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REPORT



Repeated study of items with and without repeated context: aging effects on memory discriminability

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ABSTRACT

Presenting items multiple times during encoding is a common way to enhance recognition accuracy. Under such conditions, older adults often show an increase in false recognition that counteracts benefits of repeated study. Using a false-memory paradigm with related study items and related lures, we tested whether repetition within the same encoding task or repetition across two different encoding tasks would be more beneficial to older adults' memory discriminability. Results showed that, compared to items not repeated at study, items repeated in the same context and items repeated across different contexts showed improvements in memory discriminability in both young and older adults. This improvement was primarily reflected in improved recollection responses for both age groups across both repeat study conditions, as compared to no repetition. Importantly, the results demonstrated that repetition can be used to successfully mitigate age-related deficits by increasing memory discriminability and without incurring a cost of false recognition specific to any one age group.

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Repeated encoding; aging; memory; recollection

Past research has attempted to improve older adult memory performance through encoding manipulations that are designed to strengthen the initial encoding trace. Two such approaches have been the repeated presentation of information and the presentation of information in distinct ways. Research on the first of these strategies, repetition, has shown that providing participants multiple opportunities to study and encode to-be-remembered information generally enhances memory in both young and older adults. However, at times, increased hit rates are offset in older adults by simultaneous increases in false alarm rates (e.g., Jacoby, 1999; Kilb & Naveh-Benjamin, 2011). Therefore, maximising the positive benefits of repetition has yet to be fully realised. Research on the second of these strategies, distinctive encoding, has shown that increasing item-specific processing at encoding can also enhance memory across age (e.g., Dodson & Schacter, 2002; Koutstaal, Schacter, Galluccio, & Stofer, 1999; McDermott, Buckner, Petersen, Kelley, & Sanders, 1999). That is, the additional focus on distinct details during study provides the necessary information and recollection in order to later reject lures. Surprisingly, no study to date has attempted to bridge repetition and distinctive encoding in an attempt to mitigate age-related deficits. To that end, the present study sought to strengthen memory for studied items by manipulating both repetition and distinctive encoding within the same study design. Further, we tested this in a false-memory paradigm using related

items and related lures, an approach that often results in increased rates of false memories in older adults (for a meta-analysis, see McCabe, Roediger, McDaniel, & Balota, 2009).

Past research examining the effect of repetition on memory performance has, in some cases, shown varied effectiveness for young and older adults. In young, repetition typically results in increases to hits and decreases to false alarms. In contrast, older adults will also show increased hit rates, but at times have also shown increases in false alarm rates (Jacoby, 1999; Roediger & McDermott, 1995), such that overall memory discriminability (d') does not show repetition-related improvements. Results like these have been attributed to age-related reductions in recollection, which is critical in opposing familiarity that results from repeated study (Jacoby, 1999). Recollection refers to memory for contextual and specific details of any individual episode, whereas familiarity is a fairly automatic process that is void of any recollection and absent of defining details (for review, see Yonelinas, 2002). Importantly, this failure to recollect specific details leaves familiarity unopposed, leading to increased false recognition in older adults when lures share common features with encoded items. Despite these previous findings, repetition in older adults is not without merit. For example, past research has used repeated study to successfully match older adult item memory performance to that of young adults (e.g., Daselaar et al., 2006).

Researchers have also enhanced memory performance in older adults by presenting to-be-remembered information in distinctive contexts or formats (Dodson & Schacter, 2002; Koutstaal et al., 1999; McDermott et al., 1999). For example, Koutstaal et al. (1999) found that the encouragement of distinct encoding of perceptual details resulted in decreased false recognition in older adults. They further suggested that an encoding task, such as likeability ratings on a five-point scale, could encourage distinctive encoding and item-specific processing. Further, the presentation of information across contexts is posited to enhance the distinctive encoding of specific studied details, which supports recollection-based acceptance of targets and counteracts familiarity, aiding in the rejection of lures. Dodson and Schacter (2002) argued that such a distinctive heuristic provides individuals with a strategy to determine why a particular word at retrieval is familiar, thus resolving feelings of familiarity and preventing false recognition.

