/K/N instructions were given verbally as well as displayed on screen prior to each test phase. Participants were told to make a remember response by pressing the "R" key when they felt the image on screen was old and they recalled contextual details about the study episode. These additional details could be the image that was previously paired with this item, or the scenario they imaged when they studied it, or a thought or feeling elicited by the image. Alternatively, if they felt the image was old but did not recall any contextual details about the study episode, they were instructed to indicate the item was familiar by pressing the "K" key. If they felt they had not seen the image before, participants indicated the image was new by pressing the "N" key. A reminder of key-mappings was present on every trial. Within each block, the image was old 63% of the time (34 trials) and new 37% of the time (20 trials). Fewer new trials were included to keep the test phase reasonable in length and the overall experiment time under 90 minutes.

Associative memory

After the single item recognition response, the image stayed on the screen and a second image appeared. In other words, the object-scene pair displayed to participants during the associative memory judgment comprised of the image just viewed during single item recognition alongside a second stimulus from the other stimulus category. This second stimulus could be new, or it could have been viewed at study either as part of the present pair or in another pairing. New items were items that participants had not seen before, either during the study phase or previously in the test phase.

Thus, there were five associative memory trial types in total: (1) intact pairs, (2) recombined pairs, (3) pairs containing an old scene paired with a new object, (4) pairs containing a new scene paired with an old object, and (5) pairs containing a new scene paired with a new object. Participants were instructed to answer the question "Were these two images paired together at study?" by indicating yes ("Y" key) or no ("N" key) on the keyboard. The associative memory test trials were self-paced and participants took as long as they needed to respond. If the first item that was presented (i.e., during the single item recognition) was new, then participants were instructed to respond "no" to the associative memory question. After the test phase ended, participants were instructed to press any key to continue and initiate the study phase for the next block.

Condition assignment

There were three conditions in total: (1) *distinct scenes-similar objects* in which distinct scenes were paired with similar backpack objects; (2) *similar scenes-distinct objects* in which similar forest scenes were paired with distinct objects; (3) *similar scenes-similar objects* in which similar forest scenes were paired with distinct backpack objects. Note, in order to keep the experiment under 1.5 hours we chose not to include a distinct scenes-distinct objects condition (see Discussion for further rationale). Conditions were blocked with six blocks in total (i.e., two blocks of each condition). Block order was counter-balanced across participants in a Latin matrix square design such that no participants saw the same condition twice in a row (e.g., 123123, 231231, etc.). Within each of these blocks, there were 14 trials of each associative memory trial type, with the exception of the recombined pairs (old scenes paired with old objects) and the new scenes paired with new objects, which each had 6 trials per block.

Statistical analysis

For all results reported below, the Kenward-Roger method was used to approximate degrees of freedom. Common factors for all analyses of variance reported below include group (young versus older adults) and condition (distinct scenes-similar objects, similar scenes-distinct objects, and similar scenes-similar objects). We modeled the data using linear mixed effects models with fixed effects based on experimental hypothesis and random effects structures to account for the effects of individual participants. We began each model with a random effects structure that was the maximal justified by the design (including random slopes) (Barr et al., 2013). We systematically pruned the random effects structure until the model converged while avoiding a singular solution (i.e., overfitting) (Singmann & Kellen, 2019). Models that included random slopes either failed to converge or reached a singular solution, therefore the models reported only include random intercepts for random effects.

One of the primary aims of this experiment was to investigate how aging impacts associative memory judgments for different stimulus types. Specifically, we were interested in whether there would be differences when an old object was paired with a new scene, relative to when an old scene was paired with a new object. Because both these trial types involve only a false alarm or a correct rejection, we cannot conduct signal detection analyses and calculate measures like d prime or criterion for the key comparison of interest. We were most interested in how the proportion of false alarms would differ across the trial types, and thus, we powered our design to be able to investigate these differences. Specifically, for each condition there were 14 intact pairs where the response could be either a hit or a miss, and 40 pairs where the association was new in some way and the response could be either a false alarm or a correct rejection (6 pairs containing two old items, 28 pairs containing one new item and one old item, and 6 pairs containing two new items). In order to address our main research question, we compared the proportion of false alarms for each of the associative memory trial types, which enabled us to assess the effectiveness of distinctive objects versus scenes in rescuing associative memory deficits in aging.

Results

Vividness ratings

First, we considered whether vividness ratings during the encoding task differed across groups or conditions (Table 2). We ran a linear mixed effects model, with fixed effect predictors for group (young versus older adults) and condition (distinct scenes-similar objects, similar scenes-distinct objects, and similar scenes-similar objects) predicting vividness ratings. We found a main effect of condition ($F(2, 114) = 6.52$, $p = .002$) such that the similar scenes-similar objects condition had lower vividness than both the distinct scenes-similar objects ($t(114) = 3.12$, $p < .01$) and the similar scenes-distinct objects ($t(114) = 3.14$, $p < .01$). Vividness ratings for the distinct scenes-similar objects condition did not differ from the similar scenes-distinct objects condition ($t(114) = 0.02$, $p = .99$). There was neither a main effect of group ($F(1,57) = 0.59$, $p = 0.44$) nor group by condition interaction ($F(2,114) = 0.06$, $p = 0.94$).

Table 2. Vividness ratings of pairs at encoding.

	Distinct Scenes, Similar Objects	Similar Scenes, Distinct Objects	Similar Scenes, Similar Objects
Young Adults	3.16 (0.93)	3.14 (0.88)	3.00 (0.92)
Older Adults	2.93 (0.83)	2.94 (0.81)	2.72 (0.94)

Standard deviations are indicated in parentheses.

