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The ironic effect of guessing: increased false memory for mediated lists in younger and older adults

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Abstract

Younger and older adults studied lists of words directly (e.g., *creek, water*) or indirectly (e.g., *beaver, faucet*) related to a nonpresented critical lure (CL; e.g., *river*). Indirect (i.e., mediated) lists presented items that were only related to CLs through nonpresented mediators (i.e., directly related items). Following study, participants completed a condition-specific task, math, a recall test with or without a warning about the CL, or tried to guess the CL. On a final recognition test, warnings (vs. math and recall without warning) decreased false recognition for direct lists, and guessing increased mediated false recognition (an ironic effect of guessing) in both age groups. The observed age-invariance of the ironic effect of guessing suggests that processes involved in mediated false memory are preserved in aging and confirms the effect is largely due to activation in semantic networks during encoding and to the strengthening of these networks during the interpolated tasks.

Keywords

False memory; spreading activation; aging; ironic effect of guessing

Memory errors can be errors of omission (such as forgetting or failing to properly encode information) or errors of commission (e.g., remembering events that did not occur or remembering them differently from how they originally unfolded; Roediger & McDermott, 1995; Schacter, 1999). Both types of errors tend to increase with age, with older adults being more susceptible to forgetting and to false memories than younger adults (Balota, Dolan, & Duchek, 2000). A number of laboratory paradigms – such as associative recognition (Castel & Craik, 2003) and false fame (Jennings & Jacoby, 1997) –show age-related decreases in memory accuracy. Few paradigms, however, have been as influential to the study of memory distortions as the associative list paradigm, which elicits robust and highly replicable memory intrusions.

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The Deese–Roediger–McDermott false memory paradigm

In the Deese–Roediger–McDermott (DRM) associated-list paradigm (Deese, 1959; Roediger & McDermott, 1995), participants study lists of items (e.g., *bed*, *rest*, *tired*) that are all related to a single, nonpresented critical lure (CL; e.g., *sleep*). On recall and recognition tests administered immediately or after a delay, the CL is falsely remembered at high rates, often similar to those for studied items (see Gallo, 2006 for a review and discussion).

False memories can be readily explained by one of the leading accounts of false memory, the dual-process Activation Monitoring Theory (AMT; Roediger, Balota, & Watson, 2001a; but see the discussion for an explanation of the Fuzzy Trace Theory (FTT) false memory account, Brainerd & Reyna, 2002). According to AMT, converging activation in semantic and lexical networks from list items increases the accessibility or familiarity of the CL. Failing to accurately monitor the source of the activation (Johnson, Hashtroudi, & Lindsay, 1993) contributes to errors at test. In support of the role of automatic activation processes, increasing the associative strength between list items and CLs, either by increasing list length (Coane, McBride, Raulerson, & Jordan, 2007; Robinson & Roediger, 1997), or selecting items that are strongly associated to the CL (Gallo & Roediger, 2002; Roediger, Watson, McDermott, & Gallo, 2001b), yields higher rates of false memory.

The monitoring component of AMT involves determining the source of an item's familiarity or activation at retrieval. As defined by Johnson and Raye (1981), *reality monitoring* involves discriminating between internally generated and externally experienced sources of information. According to AMT, the DRM CL is implicitly generated (consciously or otherwise during encoding and/or retrieval; Coane & McBride, 2006) and successful monitoring involves discriminating it from studied list items. To the extent that the CL and the list items share perceptual or conceptual features, this discrimination is likely to be more difficult, especially for older adults (Henkel, Johnson, & De Leonardis, 1998). Successful monitoring depends on effective controlled and attentional processes (Roediger et al., 2001a). Factors that increase successful source monitoring, such as explicit warnings about the nature of the lists and instructions that critical items were omitted and should not be recalled, can decrease false memories (e.g., McCabe & Smith, 2002; see Gallo, 2010, for discussion). Another factor that influences monitoring success is the ease with which participants will be able to detect the missing word they have been warned about. When the CL is easier to identify, participants can more readily use the warning to reject it (Neuschatz, Benoit, & Payne, 2003). The ability to capitalize on warnings further depends on working memory capacity (WMC), such that individuals with higher WMC are more successful at avoiding errors when warned (McCabe & Smith, 2002; Watson, Bunting, Poole, & Conway, 2005). A key function of WMC is attentional control, which includes planning, goal maintenance, and maintaining and processing information in the presence of interference (Kane & Engle, 2002). Identifying the CL during study and later remembering it was not on the list allows participants to engage in a recall-to-reject strategy (e.g., Gallo, 2004), whereby they can retrieve details of the occurrence of the actual list items and use that information to reject the CL as a foil.

Mediated false memory

Recently, Huff and colleagues (Huff, Coane, Hutchison, Grasser, & Blais, 2012; Huff & Hutchison, 2011) provided evidence consistent with AMT by demonstrating that false memories can occur following study of mediated lists – lists that are only indirectly related to the CL through nonpresented mediators (see Figure 1). The logic of using mediated lists emerged from semantic priming studies in which indirectly related primes (e.g., *lion*) facilitate lexical access to targets (e.g., *stripes*) through a nonpresented mediator (e.g., *tiger*; Balota & Lorch, 1986). Such mediated priming effects are consistent with an activation account in which activation spreads across multiple nodes in a network in an automatic fashion (Collins & Loftus, 1975; Hutchison, 2003). Huff et al. (2012) compared memory performance for mediated lists to directly related DRM lists. Following study of each list, participants completed math problems, free recall, free recall with a warning about CLs, or attempted to guess the CL. A final recognition test was then administered.

A key finding in Huff et al. (2012) was the *ironic effect of guessing*. For direct lists, attempting to guess the CL or receiving a warning caused a reduction in later false recognition (vs. recalling the list), consistent with past findings (Gallo, Roberts, & Seamon, 1997; McCabe & Smith, 2002) and with the hypothesized monitoring process in AMT (i.e., activation of the CL was counteracted by increased monitoring when participants were given guessing instructions or warnings). However, for mediated lists, attempting to guess CLs after each list (vs. recalling the list) actually *increased* later false recognition relative to an initial math or recall task and, in fact, resulted in the highest rate of false recognition. Furthermore, warnings numerically increased false recognition of mediated CLs relative to recall only. This dissociation suggests that behaviors aimed at (and effective in) reducing errors on direct lists can actually increase errors on mediated lists, an "ironic effect." For directly related CLs, more elaborate processing strategies during encoding presumably led to not only increased activation of the CL, but correct CL identification (e.g., Neuschatz et al., 2003), and thus rejection. However, because participants were not successful in identifying mediated CLs during the guessing task (approximately 5% of accurate guesses), they could not then reject them on a final test.