Previous work in young, but not older adults, has sought to combine the beneficial effects of repeated study and distinctive encoding by evaluating how repetition across distinct encoding contexts affects memory performance (e.g., Burnkrant & Unnava, 1987; Hintzman & Stern, 1978; Unnava & Burnkrant, 1991). Results demonstrated that such repetition improves later memory above-and-beyond repetition in the same context. For example, Hintzman & Stern (1978) placed names in sentences that repeated in either the same sentence or in different sentences. They found better recall for target words when the words were repeated across different sentences. The authors attributed this memory benefit to the creation of multiple memory traces that support retrieval by providing multiple “routes” to a single memory. Interestingly, similar manipulations have not been utilised in older adults. That is, repetition effects have not been examined across encoding manipulations or contexts. Given the benefit observed in young, as well as individual benefits to older adults, it is of interest to know whether repetition enhancements in older adults can also benefit from encoding across different contexts.

The current study was further motivated by evidence in young adults showing that repeating across contexts versus within context can result in different contributions of recollection and familiarity to recognition performance. In one study (Opitz, 2010), recollection increased compared to no repetition regardless of context manipulation. Interestingly, higher levels of familiarity were reported for recognition of objects that had been repeated across different contexts compared to repetition within a single context. The author suggested that across-context repetitions might result in decontextualisation, or item representation void of contextual information. Further, the author suggests this might be driven by a familiarity-based mechanism. This conclusion makes repetitions across contexts particularly enticing for mitigating memory deficits in older adults. Despite deficits in

recollection, older adults maintain relatively intact familiarity (for review, see Yonelinas, 2002). Therefore, a repetition strategy posited to rely on age-spared familiarity, as compared to age-degraded recollection, could provide a boost to older adult performance. However, if this is the case, it is unclear if this reliance on familiarity would also produce deleterious effects on memory discriminability (by increasing false recognition of related lures). The present study sought to extend this line of research to aging and test whether repetition within or across contexts would improve memory in older adults by increasing overall memory sensitivity and by reducing typical susceptibility to false recognition.

In the current study, participants studied categorical word lists (similar to Deese, 1959; Roediger & McDermott, 1995) using two separate encoding tasks. We manipulated item repetitions to occur either within the same encoding task or across two different deep encoding tasks (i.e., a pleasantness rating and an experience rating). We sought to elucidate whether repetition within the same encoding task or repetition across two different encoding tasks would better benefit older adults’ memory performance. We predicted that, similar to previous findings in young adults, providing two distinct encoding tasks would help older adults over and above repetition of a single encoding task. As a result of this increased benefit, we predicted that age differences in memory discriminability would be reduced in the distinctive repetition condition. Further, we will explore the relative contributions of familiarity and recollection to these repetition enhancements. We posited that providing older adults with distinct encoding tasks would improve memory specificity above-and-beyond repeated study within the same task context.

Method

Participants. Forty-one young and 39 older adults participated in the study. Two young adults were excluded due to technical malfunctions during data collection and two older adults were excluded due to failure to follow task instructions, leaving 39 young and 37 older adults reported in all analyses. The young were recruited from the Penn State Psychology Department subject pool (average age: 19.90 years, $SD = 2.25$; range = 18–29) and the older adults were recruited from the State College community (average age: 74.08 years, $SD = 6.38$; range = 62–85). Before completing the experimental task, older adult participants completed a battery of neuropsychological tests (see Table 1 for additional details). Tests were conducted in order to screen for dementia and depression in the older cohort. All individuals performed well within the normal range for their age, verifying that they were cognitively healthy. All participants provided written informed consent and received either research credit or financial compensation for their participation. All experimental procedures were approved by Penn State’s Institutional

Table 1. Participant demographics and cognitive assessment scores.

	Young (<i>n</i> = 39)	Old (<i>n</i> = 37)
Age	19.90 (2.25)	74.08 (6.38)
Years of education	13.03 (1.31)	16.81 (2.44)
Cognitive assessment tasks		
MMSE	-	29.47 (0.97)
WAIS-III		
Symbol search ^a	-	13.78 (2.30)
Digit symbol encoding	-	13.25 (3.03)
Symbol copy	-	97.78 (25.72)
Digit span ^a	-	12.74 (3.77)
Arithmetic ^a	-	12.48 (3.17)
Letter number sequencing	-	11.89 (2.14)
Vocabulary ^a	-	13.52 (3.19)
GDS short form	-	1.86 (2.50)

Note: Age and Years of Education are reported in years. Young adults did not perform cognitive assessment tasks. Means are reported, with standard deviations in parentheses. MMSE = Mini-Mental State Examination. WAIS-III = Wechsler Adult Intelligence Scale – Third Edition. GDS = Geriatric Depression Scale.