We next tested whether the vividness ratings given to the object and scene pairs during the study phase might predict memory recall for those items or that pair of items. To test this hypothesis, we first correlated vividness rating during the study phase (collapsed across conditions and groups) with single item recognition hits. We found a positive correlation between vividness rating and proportion of hits ($r = 0.151$, $t(175) = 2.0244$, $r < 0.05$). This suggests that there was a relationship between vividness during study and successful memory retrieval of individual items during the single item recognition test. We next correlated vividness with single item recognition false alarms. We found no significant correlation between vividness ratings and proportion of false alarms ($r = 0.07$, $t(175) = 0.9326$, $r = 0.3523$). We then correlated vividness rating during the study phase (collapsed across conditions and groups) with associative memory hits and false alarms. We did not find any significant relationships between vividness and associative memory hits or false alarms. We conducted these same analyses for older and younger adults separately and for each condition separately and found the same pattern of results (i.e., a significant relationship between vividness and single item hits, but no significant relationship for any other DV). Thus, for simplicity, we report the findings collapsed across age group and condition. These findings suggest that if pairs of images were encoded with self-reported high vividness, there was a higher likelihood that the individual items in the pair would be correctly recalled during single item recognition. However, vividness did not relate to the likelihood of making false alarms during the single item recognition, and it had no relationship to associative memory hits or false alarms. This suggests that vividness of object and scene pairs at encoding is not related to associative memory accuracy.

Single item recognition

Next, we examined whether single item recognition (scenes and objects viewed in isolation during R/K/N judgments) differed between groups and conditions (Figure 2). For these analyses we analyzed corrected recognition (i.e., proportion hits minus proportion false alarms), with hits defined as either remember or know responses to old items and false alarms defined as either remember or know responses to new items. We began with a linear mixed effects model, with fixed effect predictors for group (young versus older adults), stimulus type (objects versus scenes), and condition (distinct scenes-similar objects, similar scenes-distinct objects, and similar scenes-similar objects). In the random effects term, we included participant as a random intercept. We found a significant effect of stimulus ($F(1, 285) = 4.60$, $p < .05$), whereby objects had a higher hit rate than scenes ($t(285) = 2.14$, $p < .05$)). We also found a significant effect of condition ($F(2, 285) = 54.90$, $p < .001$). Post hoc analyses to investigate this main effect revealed that, collapsing across group and stimulus type, images in the similar object-similar scene condition had a lower hit rate than images in either the distinct object-similar scene ($t(285) = 9.84$, $p < .001$)) or in the similar object-distinct scene condition ($t(285) = 8.03$, $p < .001$)). There was no difference between the distinct object-similar scene and similar object-distinct scene conditions ($t(285) = 1.80$, $p = .17$). We found a significant interaction between stimulus type and condition ($F(2, 285) = 185.18$, $p < .001$). To break down this interaction, we first examined differences between conditions within each stimulus type, and then we examined

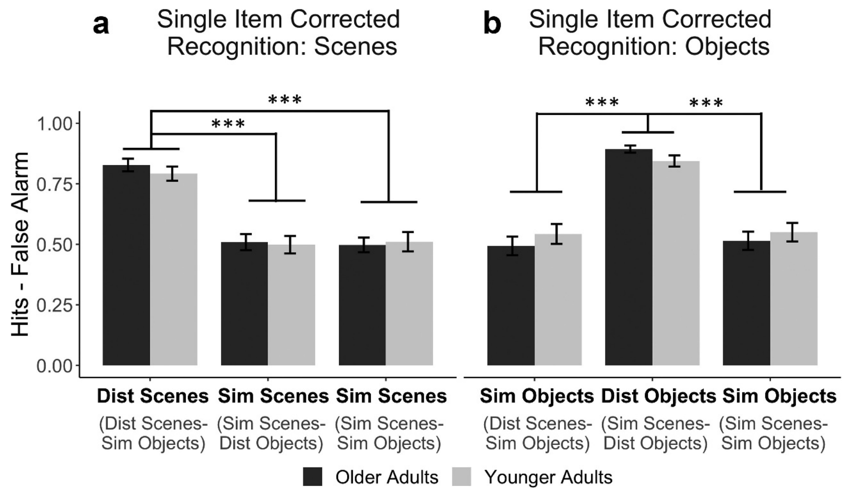

Figure 2. Single item corrected recognition (i.e., hits minus false alarms) for scenes (panel a) and objects (panel b) across all three associative memory conditions (x-axis condition labels: Dist = Distinct, Sim = Similar). a) for scene recognition there was a main effect of condition, whereby the distinct scenes in the distinct scenes-similar objects condition were best recognized. b) Similarly, for object recognition there was a main effect of condition, whereby distinct objects in the similar scenes-distinct objects condition were best recognized. a-b) Comparisons across stimuli revealed that distinct scenes had lower recognition scores than distinct objects, whereas similar scenes and similar objects were matched across conditions. There were no group differences in single item recognition. ***p < .001. Error bars denote ±1 standard error. Note that for corrected recognition, chance is zero.

differences between stimulus types to compare recognition for distinct scenes versus distinct objects, and similar scenes versus similar objects. These results are reported below.