As demonstrated by Huff et al. (2012), interpolated tasks are a critical aspect of mediated false memory. Although automatic spreading activation during initial encoding can result in small but reliable false recognition on an immediate test (Exp. 2 in Huff et al.), tasks that recruited additional processing (i.e., free recall, free recall with a warning, CL guessing) increased later false recognition, presumably through the formation of broader associative networks (Meade, Watson, Balota, & Roediger, 2007). Thus, although initial activation in semantic networks is critical, controlled or effortful processes during initial retrieval can expand semantic networks to include mediated items (Carpenter, 2011).[1]

[1]Although we have framed the discussion in the context of AMT (Roediger et al., 2001a), we note that an alternative theoretical account, namely FTT (e.g., Brainerd & Reyna, 2002) also predicts that deeper processing during encoding would increase the process of gist extraction, thereby resulting in increases in semantically driven responding.

False memory in healthy aging

In the present study, we extended the mediated false memory paradigm to healthy older adults. Healthy aging is frequently associated with declines in memory functioning, both real and perceived. Older adults often complain of decreased memory, express concerns about maintaining healthy cognitive functioning, and are more susceptible to failures in retrieval from both episodic and semantic memory (see Balota et al., 2000). Several theoretical explanations for age-related declines have been proposed. For example, according to the inhibition deficit framework (e.g., Hasher & Zacks, 1988; Lustig, Hasher, & Zacks, 2007), older adults are less able to suppress task-irrelevant information, which in turn results in increased distraction in working memory and negatively affects retention. Similarly, Craik and colleagues (e.g., Craik & Byrd, 1982; Morris, Craik, & Gick, 1990) have argued that deficits in controlled processes, such as working memory and attentional control, prevent older adults from spontaneously utilizing effective encoding strategies (e.g., elaboration), although they will use such strategies when instructed to do so. Both of these theoretical accounts attribute some of the failures in memory performance observed in aging populations to declines in controlled processes.

With regard to the predictions from AMT, older adults frequently manifest preserved automatic processing while suffering decreased controlled processing. In fact, older (vs. younger) adults show inflated levels of false memory coupled with reduced veridical memory (e.g., Balota et al., 1999; Kensinger & Schacter, 1999). Other experimental paradigms suggest that older adults often remember fewer details and rely more on general themes or gist traces (see Balota et al., 2000). Importantly, automatic semantic activation processes are relatively spared in aging (e.g., Balota & Duchek, 1988, 1989) and older adults have indeed shown equivalent CL activation during encoding for directly related lists (Dehon, 2006; Dehon & Brédart, 2004). Bennett and McEvoy (1999) reported equivalent mediated priming effects in younger and older adults, suggesting that semantic spreading activation is preserved in aging. Furthermore, consistent with breakdowns in the controlled component, older adults often experience difficulties discriminating between studied items and CLs at test (Dehon & Brédart; Kensinger & Schacter, 1999; Norman & Schacter, 1997). Older adults also show reduced monitoring in recall-to-reject paradigms (Gallo, Cotel, Moore, & Schacter, 2007), as well as in false fame paradigms and exclusion tasks (Jacoby, 1999; Jennings & Jacoby, 1997). Converging evidence from multiple paradigms suggests an increased reliance on familiarity and automatic processing and decreased use of, or access to, controlled monitoring processes.

The effectiveness of warnings in the DRM paradigm appears mixed in older populations. Some studies suggest that older adults are less able than young adults to reduce false memories when warnings are provided (e.g., Dehon & Brédart, 2004). However, others found that both age groups were able to suppress false recognition when a warning was given prior to study (Dehon, 2006; McCabe & Smith, 2002; Watson, McDermott, & Balota, 2004). Furthermore, McCabe and Smith (2002) reported that older adults with higher WMC were less susceptible to false memories following an explicit warning (see Watson et al., 2005, for similar findings in younger adults), supporting the idea that controlled attentional processes are involved in successful monitoring. One explanation for why warnings may be effective at reducing errors in older populations is that older adults use less efficient encoding strategies or rely on fewer contextual cues to monitor accuracy at retrieval (e.g., Craik, 1986). When presented with a warning, older adults may adopt different encoding strategies or engage in enhanced monitoring at retrieval.

As mentioned earlier, explicit and implied warnings (i.e., guessing) increased mediated false recognition in young adults. However, because older adults often rely on different controlled strategies than younger adults, it is unclear whether warnings, either direct as in previous studies or implied as is the case for the guessing condition, will affect performance similarly for this age group with direct and mediated lists. Thus, one goal of the present study was to replicate the mediated false memory effect and the ironic effect of guessing in a different age group and in a new group of young adults. CL activation via the encoding of mediated lists, which is assumed to reflect similar automatic processes, should occur in both older and younger adults. However, as demonstrated by Huff and colleagues (Huff et al., 2012; Huff & Hutchison, 2011), initial activation alone only accounts for a small proportion of later mediated false recognition. Instead, later false recognition is largely dependent upon processing during the interpolated task. We examined whether and how interpolated tasks (e.g., recall, guessing), which are assumed to require more controlled processes, and type of list (direct vs. mediated) interact with age. Because of age-related changes in controlled processes, this can inform about the importance of these processes in this paradigm. In younger adults, we expected to replicate the findings of Huff et al. (2012): increased mediated false memory following warnings and guessing relative to math and recall coupled with decreased direct false memory following warnings relative to the other conditions. In older adults, consistent with McCabe and Smith (2002), we expected a reduction in direct false memory when a warning was provided relative to recall only.

In addition, to our knowledge, the guessing task is novel and it is unclear whether guessing will affect false memory for direct and mediated lists similarly between younger and older adults. For example, Watson et al. (2004; see also Kensinger & Schacter, 1999) found that older adults did not reduce false memories over repeated study test trials, whereas younger adults did, suggesting the older group did not engage in self-initiated strategic encoding. Thus, unlike younger adults who showed a reduction in false alarms for direct items following either guessing instructions or explicit warnings (Huff et al., 2012), older adults might only show reduced direct false alarms following explicit warnings and not following guessing. It is also possible that older adults might show an increase in direct false memory following guessing because of increased semantic activation that is not countered by increased monitoring. For mediated lists, guessing and warnings likely place more extensive demands on working memory as participants maintain list items while trying to identify the CL. Due to age-related differences in controlled processes, older adults might have special difficulty engaging in such processes and thus might not show the ironic effect.