^aThese cognitive assessments were only collected for 23 older adult participants.

Review Board for the ethical treatment of human participants.

Apparatus and Materials. Stimuli were displayed and data were collected using COGENT through MATLAB (MathWorks, Natick, MA), at a screen resolution of 800 (H) × 600 (V) at 60 Hz on 17" LCD testing monitors. Stimuli consisted of words from 25 categories (e.g., flowers, sports, candy). Word lists were compiled by first generating a list of category names and generating words related to each category with 14 words from each category selected by the research team for further testing. Individuals then ranked these category exemplars in order of category fit on a scale of 1–14, with one indicating that the exemplar fit the category the most and a rating of 14 indicating that the exemplar fit the category the least. Ratings were then averaged across individuals to identify the 8 most related words to each of the 25 categories. Similar to procedures from the Deese-Roediger-McDermott (DRM) paradigm (Deese, 1959; Roediger & McDermott, 1995), the top two items in each list were used as lures during retrieval while items 3–8 were presented during encoding.

Encoding was broken up into 4 study blocks, each including 150 words. Words were presented individually with all words from a given category presented consecutively. The categories and their respective words were classified into one of three repetition conditions: (1) presented once during study (single presentation), (2) presented twice in the same encoding task (repeat-same), or (3) presented twice under two different encoding tasks (repeat-different). Each block included: (1) 5 categories in the single presentation condition; (2) 10 categories in the repeat-same condition; and (3) 10 categories in the repeat-different condition.

Four hundred words were presented at retrieval: Three targets and three related lures from each category presented at study. A total of 60 targets and 60 related lures were presented from each of the three encoding conditions (single presentation, repeat-same, repeat-different).

A total of 40 lures from categories not presented during the study phase (unrelated lures) were also presented. An equal number of targets and lures from each condition were presented in each of four test blocks. Words were presented in a pseudorandom order, so that no more than two words from the same category were presented consecutively.

Procedure

The study and test phases took place across two sessions, separated by approximately 24 hours. During the study session, participants were told that they would be learning words for a memory test. They were informed that they would be viewing one word at a time on the screen and for each word would be required to answer one of two questions: (1) "How pleasing is this item?" or (2) "How much experience do you have with this item?" Participants were instructed to make their ratings on a 4-point scale. When rating how pleasing an item was, participants used 1 to indicate an item was not pleasing and used a 4 to indicate an item was very pleasing, with 2 and 3 indicating a rating somewhere in between. With respect to experience, a rating of 1 indicated that they had no experience with the item and 4 indicated that they had a lot of experience with the item (with a 2 and 3 indicating a rating somewhere between). Each block required only one of these questions to be answered, such that two of the four blocks consisted of the *pleasing* rating and the other two consisted of the *experience* rating. Pleasing and experience blocks alternated and the order was counterbalanced across participants.

During retrieval, memory was tested using the Remember/Know/New response paradigm ("familiar" was used in place of "know" for clarity) to separate responses based on recollection from those based on familiarity. In accord with typical task instructions, participants were told to respond "remember" if they recognised the word *and* they remembered specific details about its presentation during the study phase. They were told to respond "familiar" if they recognised the word, but they could not remember *specific* details about it. Finally, if the participant thought that the word was *not* presented during encoding, they were instructed to select the "new" response. When they completed all four retrieval blocks, participants were debriefed.

Statistical analyses

To test the effects of repeated study on overall recognition accuracy, we computed a separate d' for each condition by collapsing across "remember" and "familiar" responses to targets and lures from each categorical list. To correct for hit rates of 1 or false alarm rates of 0 that render d' indeterminate, these values were replaced by $(n - 0.5)/n$ or $0.5/n$, respectively, where n is equal to the total number of trials in that condition (Macmillan & Kaplan, 1985; Stanislaw

Table 2. Behavioral Results Means (Standard deviation).