Scene corrected recognition

Beginning with single item recognition for scenes, we conducted a linear mixed effects model with group and condition as fixed effects and participant as the random intercept in the random effects term, examining corrected recognition for scenes viewed in isolation (Figure 2(a)). We found a main effect of condition (F(2,114) = 127.35, p < .001), whereby distinct scenes were better remembered than similar scenes. Specifically, distinct scenes presented in the distinct scenes-similar objects condition were better remembered than similar scenes presented in the similar scenes-distinct objects condition (t(114) = 13.61, p < .001), as well as relative to similar scenes presented in the similar scenes-similar objects condition (t(114) = 14.01, p < .001). There was no difference in scene recognition between the two similar scene conditions (t(114) = 0.40, p = .91). We found neither a main effect of group (F(1,57) = 0.18, p = .67), nor a condition by group interaction (F(2,114) = 0.25, p = .78).

Object corrected recognition

Similarly, we conducted a linear mixed effects model with group and condition, examining corrected recognition for objects viewed in isolation (Figure 2(b)). We found a main effect of condition (F(2,114) = 130.14, p < .001), whereby distinct objects were better remembered than similar objects. We found that distinct objects presented in the similar scenes-distinct objects condition were better remembered than similar objects presented in the distinct scenes-similar objects condition ($t(114) = 14.57$, $p < .001$), as well as relative to similar objects presented in the similar scenes-similar objects condition ($t(114) = 13.27$, $p < .001$). There was no difference in object recognition between the two similar object conditions ($t(114) = 1.29$, $p = .39$). We found neither a main effect of group ($F(1,57) = 0.08$, $p = .77$), nor a condition by group interaction ($F(2,114) = 2.18$, $p = .12$).

Scene versus object corrected recognition

Finally, we investigated whether recognition for distinct items and similar items differed across stimulus category. We first examined corrected recognition for distinct stimuli using a linear mixed model with group and stimulus type (distinct scenes and distinct objects) as fixed effect predictors of recognition. We found a main effect of stimulus category ($F(1,57) = 11.21$, $p < .01$), such that distinct objects were better remembered than distinct scenes ($t(57) = 3.34$, $p < .01$). This between-stimulus difference is further addressed in the Control Analyses section below (Figure 3). There was no interaction between group and stimulus type ($F(1,57) = 0.14$, $p = .71$), indicating that the better memory for distinct objects relative to distinct scenes did not differ by age group. Lastly, we examined whether corrected recognition for similar stimuli differed across stimulus type. We ran a linear mixed model with group, stimulus type (similar scenes versus similar objects), and condition (paired with a distinct versus similar image) as fixed effect predictors and found

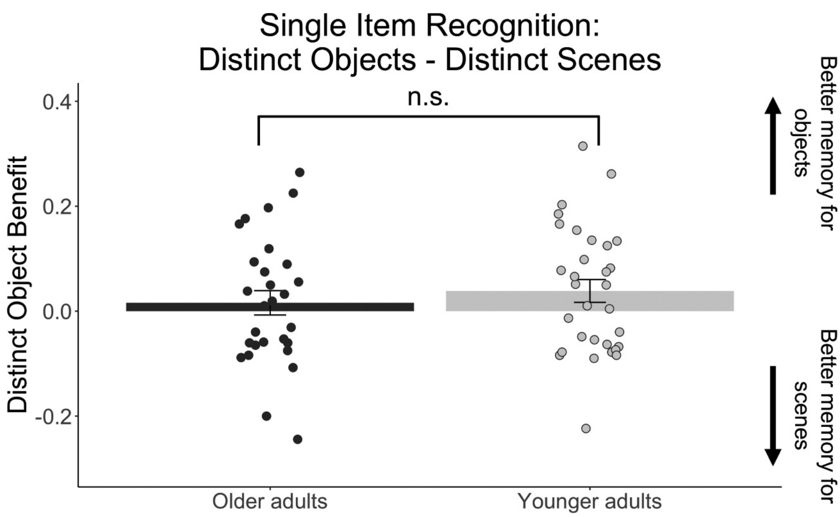

Figure 3. Distinct object benefit scores for older and younger adults. Distinct object benefit (i.e., corrected recognition for distinct objects minus distinct scenes) was numerically greater than zero, however the distinct object benefit was not significantly different than zero for older or younger adults. This suggests that distinct objects were not significantly better remembered than distinct scenes. We found no difference in distinct object benefit for older and younger adults. Together, these plots demonstrate that the marginally better recognition memory for distinct objects relative to distinct scenes cannot explain the pattern of results for associative memory false alarms. Individual points represent the distinct object benefit for each individual participant. Error bars denote ±1 standard error.

Table 3. Breakdown of hits and false alarms toward Remember/Know/New Task.

	Distinct Scenes, Similar Objects		Similar Scenes, Distinct Objects		Similar Scenes, Similar Objects	
	Distinct Scenes	Similar Objects	Similar Scenes	Distinct Objects	Similar Scenes	Similar Objects
Young Adults						
Remember Hits	0.62 (0.27)	0.44 (0.26)	0.49 (0.22)	0.65 (0.26)	0.37 (0.22)	0.39 (0.26)
Know Hits	0.25 (0.22)	0.33 (0.17)	0.35 (0.16)	0.26 (0.22)	0.40 (0.18)	0.41 (0.20)
Remember FAs	0.01 (0.02)	0.03 (0.06)	0.04 (0.07)	0.02 (0.03)	0.02 (0.05)	0.02 (0.05)
Know FAs	0.06 (0.09)	0.21 (0.21)	0.31 (0.17)	0.05 (0.08)	0.26 (0.19)	0.22 (0.16)
Older Adults						
Remember Hits	0.59 (0.32)	0.34 (0.26)	0.46 (0.24)	0.67 (0.33)	0.40 (0.27)	0.35 (0.29)
Know Hits	0.36 (0.30)	0.47 (0.27)	0.41 (0.24)	0.27 (0.32)	0.43 (0.26)	0.47 (0.27)
Remember FAs	0.01 (0.03)	0.04 (0.06)	0.05 (0.08)	0.03 (0.04)	0.05 (0.08)	0.04 (0.08)
Know FAs	0.08 (0.10)	0.29 (0.22)	0.31 (0.20)	0.04 (0.05)	0.28 (0.17)	0.26 (0.21)