In addition to the memory task, participants completed a brief battery of cognitive tasks. These were used to examine whether any differences in underlying cognitive performance modulated the effectiveness of warnings and the mediated false memory effect. The constructs being assessed in the battery were WMC, processing speed, vocabulary, and executive function. The inclusion of these measures was somewhat exploratory; relatively few studies have examined predictors of false memory in aging (but see McCabe, Roediger, McDaniel, & Balota, 2009; Meade, Geraci, & Roediger, 2012; who found that measures of frontal functioning predicted false memory) and none have examined cognitive functioning predictors with mediated lists. WMC, as mentioned earlier, is a core cognitive function that is responsible for maintaining, updating, and managing interference (Kane & Engle, 2002). Whereas short-term memory, which serves more as a passive storage system, is typically preserved in old age, WMC declines across the lifespan (e.g., Balota et al., 2000; Connor, 2001). As noted, prior studies have reported correlations between WMC and the effectiveness of warnings in both younger and older adults (e.g., McCabe & Smith, 2002; Watson et al., 2005). Processing speed also typically declines with age, as physical and cognitive functions require more time to complete, and has been found to account for substantial variance in cognitive tasks (Salthouse, 1996). Presentation rate has been found to affect false memory (e.g., McDermott & Watson, 2001), such that false recall increased from very brief presentations (20 ms per item) but declined at longer presentation rates (e.g., 3000 ms). Here we held presentation rate constant; however, due to age-related differences in processing speed, younger and older adults might show different rates of false memory. Specifically, older adults might be expected to be less successful at monitoring with the time constraints in place and thus show a stronger relationship between false memory and processing speed. Vocabulary knowledge typically increases with age (Salthouse, 2004); the richer semantic representations of older adults might be expected to increase activation of nonpresented lures. Performance in mediated lists, in particular, might be sensitive to vocabulary because richer representations might support activation of more distant neighbors in the network. Furthermore, older adults typically show preserved automatic processes (e.g., Jennings & Jacoby, 1997); in the present case, the active monitoring component should be more affected by age-related declines than automatic activation processes (Balota, Black, & Cheney, 1992). Finally, we assessed executive function, defined here as the ability to direct attention to a specific task and alternate between tasks (Arbuthnott & Frank, 2000). Because these controlled functions decline in old age, and the ability to efficiently process semantic representations is preserved, older adults might be expected to show increases in false memory and a reduced ability to capitalize on warnings or strategies to reduce errors. However, because older adults typically report more years of education this might offset any increases in false recognition or recall due to increased cognitive reserve (Stern, 2002).

Method

Participants

A total of 133 healthy older adults recruited from the community and 134 younger adult Colby College undergraduates served as participants. All participants were native English speakers with corrected or corrected-to-normal vision. See Table 1 for demographics and scores on the cognitive battery (described later). Older adults were community-dwelling participants living independently who arranged their own transportation to the testing site. Three older and 11 younger adults' data were omitted from analyses because of computer failures. The analyses thus include data from 130 older adults (89 women) and 123 younger adults (83 women) with a minimum of 28 participants in each between-participant condition (see Table 2).[2] Older adults reported a mean age of 67.70 years (*SD* = 5.77, range 59–91) and a mean of 15.68 years of education (*SD* = 2.81, range 11–25). Younger adults reported a mean age of 20.20 years (*SD* = 1.52, range 18–24) and a mean of 13.50 years of education (*SD* = 1.55, range 12–16). No differences in performance on the cognitive tasks were found across conditions within each age group (all *F*s < 2.28, *p*s > .08; all pairwise comparison *p*s > .17). Eighty-six older adults also completed the Mini-Mental State Exam (MMSE; Stern, Sano, Paulson, & Mayeux, 1987). Scores ranged from 25 to 30 (*M* = 29.37, *SD* = .99), suggesting an overall cognitively healthy sample. We also note that overall performance on the cognitive measures suggests a normally aging population with sufficient variability to allow an examination of individual differences in cognitive performance.

Materials

The materials were those used in Huff et al. (2012). Twenty-four CLs were used to create both direct and mediated lists. Direct lists contained 15 items that were associates of the CL (mean backward associative strength, BAS = .16, *SD* = .18) and mediated lists contained 15 items that were associates of the direct list items (mean BAS from mediated list items to direct list items = .21, *SD* = .21), but not of the CL itself (mean BAS = .00; see Figure 1). Direct and mediated lists were roughly equated on average word length and word frequency (see Huff et al., 2012, for a fuller description of the materials). There were two study test blocks consisting of three direct and three mediated lists. List type was counterbalanced across CLs and participants. The 36-item recognition test after each block consisted of two items from each studied list and two items from six nonstudied lists (from serial positions 7 and 10), as well as the CLs from both studied and nonstudied lists that were either direct or mediated as well. Thus, false alarms to nonstudied list items and CLs were used to as a baseline to correct false alarm rates (i.e., we subtracted false alarms to nonstudied list items from hits to studied list items and false alarms to CLs related to nonstudied lists from CLs related to studied lists; see Neely & Tse, 2007) and lists were counterbalanced across studied and nonstudied conditions across participants.

Participants completed a cognitive battery consisting of the Shipley Vocabulary Test (Shipley, 1940), the Operation Span Task (Unsworth, Heitz, Schrock, & Engle, 2005), Trail-Making Test Part B (Wechsler, 1997), and the Digit Symbol Substitution Task (DSST; Salthouse, 1996). Due to time constraints, not all participants completed all tasks, but at least 113 participants in each group (approximately 84%) completed each task. See Table 1 for summary performance.

Procedure

Participants were tested individually or in small groups of 2–3 individuals. The study phase and recognition task were administered using E-Prime software (Schneider, Eschmann, & Zuccolotto, 2002). In the study phase, participants completed two blocks of six lists each. The words within each list were presented one at a time on the monitor at a rate of 1/s, with a 500 ms inter-stimulus interval. Following the final list item, task-specific instructions

[2]Due to the small number of male participants (there were between 5 and 13 men in each cell of the design, compared to 19–26 women), we did not examine performance as a function of gender.

appeared on the monitor. All participants were given 60 s to complete the condition-specific task (recall, guessing, or math; described later) and a tone indicated the end of the interpolated task phase.[3] At this point, participants pressed a key on the keyboard to begin presentation of the next list. Order of list presentation was randomized, whereas order of the items within a list was fixed across participants.