	Single presentation		Repeat-same task		Repeat-different task	
	Young	Old	Young	Old	Young	Old
Target						
Recollection	0.51 (0.20)	0.49 (0.19)	0.70 (0.20)	0.71 (0.17)	0.67 (0.20)	0.69 (0.16)
Familiarity	0.23 (0.15)	0.22 (0.11)	0.17 (0.14)	0.15 (0.10)	0.18 (0.15)	0.19 (0.11)
Miss	0.25 (0.19)	0.26 (0.14)	0.12 (0.13)	0.12 (0.09)	0.14 (0.14)	0.11 (0.09)
Related lure						
False recollection	0.22 (0.16)	0.27 (0.15)	0.22 (0.16)	0.31 (0.15)	0.25 (0.16)	0.31 (0.14)
False familiarity	0.24 (0.16)	0.25 (0.10)	0.25 (0.16)	0.24 (0.10)	0.24 (0.16)	0.26 (0.11)
Correct rejection	0.53 (0.21)	0.46 (0.16)	0.51 (0.21)	0.42 (0.18)	0.49 (0.21)	0.40 (0.15)
Unrelated lure ^a						
False recollection	0.10 (0.13)	0.12 (0.10)	-	-	-	-
False familiarity	0.19 (0.16)	0.22 (0.13)	-	-	-	-
Correct rejection	0.70 (0.23)	0.63 (0.18)	-	-	-	-

^aUnrelated lures came from categories not presented at study and do not fall into one of the three encoding conditions.

& Todorov, 1999). These values were used only for the d' analysis.

For analyses separating rates of “remember” and “familiar” responses, an adjusted familiarity rate [pKnow Hits/(1-pRemember Hits) or pKnow False alarms/(1-pRemember False alarms)] was used as the dependent variable to account for dependence between recollection and familiarity responses (Duarte, Graham, & Henson, 2010; Duarte, Ranganath, Trujillo, & Knight, 2006; Yonelinas, 2002; Yonelinas & Jacoby, 1995).

Each dependent variable of interest was entered into a 2 (age group: young, older) \times 3 (study condition: single presentation, repeat-same, repeat-different) mixed-effects ANOVA, and *post-hoc* tests were corrected for multiple comparisons using the Bonferroni method. When necessary, for all reported findings, we applied Greenhouse-Geisser corrections to violations of sphericity. Means and standard deviations for all conditions separated by response type (remember/familiar/new) are reported in Table 2.¹

Results

Signal detection (d')

Results of the mixed-effects ANOVA revealed a main effect of study condition [$F(2, 148) = 66.73, p < .001, \eta^2 = 0.47$] such that each of the repeated study conditions (repeat-

same: $M = 1.23, SE = 0.08$; repeat-different: $M = 1.18, SE = 0.07$) improved memory discriminability compared to the single presentation condition ($M = 0.71, SE = 0.05$); no difference was found between the two repeated conditions (Figure 1). The main effect of age group was also significant [$F(1, 74) = 5.28, p = .02, \eta^2 = 0.07$] with young adults showing greater sensitivity ($M = 1.17, SE = 0.08$) than older adults ($M = 0.91, SE = 0.08$). There was also a significant age group \times study condition interaction [$F(2, 148) = 3.40, p = .04, \eta^2 = 0.04$]. *Post-hoc* *t*-tests revealed an expected age deficit in the single presentation condition [$t(74) = 2.87, p < .05$] and a marginal age deficit in the repeat-same condition [$t(74) = 1.78, p = .05$], with no age differences in the repeat-different condition [$t(74) = 0.99, p = .98$]. Further, young adults showed a trend toward better performance in the repeat-same compared to repeat-different task condition [$t(38) = 2.13, p = .02$] whereas older adults did not differentiate between repetition conditions [$t(36) = 1.15, p = .78$] and showed a numeric difference in the opposite direction (repeat-different > repeat-same).