FAs are False Alarms. Standard deviations are indicated in parentheses.

no main effects (stimulus type: $F(1,171) = 0.76$, $p = .38$, condition: $F(1,171) = 0.39$, $p = .53$, group ($F(1,57) = 0.15$, $p = .70$) and no significant interactions, suggesting that similar scenes and similar objects were equally well-remembered across groups in terms of item recognition.

Though not the primary focus of the present paper, we also report the full breakdown of R/K/N responses toward single items for young and older adults across conditions inTable 3. There were three primary findings. First, collapsed across age group, more "Remember" responses were given to distinct stimuli (objects and scenes) compared to similar stimuli (Number of "Remember" responses to distinct objects > Number of "Remember" responses to similar objects: $t(177) = 4.98$, $p < 0.001$; Number of "Remember" responses to distinct scenes > Number of "Remember" responses to similar scenes: $t(178) = 4.65$, $p < 0.001$). Second, more "Know" responses were given to similar stimuli compared to distinct stimuli (Number of "Know" responses to similar objects > Number of "Know" responses to distinct objects: $t(252) = 2.42$, $p < 0.05$; Number of "Know" responses to similar scenes > Number of "Know" responses to distinct scenes: $t(261) = 2.94$, $p < 0.01$). Third, collapsed across conditions and stimulus type, older adults made more Know responses than younger adults ($t(55) = 2.02$, $p < 0.05$).

Associative memory

For associative memory, we examined three response categories: (1) hits toward previously-viewed pairings (intact pairs), (2) false alarms toward pairs of previously-viewed items that had not been paired together (recombined pairs), and (3) false alarms toward pairs containing at least one new item. Note, we investigated whether there was any effect of whether participants completed single item recognition of a scene vs. an object on associative memory hits or associative memory false alarms. We did not find any effect of scene vs. object and therefore we chose not to pursue this analysis further.

Associative Memory Hits: Intact Pairs. Beginning with associative memory hits toward intact pairs, we ran a linear mixed effect model with group (young versus older adults) and condition (distinct scenes-similar objects, similar scenes-distinct objects, and similar scenes-similar objects;Figure 4(a)) as the fixed effect predictors and with participant as the random intercept in the random effects term. We found a main effect of condition (*F*

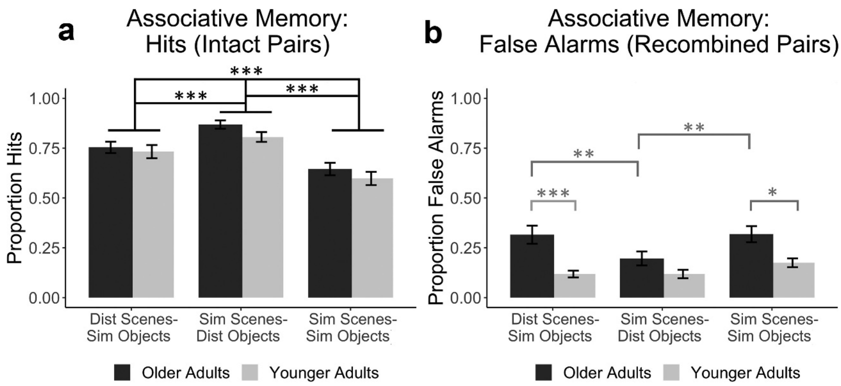

Figure 4. Associative memory hits and false alarms (x-axis condition labels: Dist = Distinct, Sim = Similar). a) Associative memory hit rate toward intact pairs. Hits were greatest in the similar scenes-distinct objects condition and were lowest in the similar scenes-similar objects condition across groups. There were no group differences in associative memory hits. b) Associative memory false alarms toward recombined pairs of previously-viewed items. We found a significant interaction whereby older adults false alarmed more often than young adults the distinct scenes-similar objects condition and in the similar scenes-similar objects condition. Black brackets represent main effects and gray brackets represent simple effects of interest. ***$p < .001$, **$p < .01$, *$p < .05$. Error bars denote ±1 standard error.

(2,114) = 83.88, $p < .001$), whereby proportion of hits was highest in the similar scenes-distinct objects compared to both the distinct scenes-similar objects condition ($t(114) = 5.63$, $p < .001$) and the similar scenes-similar objects condition ($t(114) = 12.91$, $p < .001$). Additionally, the distinct scenes-similar objects condition had a higher hit rate than the similar scenes-similar objects condition ($t(114) = 7.28$, $p < .001$). There was neither a main effect of group ($F(1,57) = 1.44$, $p = .24$), nor a group by condition interaction ($F(2,114) = 0.79$, $p = .46$).