Participants received task relevant instructions prior to the initial study phase (see Huff et al., 2012). In the math condition, participants completed arithmetic problems on a provided sheet of paper. In the recall condition, they were asked to recall as many items from the most recently presented list in a provided booklet. In the warn condition, similar recall instructions were given, but participants were also informed about the nonpresented CL and asked to try to avoid recalling it. In the guess condition, participants were told that each list had one “theme word” or common meaning and they should try to guess what it was and record it on an answer sheet. In the latter two conditions, participants were warned that this might be more difficult in some lists than others and they should try their best. Following the instructions, the study phase began.

After the sixth list in the first block, an old/new recognition test was completed. Participants were told to press the p key if the word had been presented in one of the previous six lists and the q key if it was new. Speed and accuracy were emphasized. The 36 items were presented individually in random order and remained on the screen until participants made a response. The second block of six lists began immediately thereafter following a reminder of the specific task encoding instructions and was followed by a second recognition test.

Results

In all analyses, observed statistical significance is $p < .01$ unless otherwise indicated.[4]

Initial guessing performance

Performance in the initial tasks is presented in Table 2. The proportion of correctly guessed CIs was calculated by dividing the number of correct guesses by the number of possible CIs. A lenient criterion was used (e.g., *sleepy* (vs. *sleep*) was considered correct). A mixed list type (direct, mediated) by age (younger, older) analysis of variance (ANOVA) revealed a significant main effect of list type, $F(1, 62) = 89.24$, $\eta_p^2 = .59$. Not surprisingly, direct CLs ($M = .32$, $SEM = .03$) were guessed more frequently than mediated CLs ($M = .06$, $SEM = .12$). For both age groups, the probability of correctly guessing the CL was greater than zero for both list types (all *t*s > 2.53, all *p*s < .018). Neither the effect of age nor the interaction was significant, *F*s < 2.45, *p*s > .12, suggesting that younger and older adults were similarly able to identify the CLs.

[3]Participants in the guess condition were allowed to advance to the next list once they had made their guess if the full minute was not required.

[4]As noted by an anonymous reviewer, a score on MMSE of 25 might reflect some cognitive impairment. Only one participant scored below 27; all analyses were also conducted after omitting this participant’s data. Because this did not change any of the outcomes, we report the results with the full data set for completeness’ sake.

Initial recall performance

The proportion of correctly recalled list items and CL intrusions (scored using the same criterion as the guesses) were each submitted to a 2 (age) × 2 (list type) × 2 (condition: recall, warn) mixed ANOVA, in which age and condition were between-subjects factors and list type a within-subjects factor. For correct recall, more items were recalled from direct (M = .52, SEM = .01) than mediated lists (M = .39, SEM = .01), $F(1, 124) = 523.80$, $\eta_p^2 = .81$, and younger adults (M = .51, SEM = .01) recalled more studied items than older adults (M = .39, SEM = .01), $F(1, 124) = 35.04$, $\eta_p^2 = .22$. List type and age interacted, $F(1, 124) = 4.76$, $p = .03$, $\eta_p^2 = .04$, such that the difference in recall between direct and mediated lists was slightly larger for older adults (M = .14) than for younger adults (M = .12). Finally, the list type by condition interaction was also reliable, $F(1, 124) = 9.89$, $\eta_p^2 = .07$, with direct lists showing a small decrease of .03 in veridical recall as a result of the warning, whereas mediated lists showed no change. No other effects were significant, all Fs < 1.40, ps > .23.

For false recall, the effect of list type was significant, $F(1, 124) = 172.47$, $\eta_p^2 = .58$, with direct lists (M = .25, SEM = .02) yielding more CL intrusions than mediated lists (M = .01, SEM = .005). The main effect of condition was also reliable, $F(1, 124) = 10.18$, $\eta_p^2 = .08$, with fewer intrusions in the warn (M = .10, SEM = .01) than in the recall condition (M = .16, SEM = .01), indicating the warning was indeed effective. Finally, the interaction between list type and condition was significant, $F(1, 124) = 5.63$, $p = .02$, $\eta_p^2 = .04$. Although the warnings were effective for both types of lists (both ps < .05), the reduction in intrusions was larger for direct (M = .11) than for mediated lists (M = .02). However, the latter may be constrained by floor effects. There was a marginal effect of age, $F(1, 124) = 3.07$, $p = .08$, $\eta_p^2 = .02$, reflecting slightly higher intrusion rates by older (M = .15, SEM = .01) than younger (M = .12, SEM = .01) adults. No other effects were reliable, all Fs < 1.[5] In concert with the veridical recall data, false recall performance suggests overall reduced accuracy in older adults who show reduced memory for studied items coupled with slightly higher intrusions; however, the warnings were effective in reducing false recall in both age groups.

Recognition

Raw and corrected recognition scores are presented in Table 3. Veridical and false recognition rates were corrected by subtracting false alarm rates to nonpresented control list items and CLs, respectively (data included in the analyses are in bold in Table 3).[6] These corrected recognition proportions were submitted to 2 (age) × 2 (list type) × 4 (condition: guess, math, recall, warn) mixed ANOVAs. For veridical recognition, effects of condition and list type were significant, $F(3, 245) = 7.60$, $\eta_p^2 = .08$ and $F(1, 245) = 83.26$, $\eta_p^2 = .25$, respectively. Correct recognition was highest in the guess condition (M = .60, SEM = .03),

[5]A comparison between initial guessing and initial false recall indicated that overall guessing resulted in similar numbers of CLs being produced relative to recall (M = .19 and .16, respectively), both of which were higher than false recall following a warning (M = .10), $F(2, 186) = 7.76$, $\eta_p^2 = .08$, as well as an interaction between condition and age, $F(2, 186) = 3.39$, $p = .04$, $\eta_p^2 = .04$, with older adults having slightly higher false recall than correct guesses (M = .18 and .15, respectively), whereas younger adults made fewer critical intrusions than correct guesses (M = .22 and .15, respectively). For both age groups, warnings yielded the lowest rate of CL production.

[6]Signal detection analyses (d'') were also conducted. d'' values were calculated by treating control items (CLs and list items) as false alarms and studied items (or CLs related to studied items) as hits. For the sake of brevity, we do not report the results here; however, we note that the signal detection results mirrored the corrected recognition analyses reported here.

followed by recall (*M* = .53, *SEM* = .03), warn (*M* = .53, *SEM* = .03), and math (*M* = .42, *SEM* = .03). Pairwise comparisons indicated that performance in the math condition was lower than in the other three, all *p*s < .03, whereas the remaining conditions did not differ from one another, *p*s > .32. Consistent with the recall data, more list items from direct lists (*M* = .61, *SEM* = .02) were recognized than from mediated lists (*M* = .42, *SEM* = .02). There was a marginally significant age by condition interaction, $F(3, 245) = 2.23$, $p = .09$, $\eta_p^2 = .03$. Younger adults showed a large increase in veridical recognition in the guess condition relative to recall and warn, whereas older adults did not. Performance in the guess condition was equivalent to that in recall and warn conditions (see Table 3). No other effects were significant, all *F*s < 1.