Recollection and familiarity

True recognition. In order to investigate potential differential effects of study repetition on true and false recognition, we separated d' into its constituent hit and false alarms

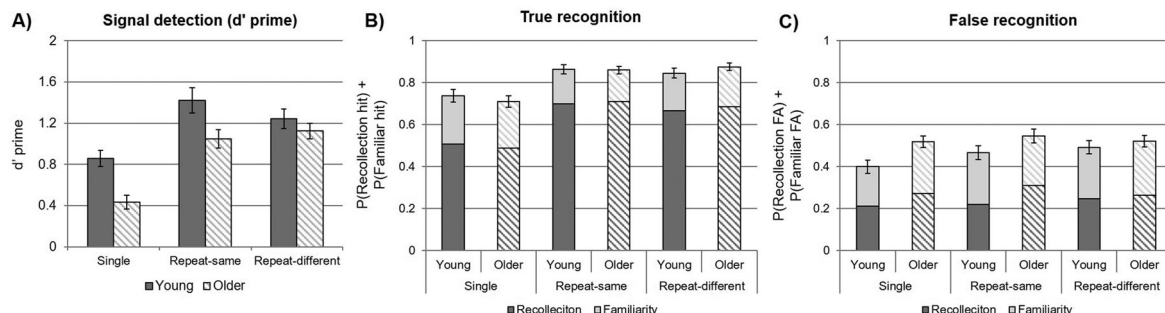


Figure 1. (A) Signal detection (d') results for both age groups across three encoding conditions. (B) True recognition rates for both age groups across all three encoding conditions. Lower portion of each bar represents “remember” hit rate, upper portion represents “familiar” hit rate. Error bars represent standard error of the mean for overall hit rate collapsed across recollection and familiarity. (C) False recognition rates for both age groups across all three encoding conditions. Lower portion of each bar represents “remember” false alarm (FA) rate, upper portion represents “familiar” false alarm rate. Error bars represent standard error of the mean for overall false alarm rate collapsed across recollection and familiarity.

rates. We first computed a mixed-effects ANOVA on the overall true recognition rate, combining both “remember” and “familiar” responses to targets. The results revealed a significant main effect of study condition [$F(1.43, 106.12) = 127.56, p < .001, \eta^2 = 0.63$], such that true recognition rates were higher for both repeated study conditions (repeat-same: $M = 0.86, SE = 0.01$; repeat-different: $M = 0.86, SE = 0.02$) compared to the single presentation condition ($M = 0.72, SE = 0.02$). There was no main effect of age [$F(1, 74) = 0.00, p = .99, \eta^2 = 0.00$], but there was a significant interaction effect [$F(1.43, 106.12) = 4.06, p = .03$]. The interaction was driven by young adults showing a numeric advantage for the repeat-same condition relative to the repeat-different condition [$t(38) = 1.99, p = .16$] whereas older adults showed a trend in the opposite direction [$t(36) = 2.18, p = .11$].

Given well-described age deficits in recollection-based memories, we were interested if the benefit of study repetition identified above was driven by increases in “remember” or “familiar” responses to targets. Separate mixed-effects ANOVAs were computed for recollection hits and adjusted familiarity hits. Regarding recollection, results revealed a significant main effect of study condition [$F(1.9, 127.02) = 178.26, p < .001, \eta^2 = 0.71$] such that both repetition conditions (repeat-same: $M = 0.70, SE = 0.02$; repeat-different: $M = 0.68, SE = 0.02$) showed higher proportions of “remember” hits compared to the single presentation condition ($M = 0.50, SE = 0.02$) and the repeat-same condition also showed a higher recollection rate than the repeat-different condition. However, there was no significant main effect of age group [$F(1, 74) = 0.01, p = .92, \eta^2 = 0.00$], nor a significant interaction effect [$F(1.7, 127.02) = 1.43, p = .24, \eta^2 = 0.02$]. Regarding familiarity, results revealed a main effect of study condition [$F(2, 148) = 24.58, p < .001, \eta^2 = 0.25$] such that hits based on familiarity increased from single presentation condition ($M = 0.47, SE = 0.03$) to same task condition ($M = 0.55, SE = 0.03$) to different task condition ($M = 0.60, SE = 0.03$). There was no main effect of age, [$F(1, 74) = 0.07, p = .79, \eta^2 = 0.001$], but there was a significant age group \times study condition interaction [$F(2, 148) = 6.95, p = .001, \eta^2 = 0.09$]. *Post-hoc t*-tests showed that familiarity rates for the repeat-same condition were numerically greater than the repeat-different condition in young adults [$t(38) = 0.66, p > .99$], whereas older adults showed a significant increase in familiarity in the opposite direction [$t(36) = 4.08, p < .001$].