Associative Memory False Alarms: Recombined Pairs. Next, we analyzed false alarms made to recombined pairs (Figure 4(b)). We ran a linear mixed effects model with predictors for group and condition and found a main effect of condition ($F(2,114) = 7.77$, $p < .001$), whereby false alarm rates were lower in the similar scenes-distinct objects condition relative to the distinct scenes-similar objects condition ($t(114) = 2.58$, $p < .05$) as well as relative to the similar scenes-similar objects condition ($t(114) = 3.87$, $p < .001$). False alarm rates did not differ between distinct scenes-similar objects relative to similar scenes-similar objects ($t(114) = 1.28$, $p = .40$). We found a main effect of group ($F(1,57) = 16.06$, $p < .001$), whereby older adults made more false alarms toward recombined pairs than young adults ($t(57) = 4.00$, $p < .001$). The main effect of group was qualified by a significant group by condition interaction ($F(2,114) = 3.34$, $p < .05$), whereby older adults made more false alarms than young adults in the distinct scenes-similar objects condition ($t(122) = 4.49$, $p < .001$) and in the similar scenes-similar objects condition ($t(122) = 3.27$, $p < .05$), but did not differ relative to young adults in the similar scenes-distinct objects condition ($t(122) = 1.78$, $p = .48$).

Interestingly, when we compared older adults' performance across conditions, we found that they false alarmed significantly less often in the similar scenes-distinct objects condition relative to both the similar scenes-similar objects condition ($t(114) = 3.65$, p

< .01) and the distinct scene-similar object condition ($t(114) = 3.56$, $p < .01$), suggesting that older adults benefitted from the inclusion of a distinct object in the pair. In contrast, there was no difference in older adults' false alarms toward distinct scenes-similar objects relative to similar scenes-similar objects ($t(114) = .09$, $p = 1.0$), suggesting that the inclusion of a distinct scene did not aid older adults in rejecting novel associations – despite intact single item recognition of distinct scenes (Figure 2a). In sum, our findings are consistent with well-established age-related increases in false recognition of stimulus associations, with one important exception: when the association involved a distinct object, associative memory in older adults was intact.

The analyses thus far have been with items that were all previously-viewed (intact pairs and recombined pairs), so the extent to which familiarity with the items could be playing a role is unclear because the individual items are equally familiar. For example, older adults' elevated false alarms for recombined pairs in the distinct scenes-similar objects condition (Figure 4(b)) might reflect the fact that they were drawn in by their intact single-item memory for the distinct scene and thus incorrectly endorsed the recombined pair. To investigate whether memory for the individual images could explain our false alarm findings, we next analyzed pairs of items in the associative memory test phase that included items that participants have not previously viewed (either new distinct scenes or new distinct objects).

Associative Memory False Alarms: Pairs Containing New Items. Our last set of analyses focused on associative memory false alarms toward scene-object pairs that included at least one new item (Figure 5). Each condition had three pair types: old scene-new object, new scene-old object, and new scene-new object. To begin, we ran a linear mixed effects model with group, condition, and pair type as fixed effects terms and participant as the random intercept. We found a significant effect of group ($F(1,57) = 7.35$, $p < .01$), whereby older adults had a higher proportion of false alarms than younger adults ($t(57) = 2.71$, $p < .01$). There was a significant effect of condition ($F(2,456) = 14.05$, $p < .001$), which revealed that pairs with an old image that had been encoded in the similar object – similar scene condition were associated with more false alarms compared to old images from the similar object-distinct scene ($t(456) = 3.57$, $p < .01$) and distinct object-similar scene condition ($t(456) = 5.17$, $p < .001$). Lastly, there was a significant effect of pair type ($F(2,456) = 44.12$, $p < .001$), whereby pairs that included an old image had a higher proportion of false alarms compared to pairs that had no old images ($ps < .001$).

We also found four significant interactions, including a three-way interaction of group by condition by pair type ($F(4,456) = 5.10$, $p < .001$), a two-way interaction of pair type by group ($F(2,456) = 9.20$ $p < .001$), a two-way interaction of pair type by condition ($F(4,456) = 25.59$ $p < .001$), and a two-way interaction of condition by group ($F(2,456) = 4.85$, $p < .01$,). To break down these effects, we looked within each of our three conditions and examined the rate of false alarms toward each of the three pair types across groups (Figure 5).

False Alarms to Pairs Containing New Items: Distinct Scenes-Similar Objects. Within distinct scenes-similar objects, we ran a linear mixed effects model with group and pair type as fixed effects (Figure 5(a)). We found a main effect of group ($F(1,57) = 8.26$, $p < .01$), whereby older adults false alarmed more than younger adults ($t(57) = 2.87$, $p < .01$). We also found a main effect of pair type ($F(2,114) = 17.45$, $p < .001$). This main effect was qualified by a pair type-by-group interaction ($F(2, 114) = 11.30$, $p < .001$), whereby older