Turning to false recognition, the effects of condition and list type were again significant, $F(3, 245) = 4.94$, $\eta_p^2 = .06$, and $F(1, 245) = 284.26$, $\eta_p^2 = .54$, respectively. Across list type, false alarms were ordered, from lowest to highest, as follows: math (*M* = .23, *SEM* = .03), warn (*M* = .29, *SEM* = .03), recall (*M* = .36, *SEM* = .03), and guess (*M* = .37, *SEM* = .03). Only the differences between math and guess and math and recall were significant, (*p*s < .01 and *p* = .01, respectively). Overall false alarms to direct CLs (*M* = .51, *SEM* = .02) were higher than to mediated CLs (*M* = .12, *SEM* = .02), which, importantly, were greater than zero in both age groups, both *t*s > 4.70.

The list type by condition interaction was significant, $F(3, 245) = 3.93$, $\eta_p^2 = .05$ (see Figure 2). For direct lists, initial recall (*M* = .62, *SEM* = .04) increased false alarm rates relative to math (*M* = .43, *SEM* = .04) and warn conditions (*M* = .46, *SEM* = .04; *p* < .01 and *p* = .04, respectively), and no other comparisons were significant, *p*s > .58. Thus, warnings were effective at reducing false memory in direct lists. For mediated lists, initial guessing (*M* = .22, *SEM* = .03) resulted in false alarm rates that were higher than the other three conditions, significantly so relative to initial math (*M* = .03, *SEM* = .03; *p* < .001) and recall (*M* = .11, *SEM* = .03; *p* = .05, one-tailed), patterns consistent with Huff et al. (2012) and replicating the ironic effect of guessing. No other comparisons were significant, all *p*s > .21. Warnings, therefore, were not effective at reducing false alarms in mediated lists, in contrast to the direct lists where the CL can be identified more readily (cf. Neuschatz et al., 2003). In the math condition, a mediated false memory effect was not observed in either age group (*p* = .28 for younger adults, *p* = .83 for older adults). Neither the effect of age nor any interactions with age were significant, all *F*s < 1, suggesting that the ironic effect of guessing for mediated false memory was similarly present in both groups. We also note that Huff et al.'s mediated false alarm rate from young adults in the math, recall, warn, and guess conditions (.05, .09, .15, and .22, respectively) were consistent with the .05, .08, .13, and .24 rates observed from young adults in the present study.

Correlations with neuropsychological measures

To examine whether basic measures of cognitive performance were related to false memory, a series of correlational analyses were conducted. Prior studies have indicated that individuals higher in WMC can more successfully reduce false memories (Watson et al., 2005); we were therefore particularly interested in examining the role of working memory. Similarly, better executive control, as measured by Trails B, could also be expected to reduce errors because of the increased resistance to interference associated with this construct (Arbuthnott & Frank, 2000; Balota et al., 2000). Because slower presentation rates can reduce false memory rates (McDermott & Watson, 2001) and due to the declines in processing speed with aging, we further examined whether performance on DSST correlated with false memory; individuals with faster processing might be less susceptible to the DRM illusion given a constant presentation rate. Finally, we examined whether vocabulary knowledge, which might reflect underlying semantic and associative networks, predicted errors. For the measures of WMC, processing speed, and vocabulary, higher scores reflect better performance (e.g., higher WMC, faster processing). Therefore, if these factors reduce susceptibility to false memory the observed correlations should be negative. The executive function task, Trails B, measures time to completion; thus, higher scores reflect worse performance and a correlation with false memory should be positive if better executive function results in lower error rates.

To increase the power of the analyses, we collapsed across encoding condition within each age group, as well as examining performance separately by interpolated task condition. Overall, the analyses by encoding condition yielded inconsistent findings, with some measures predicting performance in some conditions, but not others; thus, we only report the findings collapsed across interpolated task condition. Due to large numbers of correlations, we utilized a Bonferroni correction and only consider significant relationships where $p < .003$ (for each dependent variable, we calculated 16 correlations including age, list type, and the four cognitive predictors). Correlation coefficients with an observed *p*-value between .05 and .003 are reported to provide a complete picture of the results. Neurocognitive assessments were not available for all participants, thus sample sizes ranged between 112 and 126 participants. Importantly, there were no differences in false recall, false recognition, or guessing performance between the subset of participants for whom cognitive measures were available and the full sample.

For the mediated lists, in both age groups, at the aggregate level, none of the cognitive measures predicted false recognition (all *r*s < .18, *p*s > .06). Mediated false recall was marginally correlated with processing speed in older adults, $r(66) = .32$, $p = .011$. None of the other measures correlated with false recall in older or younger adults, *p*s > .41.

Turning to the direct lists, significant correlations were obtained between WMC and false recognition in older adults, $r(120) = .35$, $p < .001$. Interestingly, this relationship was in the opposite direction than that reported by Watson et al. (2005), in that higher WMC was associated with elevated false recognition. Processing speed was also positively related to false recognition in older adults, $r(129) = .30$, $p < .001$. The correlation between false recognition and performance on Trails B was marginal and negative, $r(126) = -.22$, $p = .01$. The latter suggests that better executive function, reflected by shorter completion times on Trails B, resulted in reduced errors. Vocabulary performance was not related to false recognition. In younger adults, none of the correlations were significant, all *p*s > .25. In neither age group did significant correlations with false recall emerge, all *p*s > .10.

Because Watson et al. (2005) reported that increases in WMC were associated with reduced false memory, especially when warnings were provided, we examined the relationship between O-Span (Unsworth et al., 2005) performance and false recall and recognition in the recall and warn conditions. The only significant correlation was between O-Span and direct false recognition in older adults in the recall condition, $r(31) = .55$, $p = .001$ and, once again, the relationship was positive.

Because of the relative novelty of the guessing task, we examined whether any cognitive measures predicted performance in the interpolated task. Initial guessing performance was generally positively correlated with WMC and processing speed and negatively related to performance on Trails B (see Table 4). Although there were small differences between younger and older adults, overall the patterns suggested that larger WMC, faster processing, and better executive control were associated with more correct CL guesses, although for the mediated lists the effect was more pronounced in older adults than in younger adults.

