THE ROLE OF THE MEDIAL TEMPORAL LOBES IN OLDER ADULTS' ASSOCIATIVE MEMORY DEFICIT: A BEHAVIORAL STUDY

By

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ABSTRACT

It is well established that older adults show a deficit in episodic memory. The associative deficit hypothesis (ADH) (Naveh-Benjamin, 2000) suggests that an age-related reduced ability to create links between units of information is a major contributor to the episodic deficit. It has been a robust finding that older adults show a disproportionate decline in associative memory relative to item memory when compared to young adults. Previous researchers have investigated the role of the frontal lobes (FL) by studying the effect of reduced attentional resources in the associative deficit. However, they have not found that divided attention in young adults produces the disproportionate associative decline seen in aging and it is thought that some cognitive process other than the allocation of attentional resources may contribute to the associative deficit. The present study intended to use a divided attention (DA) task that also engages medial temporal brain regions (MTL) in order to tax additional parts of the network involved in creating associations and provide indirect support for the role of the MTL in the associative deficit. However, the associative memory deficit in older adults was not replicated due to unique poor associative memory performance of some young adults in the study. Analyses excluding these participants show support for the role of the MTL in the associative deficit. However, the young poor performers may provide support for the role of FL function in the associative deficit and show that poor associative memory may not be limited to the older adult cohort.

BACKGROUND

Memory is a complex phenomenon composed of many types. These varying types are not affected equivalently by the process of aging. For example, under the category of long-term declarative memory, episodic and semantic memory (Squire, 1992) appear to have different patterns of aging (Rönnlund, Nyberg, Bäckman, & Nilsson, 2005). Episodic memory, memory for events, shows a decline with an earlier onset and much steeper trajectory than semantic memory, memory for general knowledge (Rönnlund et al., 2005).

Various cognitive hypotheses have been proposed to account for the decline in episodic memory. As summarized by Naveh-Benjamin (2000) they consist of the following: a deficit in semantic processing, a failure in metamemory, deliberate recollection, or inhibitory processes (Hasher & Zacks, 1988), and a reduction in processing resources (Light, 1991) and processing speed (Salthouse, 1996). Naveh-Benjamin (2000) points out that none of these fully account for the episodic memory deficits in aging. An alternative idea, which has served as a starting point for Naveh-Benjamin's theorizing is that older adults have a reduced ability to bind together pieces of information (Chalfonte & Johnson, 1996). In order to remember a specific event, one must not only remember pieces of information, e.g., place, time, people, names, activities, but also bind and associate them together. Naveh-Benjamin (2000) proposed that a large portion of the episodic memory deficit in older adults is due to an associative memory deficit such that older adults have more difficulty encoding and retrieving links between units of information.

To test this ADH, item and associative memory are often compared. It has been reliably found that, compared to younger adults, older adults perform disproportionately poorer on associative memory tests compared to item memory tests (Old & Naveh-Benjamin, 2008). This effect may be moderated depending on the type of task. For example, the associative deficit is greater under intentional compared to incidental encoding instructions and in recognition compared to recall (Old & Naveh-Benjamin, 2008). Despite the variability that may occur according to the task, the associative deficit in older adults is a robust finding that has been tested many times and in many ways.

What is driving the associative deficit? Likely, a complex set of multiple interacting processes underlies the deficit. In attempting to dissect the causes of the associative deficit, investigators first targeted attentional resources as a possible candidate. The rationale here is that age-related associative deficits can be viewed as a consequence of reduced available processing resources, resulting in poorer integration of elements from an event. If conscious attentional processing is a prerequisite for binding, then an impairment of such processing should lead to inefficient binding and poor formation of associations. Attentional resources are thought to be mediated by the frontal lobes (Norman & Shallice, 1986), an area of the brain that atrophies with age (Raz & Rodrigue, 2006).

The hypothesis that reduced attentional resources lead to impairment in associative memory has been tested with a divided attention paradigm in younger adults under the assumption that aging and divided attention produce similar resource reductions (Craik & Byrd, 1982). Divided attention paradigms with young adults had previously shown that their performance on item memory tasks is reduced to that of older adults, when attention is divided at encoding (Anderson, Iidaka, Cabeza, Kapur, McIntosh, & Craik, 2000). It seemed likely that dividing attention would also reduce young adults' performance in associative memory tasks to the level of older adults' performance. This has been tested with various primary tasks such as object picture pairs (Naveh-Benjamin, Hussain, Guez, & Bar-On, 2003), visual word-nonword pairs, word-font pairs, auditory word pairs (Naveh-Benjamin, Guez, & Marom, 2003), visual word pairs (Castel & Craik, 2003; Kilb, & Naveh-Benjamin, 2007; Naveh-Benjamin et al., 2003a; Naveh-Benjamin, Guez, & Shulman, 2004), and visual word-scene pairs (Craik, Luo, Sakuta, 2010). Various secondary tasks have also been used, such as auditory digit monitoring (Castel & Craik, 2003; Craik et al., 2010; Naveh-Benjamin et al., 2003b; Naveh-Benjamin et al., 2004), a three-tone continuous response task (CRT) (Kilb, & Naveh-Benjamin, 2007; Naveh-Benjamin et al., 2003a), and an asterisk tracking CRT (Naveh-Benjamin et al., 2003a). The common finding in each of these studies is that young adults' performance on item memory is lowered to the level of older adults' performance (as seen in previous studies), but associative memory performance is reduced the same proportion as item memory. This means that it is not equivalent to older adult associative memory, because older adults show a disproportionate decline. These findings support the theory that reduced attentional resources cannot entirely account for the associative deficit, though it likely plays a part.