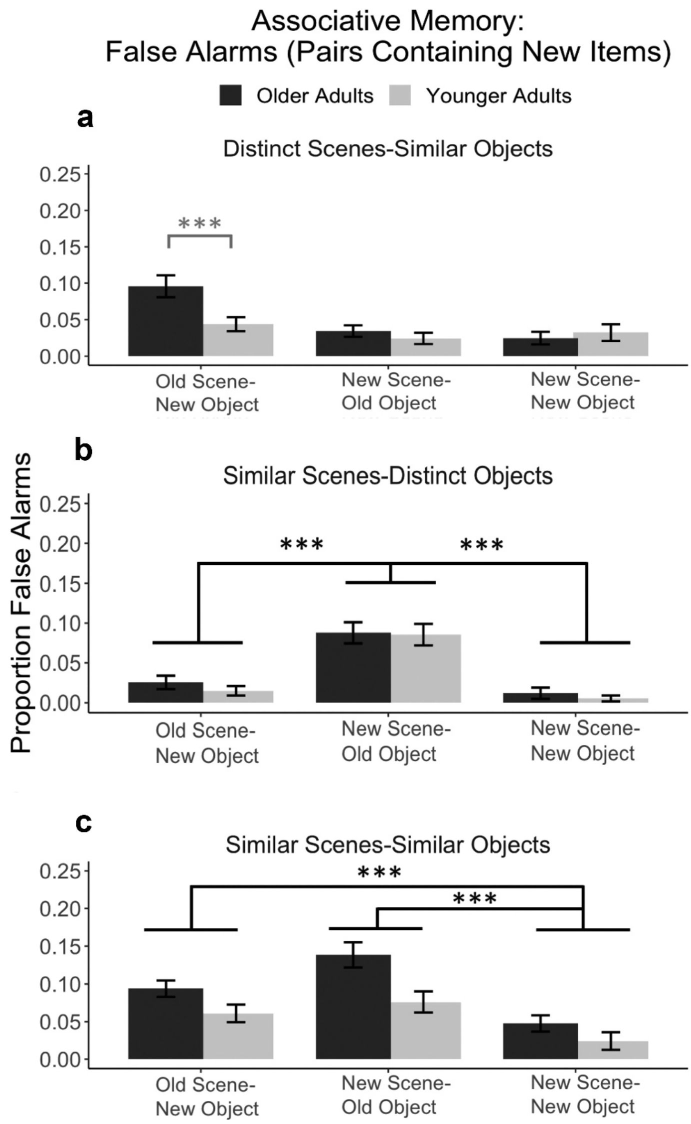

Figure 5. Associative memory false alarms toward pairs that included new items. a) in the distinct scenes-similar objects condition, we found a significant interaction whereby older adults false alarmed significantly more than young adults when the distinct scene was old (i.e., old scene-new object pairs), but not when the distinct scene was new. These results suggest that false associative recognition in older adults was biased by previously-viewed distinct scenes. b) in contrast, in the similar scenes-distinct objects condition, we found no effect of age group, suggesting that both younger and older adults were being lured in by the distinct objects. c) in the similar scenes-similar objects condition, we found a significant main effect of group whereby older adults made more false alarms than younger adults for all pair types. ***p < .001. Black brackets represent main effects and gray brackets represent simple effects of interest. Error bars denote ±1 standard error.

adults false alarmed more than young adults when distinct scenes were old and similar objects were new (i.e., old scene-new object pairs; $t(143) = 5.31$, $p < .001$), suggesting that old distinct scenes led to elevated false associative recognition in older adults relative to young adults. Young and older adults' false alarm rates did not differ when distinct scenes were new, regardless of whether similar objects were old (i.e., new scene-old object pairs; $t(143) = 0.78$, $p = .96$) or similar objects were new (i.e., new scene-new object pairs; $t(143) = 0.24$, $p = .99$). Thus, similar to our findings for recombined pairs (Figure 4(b)), we found that inclusion of an old distinct scene did not aid older adults in rejecting novel pairs, suggesting that single-item recognition of the previously-viewed distinct scene lured them to false alarm to the pairing. Young adults did not exhibit this tendency.

False Alarms to Pairs Containing New Items: Similar Scenes-Distinct Objects. Within similar scenes-distinct objects, we ran a linear mixed effects model with group and pair type as fixed effect predictors for associative memory false alarms (Figure 5(b)). We found a main effect of pair type ($F(2,114) = 59.99$, $p < .001$), whereby false alarm rates were highest when distinct objects were old and similar scenes were new (i.e., new scene-old object pairs) relative to when distinct objects were new and similar scenes were old (i.e., old scene-new object pairs; $t(114) = 8.91$, $p < .001$) and when distinct objects and similar scenes were both new (i.e., new scene-new object pairs; $t(114) = 9.96$, $p < .001$). There was no difference between false alarm rates toward pairs containing old similar scenes (i.e., old scene-new object pairs) and pairs containing two new similar items (i.e., new scene-new object pairs; $t(114) = 1.05$, $p = .54$). We found neither a pair type-by-group interaction ($F(2,114) = 0.86$, $p = .42$) nor a main effect of group ($F(1,57) = 1.32$, $p = .26$). Thus, in contrast to what we observed for pairs containing old distinct scenes, older and young adults demonstrated the same tendency to false alarm when the pair contained a previously-viewed distinct object.

False Alarms to Pairs Containing New Items: Similar Scenes-Similar Objects. Within the similar scenes-similar objects condition, we ran linear mixed effects model with group and pair type as fixed effects (Figure 5(c)). We found a main effect of group ($F(1,57) = 9.25$, $p < .01$), where older adults had more false alarms than younger adults ($t(57) = 3.04$, $p < .01$). We found a main effect of pair type ($F(2,114) = 25.76$, $p < .001$), whereby associative false alarms were lowest when both similar items were new (i.e., new scene-new object pairs) relative to when similar scenes were old and similar objects were new (i.e., old scene-new object pairs; $t(114) = 4.93$, $p < .001$) and relative to when similar scenes were new and similar objects were old (i.e., new scene-old objects; $t(114) = 6.98$, $p < .001$). We found no difference in false alarms between pair types that contained one old similar item (i.e., old scene-new object vs. new scene-old object pairs; $t(114) = 2.04$, $p = .10$). We did not find a significant pair type-by-group interaction ($F(2,114) = 2.71$, $p = .07$). These findings show that regardless of pair type, older adults were more likely than young adults to false alarm to pairs involving similar scenes and objects.