False recognition. Given previously identified age-related increases in false recognition rates associated with repeated study, we first computed a mixed-effects ANOVA on the overall false recognition rate, collapsing across “remember” and “familiar” responses. Results revealed a main effect of study condition [$F(1.82, 134.76) = 11.10, p < .001, \eta^2 = 0.13$], with a significant linear effect [$F(1, 74) = 28.16, p < .001, \eta^2 = 0.28$] of increasing false recognition from the single presentation ($M = 0.49, SE = 0.02$) to the repeat-same ($M = 0.51, SE = 0.02$) to the repeat-

different condition ($M = 0.53, SE = 0.02$). There was a marginal main effect of age [$F(1, 74) = 3.18, p = .08, \eta^2 = 0.04$], such that false recognition rates were somewhat higher in older ($M = 0.54, SE = 0.03$) compared to young adults ($M = 0.47, SE = 0.03$). The interaction effect was not significant [$F(1.82, 134.76) = 0.31, p = .74, \eta^2 = 0.004$], such that the effect of repetition did not disproportionately increase false recognition in older adults.

Similar to true recognition above, we further investigated false recognition by individually evaluating false recollection and false familiarity. Results revealed a main effect of study condition [$F(2, 148) = 8.82, p < .001, \eta^2 = 0.11$], with a significant linear effect [$F(1, 74) = 17.64, p < .001, \eta^2 = 0.19$] of increasing false recognition from single presentation ($M = 0.24, SE = 0.02$) to repeat-same ($M = 0.27, SE = 0.02$), to repeat-different ($M = 0.28, SE = 0.02$). There was also a significant main effect of age group [$F(1, 74) = 4.41, p = .04$], such that older adults showed higher rates of false recollection ($M = 0.30, SE = .02$) than young adults ($M = 0.23, SE = .02$). Importantly, there was no significant interaction effect [$F(2, 148) = 1.79, p = .17, \eta^2 = 0.02$]. Thus, repeated study did not disproportionately increase false recollection in older adults. Regarding familiarity, the comparison of adjusted familiarity false alarms revealed a significant main effect of study condition [$F(2, 148) = 3.81, p = .02$] with a significant linear increase [$F(1, 74) = 8.54, p = .005, \eta^2 = 0.10$] in false familiarity from the single presentation ($M = 0.33, SE = 0.02$) to the repeat-same ($M = 0.34, SE = 0.02$) to the repeat-different ($M = 0.36, SE = 0.02$) conditions. The main effect of age was not significant [$F(1, 74) = 1.60, p = .21$]. Again, importantly there was no significant interaction between study condition and age [$F(2, 148) = 0.39, p = .68, \eta^2 = 0.005$], suggesting that the effect of repetition did not disproportionately increase false familiarity in older adults.

General discussion

In the current study, we evaluated whether repetition across different contexts, as compared to repetition within a single context, would enhance memory discriminability and mitigate age deficits typically observed in older adults. Overall, we found that repetition at encoding, regardless of repetition condition, resulted in enhanced memory performance in both young and older adults, as measured by *d*-prime as well as reduced age deficits in both repetition conditions. Further, we found a greater difference between young and older adults in the repeat-same condition compared to the repeat-different condition, where there was no age deficit. Taken together, these results suggest that repetition has the potential to benefit memory across age in a study using related words.

With respect to encoding repetition, while both repetition conditions successfully mitigated age deficits in discriminability compared to the age deficit found in the