Because higher education is associated with greater levels of cognitive reserve, this might have allowed older adults, who had more years of education, to counteract the effects of increased age and be resistant to false memory. However, education was unrelated to false memory in all conditions and in both age groups, all *p*s > .09, with the exception of the older adults in the guess condition, where higher levels of education were marginally associated with higher rates of false recognition for direct lists, $r(31) = .40$, $p = .02$. Thus, education did not seem to affect false memory overall, and in the one case it did, the effects were the opposite of what one might expect from a cognitive reserve account.

Discussion

The present experiment examined the effects of math, recall, warning, and guessing on subsequent direct and mediated false recognition in younger and older adults. As reported in Huff et al. (2012), mediated false memory depended on the type of encoding task, suggesting that automatic activation alone, in the absence of prior retrieval or elaborative processing, did not yield measurable false alarms. To determine the extent of the involvement of controlled or strategic processes, older adults completed the same tasks. Importantly, the ironic effect of guessing was obtained in both younger and older participants: prior guessing increased false alarms for mediated lists relative to prior math or recall, but not for direct lists. In addition, prior recall boosted false alarms relative to initial math for direct lists, but not mediated lists, consistent with Huff et al. (2012; see also Roediger & McDermott, 1995). Warnings effectively reduced false alarms relative to recall for direct lists, but not mediated lists, consistent with the notion that the identifiability of the CL is critical for warnings to be effective.

The increase in false alarms following guessing for mediated lists suggests that interpolated tasks that encourage retrieval and further processing of list items broaden the semantic and associative networks laid down during the encoding phase (Meade et al., 2007). The relative age-invariance observed in the present study suggests that, although this additional processing is necessary to elicit mediated false memory (as indicated by the absence of any mediated false memory in the math condition), these processes do not seem to depend on intact attentional control. In other words, interpolated tasks that promote the formation of an interconnected network of study items, thereby strengthening the associative pathways between list items, will result in a boost to the activation level of the CL, even when the CL is not directly related to the list items, as in mediated lists.

Interestingly, we observed few age effects overall, with performance on the initial tasks being quite similar across age groups. In fact, on these tasks, both younger and older adults were able to reduce false recall when a warning was presented, although this effect was mostly restricted to false recall on direct lists, given that mediated CL recall was at floor. Further, both age groups were equally able to guess the CL, and more successfully on direct lists. One age-related difference was observed in recall: We replicated the typical finding that younger adults outperformed older adults in veridical recall (e.g., Balota et al., 1999; Watson et al., 2004). However, the groups did not differ in veridical recognition (Jacoby, 1999), consistent with the notion that tests that offer additional environmental support, such as recognition, often show reduced age-related deficits (Craik, 1986; Craik & McDowd, 1987). In fact, both age groups showed improved veridical recognition in all conditions relative to the math condition, suggesting that interpolated tasks that require retrieval or additional processing of list items strengthens these memory traces, akin to a testing effect (e.g., Roediger & Karpicke, 2006). Further evidence of age invariance was seen in false recall and recognition, a finding that is somewhat at odds with prior literature showing increased false recognition in older adults (Kensinger & Schacter, 1999; Norman & Schacter, 1997; Tun, Wingfield, Rosen, & Blanchard, 1998; but see Balota et al., 1999; McCabe & Smith, 2002; for evidence of age-equivalence in false recognition).

To our knowledge, this is the first study to demonstrate mediated false memory in an aging population. From a theoretical perspective, there was reason to believe older adults might not show such effects, either because of reduced processing resources (Craik & Byrd, 1982) or reduced spontaneous elaboration (Craik, 1986), factors that might have resulted in a failure to engage in the type of processing necessary for activation to converge upon the mediated CL. One of our hypotheses was that older adults would not show the ironic effect of guessing because of the additional effortful processes and demands on working memory involved in identifying the mediated CL. In the guess condition, it was possible that older adults would find the task too frustrating and/or difficult or lack sufficient WMC to actively maintain list items to promote the formation of a richly integrated network to activate the CL. In fact, there were significant age-related differences in WMC and processing speed, factors that would be expected to influence the ability to actively maintain list items in order to make a guess. Because the mediated false memory effect does appear to depend, at least in part, on additional activation due to interpolated tasks that require deeper processing, it was possible older adults would have reduced mediated false memory. Clearly, the data show otherwise, suggesting that the involvement of intentional or effortful processes might be minimal or obligatory given specific task instructions and depend more on automatic activation of semantic and lexical networks during such interpolated tasks.

Overall, the results of correlational analyses examining the relationship between measures of basic cognitive functioning and false recall and recognition yielded few clear patterns. None of the measures predicted false memory in the mediated lists, perhaps a reflection of the list construction, where CLs are not identifiable. The most robust correlations were between direct false recognition and measures of executive function (Trails B; Wechsler, 1997) and

WMC (O-Span; Unsworth et al., 2005) and generally these were only present in our older adult sample. Specifically, decreased executive function, reflected by longer completion times on Trails B, was associated with decreased false recognition. This might reflect a reduction in the resources available to devote to the original encoding task. Poorer encoding would result in weaker episodic traces, which would, in turn, provide less activation to the CL. In fact, longer response times (RTs) (i.e., poorer performance) on Trails B were also generally associated with reduced veridical recall and recognition in both age groups (with *r*s ranging from −.11 to −. 26). Conversely, greater WMC was associated with higher, not lower, rates of false memory in older adults. Performance between these two tasks was also negatively correlated in both age groups ($ps \leq .01$; see Salthouse, 1994). Thus, the underlying constructs appear to exert distinct effects on false memory. Because both are also related in opposite manners with veridical memory, it seems possible that the dissociation in false recognition is driven by differences in encoding.

As noted, Watson et al. (2005) and McCabe and Smith (2002) reported reductions in false memory in high-span individuals relative to low-span individuals when warnings were given, whereas our data suggest a positive relation. A clear difference is that, in the present study, the positive correlations were primarily in the recognition task, which was preceded by initial encoding tasks, whereas Watson et al. examined recall and McCabe and Smith examined recognition without a prior recall or guessing task. In the initial recall task, however, we also failed to find a relationship between WMC and false memory. One possibility is that the presence of mediated lists (in which CL detection is nearly zero) affected individuals' ability or motivation to detect and reject CLs even for direct lists. Thus, exactly how warnings and WMC moderate false memory is not clear. Future studies that examine individual differences in susceptibility to errors are clearly warranted.