Control analyses

Single Item Recognition: Distinct Objects versus Distinct Scenes. As mentioned above, we found that both older and younger adults had significantly higher single item recognition for distinct objects than for distinct scenes ($t(57) = 3.34$, $p < .01$) (Figure 2). Due to this difference, it could be suggested that distinct objects served as stronger mnemonic cues than distinct scenes during associative memory retrieval simply because distinct objects were better remembered on an individual basis. It should be noted that this explanation is unlikely as both young and older adults showed a recognition advantage for distinct objects over distinct scenes, yet only older adults showed increased false alarms in the distinct scenes-similar objects condition relative to the similar scenes-distinct objects condition (Figures 4(b) and5(a)). Nonetheless, we aimed to further rule out the notion that older adults demonstrated relatively more associative memory false alarms in the distinct scenes-similar objects condition because objects were better remembered than scenes.

Using our full dataset, we calculated a "distinct object benefit" score for each participant based on single item recognition (i.e., corrected recognition for distinct objects minus corrected recognition for distinct scenes). We found that older and younger adults had similar distinct object benefit scores (i.e., mean distinct object benefit; Older adults: $M = 0.02$ ($SD = 0.12$), Younger adults: $M = 0.04$, $SD = 0.12$). One sample, two-sided t-tests revealed that the distinct object benefit was not significantly different from zero for older adults ($t(27) = 0.68$, $p = 0.49$) or young adults ($t(30) = 1.77$, $p = 0.08$). This suggests that, within subjects, distinct objects did not confer a greater memory benefit over distinct scenes. We did not find a significant difference in distinct object benefit between older and younger adults ($t(57) = -0.71$, $p = 0.47$).

Even though we did not find a significant difference in distinct object benefit between older and younger adults, we wanted to directly test the relationship between the distinct object benefit and the proportion of false alarms in the associative memory test. We conducted a linear mixed effects model on the proportion of false alarms with distinct object benefit, group (young versus older adults), and condition (distinct scenes-similar objects and similar scenes-distinct objects) as predictors and participant as the random intercept in the random effects term. If distinct object benefit was related to the number of false alarms that older adults made, we would expect to find a main effect of distinct object benefit. We did not find a main effect of distinct object benefit ($F(1,55) = 1.08$, $p = 0.30$), suggesting that enhanced single item recognition memory for distinct objects cannot explain the differences in associative memory false alarm results in older adults.

Discussion

Here we investigated how distinctive aspects of otherwise overlapping events helped young and older adults recall specific episodes. Specifically, we examined whether there were stimulus-specific differences in scenes versus objects as distinctive cues. Although we did not find age-related differences in single item recognition of either scenes or objects, we did find age-related differences in associative memory judgments for scene-object pairings. Specifically, older adults showed elevated false recognition for recombined scene-object pairs, even when the scenes were distinct. However, these age-related associative memory deficits disappeared if the pair contained an object that was visually distinct. When associative memory judgments involved old items paired with new items, we found that inclusion of old distinct scenes led to higher rates of false associative recognition in older adults. In contrast, older adults did not differ from younger adults when an old distinctive object was paired with a new scene. This suggests that distinctive objects are more powerful associative memory retrieval cues for older adults than are distinctive scenes. Additionally, because there was no time delay between study and test blocks, we do not believe that these results are attributed to long-term forgetting or memory decay, and instead theorize that the differences in false alarms between younger and older adults are driven by an impoverished representation of the memory in older adults due to a change in scene processing that occurs during encoding. Together these findings add further nuance to the body of work demonstrating false associative memory with aging (Bastin & Van der Linden, 2005;Castel & Craik, 2003;Chalfonte & Johnson, 1996; Cohn et al., 2008;Gutchess et al., 2007;Kessels et al., 2007;Naveh Benjamin et al., 2004; Naveh Benjamin, 2000;Old & Naveh Benjamin, 2008), and suggest that the stimulus-specific nature of this effect might be a reflection of age-related changes to the neural mechanisms underlying scene processing.

The present work converges with emerging evidence suggesting that older adults rely on distinct objects to retrieve associative information, which might be due to age-related changes in brain regions important for scene processing. Recent work has shown a difference in older adults' memory for objects and object position within a scene (Tran et al., 2021). Specifically, older adults performed worse than younger adults at recognizing changes in object position within a scene but performed similarly to younger adults at recognizing a change in object identity. These results, in addition to the results presented here, support the hypothesis that older adults use distinct objects more than distinct scenes to differentiate memories. This idea is particularly striking given the important role of scenes in scaffolding memory (Bird & Burgess, 2008;Gaffan, 1994; Hassabis & Maguire, 2007;Lee et al., 2012;Robin et al., 2015;Zeidman et al., 2014). One possible explanation is that areas thought to process spatial scenes, namely the hippocampus, show dysfunction with aging that results in impoverished scene representations (Antonova et al., 2009;Heo et al., 2009;Wimmer et al., 2012). Although such imprecise scene representations may lack details that are important for discriminating between memories for events with overlapping scenes, they may be sufficient to support single item recognition of distinct scenes, particularly via recognition of category-level information (e.g., a cityscape and a hospital room may be easily differentiated in memory based on their category). In addition to decreases in hippocampal differentiation with age (Yassa et al., 2011), neural differentiation has been shown to decrease in older adults, specifically in scene-selective regions like the parahippocampal place area and retrosplenial cortex (Srokova et al., 2020). Together, changes in neural differentiation in key regions that represent scenes might explain why older adults in the present experiment were unable to use distinct scenes to differentiate their memories.