single presentation condition, despite our hypothesis, we found no significant difference between conditions in improving overall memory discriminability. Interestingly, though not significant, repetition conditions appear to affect memory differently within each age group. That is, young adults showed a numeric advantage to the repeat-same condition, whereas older adults showed the opposite trend. This result contrasts with previous findings indicating that young adults show a greater benefit for repetition across distinct encoding contexts (e.g., Hintzman & Stern, 1978; Unnava & Burnkrant, 1991), which may be due to the fact that previous studies provided a larger number of encoding contexts for each item (e.g., repeated items had three or six different contexts in Hintzman & Stern, 1978), or employed the usage of more salient stimuli (i.e., pictures) (Unnava & Burnkrant, 1991). Although we predicted that repeated study in distinctive contexts would show a greater benefit for older adults' memory, it is nonetheless encouraging that repeated study improved memory irrespective of specific design characteristics related to repetition. One potential limitation in our manipulation of *distinct* contexts may be decisions regarding how pleasant one finds something or how much experience one has with an item could be based on similar criteria. Thus, the two conditions may have failed to instill unique and distinct memory traces. Future research should take these differences into consideration when evaluating how quantity and/or quality of contexts influence memory performance under repeated study conditions.

Despite older adults not deriving differential benefits from the two repetition conditions, it is important to also highlight that repetition helped achieve better rates of true recollection for both young *and* older adults, while not resulting in differential rates of false memories across groups. Given that the rate of true recollection in older adults is typically reduced to that observed in young adults (Yonelinas, 2002), the current findings are encouraging, in that they suggest that, through encoding repetition, true recollection can be enhanced in older adults, without being offset by disproportionate increases in false memories (see below for more on this point). Additionally, both repetition conditions resulted in greater familiarity compared to no repetition. Further, older adults showed significantly more familiarity for true recognition in repeat-different conditions compared to repeat-same. This potentially suggests that the process of encoding words across multiple contexts leads older adults to recall less specific details of the word's encoding context (or increased competition and interference between the two contexts; for more on this perspective, see Yassa & Reagh, 2013). Such a difference was not significant in young adults and actually trended in the opposite direction. Taken together, whereas both repetition types resulted in greater recollection in both age groups, we found that repetition across multiple contexts led to greater familiarity in older adults, suggesting differential

influences of repetition type on the relative contributions of recollection and familiarity.

With respect to false alarms, while previous studies have suggested that study repetition can lead to increases in both hit rates and false alarm rates in older adults, (lending to the ironic effects of repetition; e.g., Jacoby, 1999; Kilb & Naveh-Benjamin, 2011), the current study did not observe such a dissociation. The fact that increased false alarm rates were accompanied by increased familiarity responses in both age groups, suggesting that increases in false memories may be related to increases in the gist trace (i.e., general categorical or semantic information that is common across many similar events; Brainerd, Reyna, & Kneer, 1995). We note that this increase in false alarms between repetition and single presentation was most pronounced in the repeat-different condition. This tentatively suggests that repetitions across context resulted in greater gist trace compared to repetition within the same encoding context. This is further supported by previous work in young adults demonstrating that recognition performance for objects repeated across multiple contexts was driven by familiarity (Optiz, 2010). While we acknowledge that some studies have reported decreases in false alarms for young adults when using repetition (Jacoby, 1999; Kilb & Naveh-Benjamin, 2011), this could be the result of larger repetition frequencies (e.g., five repetitions were reported in Light et al., 2006 compared to our two repetitions). Though, we note our findings are consistent with those of a more recent study that found that the level of similarity between the lure and the repeated items influenced the ability to correctly avoid false endorsement (Reagh & Yassa, 2014), such that repetition actually led to more false recognition for related lures compared to lures that had low similarity to targets. Further, past studies reporting increases in older adult false alarms for repeated stimuli have typically used larger repetition frequencies (e.g., Light et al., 2004 used four repetitions). The current investigation used only two repetitions. This suggests that with two repetitions, older adults can benefit from repeated study without incurring higher false alarm rates, whereas larger repetition frequencies increase the likelihood of false alarms specific to repetition.

In conclusion, it is well established that age-related memory deficits are the result of both reduced true recognition and increased false recognition (for a meta-analysis, see McCabe et al., 2009). Here, we demonstrated that repetition can be used to successfully increase memory discriminability and recollection in both young and older adults without inducing a cost of false recognition specific to any one age group.

Note

1. At the request of a reviewer, we ran separate linear regressions for each dependent variable and for each age group. In short, we found continuous age was a predictor of a subset of hit

rates across age groups but continuous age was never a significant predictor of d' . The full reporting of this analysis can be found in Supplemental Materials.

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No potential conflict of interest was reported by the authors.

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