One piece of evidence that suggests high spans are more likely to form list associations at encoding can be found in the guessing data. Our correlations showed a positive relationship between WMC and correct guessing for mediated and direct lists. Thus, it seems higher spans are able to at least determine the associative structure of the lists, which increases both veridical and false recognition (a more-is-less pattern; Toglia, 1999). This analysis is consistent with the idea that guessing is dependent on an individual's ability to maintain and process list items in working memory to identify the CL and that this relationship is strongest for direct lists, whereas floor effects in guessing mediated CLs might mask any correlations.

As outlined in the "Introduction," it was possible that effects of guessing would differ across ages. Because of deficits in self-initiated strategies (e.g., Craik & Byrd, 1982) and poorer source monitoring (e.g., Henkel et al., 1998), guessing might have resulted in the opposite pattern for older adults than young adults (i.e., increased direct false memory and reduced mediated false memory). Clearly, such a pattern did not occur, suggesting that older adults were equally successful as young adults at monitoring for CLs under warn and guess conditions. We note that, unexpectedly, younger adults did not show reductions in direct false memory following guessing, a finding somewhat at odds with Huff et al. (2012), whereas older adults did. Why the present sample of younger adults did not show reductions in direct false memory in this condition is not clear. However, the three-way interaction between condition, list type, and age was not reliable, suggesting an overall similarity in how both age groups performed following the interpolated tasks.

Although we have focused on AMT (Roediger et al., 2001a) as an explanatory mechanism for list-based false memories, there are other theoretical approaches that can account for many of the findings reported in the literature. In particular, FTT (Brainerd & Reyna, 2002) is another popular account for false memories in the DRM paradigm. According to FTT, memory decisions are based on both verbatim and gist representations. The former include item-specific information and perceptual details, whereas the latter depend on the meaning of the list or to-be-remembered event. As such, in the DRM paradigm, veridical memory can be supported by both verbatim and gist traces. CL false memories, however, depend on the gist trace because these items do not have verbatim traces. FTT can also provide a viable explanation for age-related changes in memory by assuming that older adults rely more on gist traces than young adults (e.g., Tun et al., 1998). However, it seems that some modifications would be necessary to the basic framework to explain the mediated false memory effect. Specifically, because gist is driven by similarity or relatedness among list items and mediated lists do not have a clear or detectable gist (as evidence by the very low accurate guesses in the present study and in Huff et al., 2012), it is not clear how FTT would explain such findings. As suggested by Huff et al., one might need to posit a weak gist trace that is insufficient to support guessing or false recall, but sufficient to bias an old response on a recognition test. Conversely, AMT can readily account for these results by assuming the automatic spread of activation to nonpresented but related items.

In sum, the present study successfully replicated the ironic effect of guessing reported in Huff et al. (2012) and extended the mediated false memory paradigm to a group of healthy older adults. One reason for testing this population was to indirectly assess the extent to which this effect is dependent on processes that require intact attentional control. Because aging is associated with deficits in both controlled processes and self-initiated strategies for learning, it was possible that the mediated false memory effect would manifest differently in this group. One of the most notable findings in the present study, however, was the remarkable similarity between younger and older adults, even though performance on a battery of tasks designed to measure basic cognitive processes (e.g., processing speed, working memory) showed clear deficits among older adults. Thus, we conclude that mediated false memory depends largely on automatic processes that are preserved in aging and that the interpolated tasks (e.g., recall, guessing) exert similar effects in younger and older adults in terms of both benefits (i.e., increased veridical memory) and costs (i.e., increased false memory). Future studies could examine response latencies, which have been found to discriminate between veridical and false memory (e.g., Coane et al., 2007). Similarly, it would be of interest to explore age differences in false memory through the lens of RTs. One possibility is that although accuracy rates are comparable across younger and older adults, there might be distinct patterns in speed, with older adults responding faster due to familiarity or gist-based responding, whereas younger adults might be more likely to engage in slower monitoring processes.

In a broader context, the present study confirms that automatic processes in aging are preserved and that, given the appropriate instructions, older adults can and will engage in the type of processing that can benefit memory accuracy (i.e., warnings reduce false memory without negatively affecting veridical memory). Although guessing was associated with increased mediated false memory, this task also yielded increases in veridical recognition relative to the math control. If we were to perform a cost–benefit analysis, it seems plausible that guessing, or more broadly, encouraging older adults to attend to similarities or try to find patterns in to-be-learned materials might be an effective encoding strategy. Clearly, this approach is akin to a form of relational processing, which also can increase veridical and false memory in parallel (Huff & Bodner, 2013). By capitalizing on preexisting relations and the automatic processes that can result in measurable changes in accessibility or familiarity, older adults can, at least under some circumstances, perform at the same level as younger adults.

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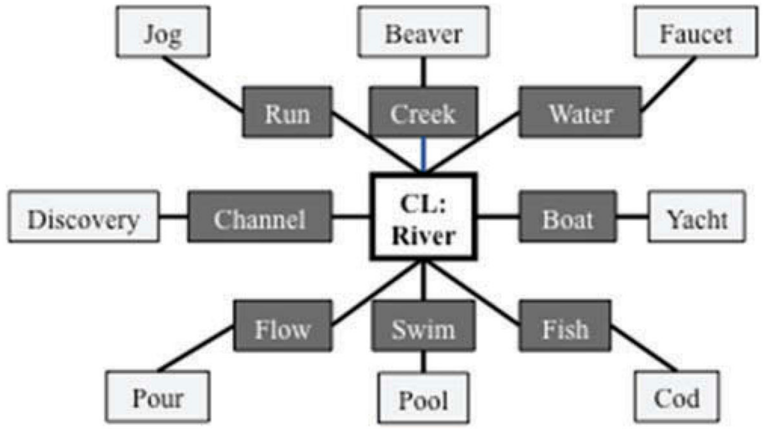

Figure 1.
Sample list items for the critical lure *river*. Dark boxes represent direct list items, and light boxes represent mediated list items. Participants only studied one type of list for a given critical lure.

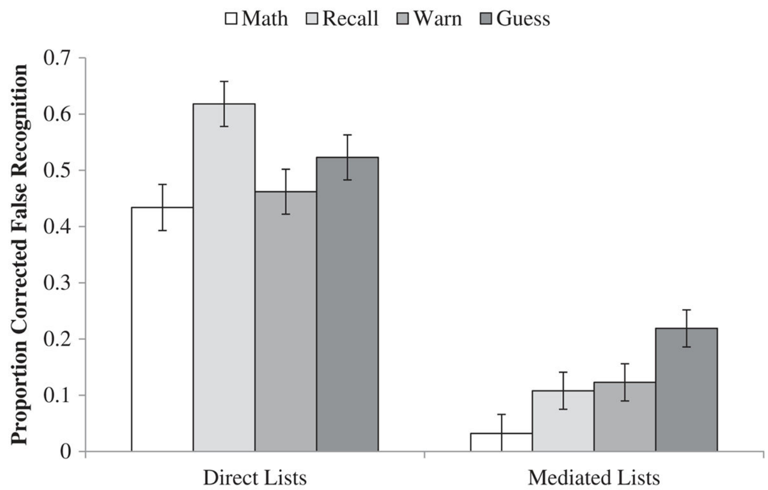

Figure 2.