Distinctive stimulus characteristics have long been thought to facilitate memory by promoting event differentiation (Dodson & Schacter, 2001;Schacter et al., 2001;Standing, 1973;von Restorff, 1933). Indeed, recent work in young adults showed that learned associations between similar and distinct images led to greater neural differentiation of similar items and to an increased ability to resolve interference (Favila et al., 2016). With aging, however, neural representations tend to be less well-differentiated, which has been demonstrated by way of hemispheric asymmetry (Cabeza, 2001,2002;Gutchess et al., 2005), and neural dedifferentiation (Carp et al., 2011;Dennis et al., 2007;Goh, 2011;Koen & Rugg, 2019;Park et al., 2001,2004). It has been suggested that dedifferentiation with aging may underlie false item recognition, evident from lost access to details from encoding as well as increased reliance on gist (Dennis et al., 2014). Thus, a fruitful avenue for future work may be in determining whether neural dedifferentiation with aging also underlies false associative recognition.

Although in young adults, spatial information is thought to scaffold episodic memory and act as a powerful memory cue (Hebscher et al., 2018;Robin & Moscovitch, 2014;Robin et al., 2015), the role that scenes and spatial information plays in associative memory might change as our brains age. The visual processing of scene images is thought to be supported by the hippocampus (D. Douglas et al., 2017;Lee et al., 2005,2008;McCormick et al., 2017), and therefore age-related hippocampal dysfunction may have affected scene processing at encoding and retrieval. Indeed, Douglas and colleagues (D. M. Douglas, 2016) found that healthy older adults had abnormal eye movements toward scene images that contained structural anomalies, but not to objects with similar anomalies, suggesting that older adults' perceive spatial configurations in an altered manner. As a result of impoverished scene representations, older adults may not rely on scene information to anchor or categorize their memories. Thus, whereas in young adults scene context information more strongly differentiates neural representations of multi-item events than either object or person information (Robin et al., 2018), for older adults scene information may play a less prominent role in shaping episodic representations.

A limitation of the current study is that similar items were always both visually and conceptually similar (specifically, similar objects were always backpacks and similar scenes were always forests). This might have made it more difficult for participants, especially older adults, to create distinct imagined scenarios. For example, it is possible that it was more difficult for participants to generate distinct imagined scenarios with backpacks because of the limited number of ways for a backpack to interact with a scene (e.g., always imagining carrying the backpack in every scene). This limitation also applies to the similar scene condition, where the number of ways to imagine any object within a forest is also limited, making it difficult to create distinct imagined scenarios within multiple different forests. While the decision to use visually and conceptually similar objects and scenes might have affected the distinctiveness of the imagined scenarios, we do not believe that this aspect of our design takes away from the interpretation of our findings. In fact, we designed the experiment such that all of the similar objects and all of the similar scenes were both visually and conceptually similar to one another in order to create conditions in which participants had to use more detailed representations of the object and scene pairs in order to successfully recall the exact items and recognize the correct pairs of items. Moreover, theoretical motivation for this study was driven by the evidence that objects and scenes that belonged to similar conceptual categories lead to more interference in memory than perceptually similarities (Konkle et al., 2010a,2010b). Here we wanted to keep both visual and conceptual aspects similar for a set of objects (backpacks) and a set of scenes (forests) in order to directly compare the two stimulus classes and their role in associative memory and to determine which type of information is more impaired when faced with high interference (i.e., similar objects vs. similar scenes). Future research is needed to determine whether distinctive objects are more powerful associative memory retrieval cues for older adults than are distinctive scenes when the stimuli are visually similar but conceptually distinct.

When designing the experiment, we chose not to include a distinct-scene and distinct-object condition. We aimed to collect as much data from each participant as possible while also maintaining a high quality of data. Keeping the experiment under 1.5 hours long was important for keeping participants on task throughout the whole experiment. The addition of this fourth condition would have made the task too long and the quality of data that were collected (from both younger and older adults) would have suffered. While this may be a limitation of the current study, we do not believe the inclusion of a distinct-scene and distinct-object condition would reveal new differences between older and younger adult's associative memory performance that would change the interpretation of the results. In the current experiment, we see that whenever an object is distinct, older adult's memory is consistently comparable to younger adults. The distinct object alone is enough to bolster the older adults up to the level of younger adults. For example, we find that for recombined pairs of old items when objects were distinct and scenes were similar (Figure 4(b)), older adults had similar rates of false alarms compared to younger adults, even though the scenes were difficult to tell apart. This suggests that the distinct objects alone are enough to rescue older adult's memory and prevent them from false alarming. We see additional evidence of this for recombined pairs that include a new item (Figure 5(b)). Again, when there is a distinct object paired with a similar scene (whether the distinct object is old or new), older adults had a similar rate of false alarms to younger adults. We conclude, therefore, that a distinct object distinct scene condition would not reveal any differences between older and younger adult's false alarms rates and that older and younger adult performance would be similar.

In sum, the present study provides novel evidence that there are stimulus-specific differences in associative memory between young and older adults, such that for older adults distinct objects are better associative memory retrieval cues than distinct scenes. These results suggest the counter-intuitive notion that older adults more easily differentiate their memories based on the objects within an event, not the scenes that set the stage for the event. We suggest that this is driven by age-related changes to the hippocampus and other brain regions important for scene processing, therefore leading older adults to rely on preserved representations of objects compared to potentially degraded or weaker representations of scenes.

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ORCID

Nichole R. Bouffard http://orcid.org/0000-0001-7044-5695
Andy C. H. Lee http://orcid.org/0000-0002-8546-5311

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