Proportion corrected recognition (studied – control) of critical lures as a function of list type and condition. Error bars represent the standard error of the mean. Data are collapsed across age.

Table 1

Performance on the cognitive battery as a function of age (*SD*).

	Younger adults	Older adults	*p*-Value
Age	20.20 (1.52)	67.70 (5.77)	<.001
Education	13.50 (1.55)	15.68 (2.81)	<.001
O-Span	27.66 (6.86)	21.98 (7.89)	<.001
Shipley	31.22 (3.84)	34.99 (3.80)	<.001
DSST	66.03 (9.71)	50.54 (10.26)	<.001
Trails B	48.23 (16.51)	82.56 (41.18)	<.001

Notes: A minimum of 113 participants' scores in each age group are included. O-Span, Operation Span Task (Unsworth et al., 2005; measure of working memory, scores reflect the number of items correctly recalled in order); Shipley, Shipley Vocabulary Test (Shipley, 1940; scores reflect the number of items correctly defined); DSST, Digit Symbol Substitution Task; Salthouse, 1996; scores reflect the number of trials correctly completed; Trails B (measure of executive function; Wechsler, 1997; scores reflect the number of seconds required to complete the task).

Table 2

Proportion (SE) of recall of list items and CLs and proportion of correctly guessed CLs as a function of initial task, age, and list type.

	Initial task			
	Math	**Recall**	**Warn**	**Guess**
List items				
Younger adults				
N	28	30	31	34
Direct items	–	.59 (.02)	.55 (.02)	–
Mediated items	–	.45 (.01)	.45 (.02)	–
Older adults				
N	32	34	33	31
Direct items	–	.48 (.01)	.46 (.02)	–
Mediated items	–	.32 (.02)	.33 (.02)	–
Critical lures				
Younger adults				
N	28	30	31	34
Direct items	–	.29 (.04)	.17 (.04)	.36 (.04)
Mediated items	–	.01 (.01)	.00 (.00)	.08 (.02)
Older adults				
N	32	34	33	31
Direct items	–	.32 (.04)	.24 (.04)	.28 (.05)
Mediated items	–	.04 (.01)	.01 (.01)	.04 (.02)

Table 3

Final recognition proportions (SEs) for studied items and CLs as a function of list type, initial task, and participant age.

	Initial task			
	Math	**Recall**	**Warn**	**Guess**
List items				
Younger adults				
N	28	30	31	34
Direct items	.69 (.04)	.79 (.03)	.79 (.02)	.88 (.01)
Control direct	.22 (.03)	.16 (.03)	.17 (.03)	.13 (.02)
Mediated items	.48 (.05)	.56 (.05)	.54 (.06)	.67 (.06)
Control mediated	.17 (.03)	.11 (.02)	.13 (.03)	.08 (.02)
Corrected recognition				
Direct items	**.47 (.04)**	**.63 (.04)**	**.62 (.04)**	**.75 (.04)**
Mediated items	**.32 (.06)**	**.45 (.06)**	**.41 (.05)**	**.59 (.05)**
Older adults				
N	32	34	33	31
Direct items	.78 (.03)	.83 (.03)	.79 (.03)	.82 (.03)
Control direct	.25 (.04)	.18 (.03)	.15 (.03)	.22 (.03)
Mediated items	.55 (.04)	.55 (.04)	.56 (.04)	.64 (.04)
Control mediated	.20 (.03)	.15 (.03)	.13 (.03)	.17 (.03)
Corrected recognition				
Direct items	**.53 (.04)**	**.65 (.04)**	**.65 (.04)**	**.60 (.04)**
Mediated items	**.35 (.05)**	**.40 (.05)**	**.43 (.05)**	**.46 (.06)**
Critical items				
Younger adults				
N	28	30	31	34
Direct items	.70 (.05)	.74 (.05)	.54 (.06)	.71 (.04)
Control direct	.26 (.05)	.16 (.03)	.13 (.03)	.12 (.02)
Mediated items	.28 (.05)	.24 (.04)	.28 (.04)	.37 (.05)
Control mediated	.23 (.05)	.17 (.04)	.16 (.04)	.12 (.02)
Corrected recognition				
Direct items	**.44 (.06)**	**.58 (.06)**	**.41 (.06)**	**.59 (.06)**
Mediated items	**.05 (.05)**	**.08 (.05)**	**.13 (.05)**	**.24 (.04)**
Older adults				
N	32	34	33	31
Direct items	.73 (.04)	.85 (.04)	.72 (.05)	.73 (.04)
Control direct	.31 (.04)	.20 (.02)	.21 (.04)	.27 (.04)
Mediated items	.35 (.04)	.40 (.04)	.30 (.05)	.44 (.04)
Control mediated	.34 (.05)	.26 (.02)	.18 (.04)	.25 (.04)
Corrected recognition				
Direct items	**.43 (.06)**	**.65 (.06)**	**.51 (.06)**	**.46 (.06)**

	Initial task			
	Math	**Recall**	**Warn**	**Guess**
Mediated items	**.01 (.05)**	**.14 (.04)**	**.12 (.05)**	**.19 (.05)**

Note: Corrected recognition in bold.

Table 4

Correlation coefficients between guessing performance and cognitive performance measures.

	O-Span	Shipley	DSST	Trails B
Direct lists				
Older adults (*N*)	.45 (28)	.18 (31)	.57 (31)	−.49 (31)
p	.02	.33	.001	.01
Younger adults (*N*)	.29 (33)	.11 (33)	.32 (33)	−.34 (33)
p	.09	.53	.07	.06
All participants (*N*)	.40 (61)	.10 (64)	.46 (64)	−.44 (64)
p	.001	.42	<.001	<.001
Mediated lists				
Older adults (*N*)	.31 (28)	−.07 (31)	.36 (31)	−.37 (31)
p	.10	.70	.05	.04
Younger adults (*N*)	.07 (33)	.01 (33)	.22 (33)	−.11 (33)
p	.68	.95	.21	.54
All participants (*N*)	.35 (61)	−.07 (64)	.33 (64)	−.30 (64)
p	.05	.60	.01	.02