The focus on attentional resources has limited the study of the associative deficit to only the FL. However, there is another area of the brain that plays an important role in binding, the MTL (O'Keefe & Nadel, 1978). While FL regions mediate conscious attentional processes, MTL structures mediate more automatic processes in episodic memory (Moscovitch & Winocur, 1992). Since the results of divided attention studies portray attention as only part of the story, it may be that some form of inefficient processing in older adults' MTL contributes to the associative deficit. Results of fMRI studies show decreased activity in the left prefrontal cortex (PFC) and MTL in older adults compared to young adults during episodic encoding (Dennis & Cabeza, 2008). This supports the idea that both the PFC and MTL change with age.

Investigation of the MTL's role appears to be the next step in the study of the associative deficit. The present study conducted an experiment using a divided attention paradigm intended to also engage the MTL. Just as previous studies have used divided attention to mimic older adults' reduced attentional resources, this study endeavored to divide attention and engage the MTL to mimic the reduced efficiency in older adults' PFC and MTL.

In attempt to mimic older adults' reduced MTL efficiency in younger adults, the secondary task required participants to retrieve information from memory during the encoding phase of the primary task. Encoding and retrieval processes may not exactly overlap, but they have much common activity in MTL areas (Schacter, Curran, Reiman, Chen, Bandy, & Frost, 1999; Greicius et al., 2003). Relevant to the stimuli used in the present study, Park and Rugg (2011) found activation in some of the same hippocampal areas during encoding of word-word and picture-picture pairs. The secondary task of retrieval should engage the PFC *and* the MTL in contrast to previous secondary tasks that were focused solely on PFC engagement. Two other conditions for young adults were included for comparison: full attention and standard divided attention (i.e., divided attention that engages primarily PFC). Additionally, older adults were given only the primary memory task, under full attention. All participants received the same item and associative recognition tasks during the primary task retrieval phase. The study design was adapted from experiment one of Naveh-Benjamin et al. (2003b).

The predictions were: 1. Young adults in the full attention condition would have the highest performance of all the groups. 2. Performance of young adults in the standard divided attention task would replicate previous research in that item and associative memory scores would show equivalent declines. 3. Young adults in the MTL divided attention condition would show an associative deficit similar to older adults. 4. Older adults' performance would replicate previous research by showing an associative deficit. A disproportionate decline in associative memory for young adults in the MTL divided attention condition would provide indirect support for the involvement of the MTL in the associative deficit.

METHODS

Participants

A group of 72 healthy young adults, ranging in age from 18-23 years was recruited from an introduction to psychology course subject pool and received course credit for their participation at the University of Arizona (UA).

Table 1
Means and Standard Deviations for Age and Number of Years of Formal Education

Group		FA	DA	MTL DA	OA
Age					
	M	18.58	19.08	18.83	80.08
	SD	0.78	1.28	0.92	5.77
Education					
	M	12.50	12.75	12.46	15.79
	SD	0.83	1.07	0.88	2.30

Note: FA = Young Full Attention; DA = Young Divided Attention; MTL DA = Young MTL Divided Attention; OA = Older Adults

A group of 24 older adults, ranging in age from 71-91 years was recruited from the Aging and Cognition laboratory subject pool which consists of healthy, community-dwelling older adults. Young and older adult demographic information is reported in Table 1.The older adults had previously taken a battery of neuropsychological tests at UA within 24 months of the present experiment. The battery includes tasks that contribute to two composite measures for each participant. One score indicates relative performance on tasks associated with FL function and the other score indicates relative performance on tasks associated with MTL function (for details see Glisky, Polster, Routhieax, 1995; Glisky, Rubin, Davidson, 2001). These composite scores were used in the analyses to further investigate the role of the MTL in older adults' memory performance.

Design

There were four independent groups of participants in the study: young adults under full attention (FA), young adults under divided attention (DA), young adults under MTL divided attention (MTL DA) and older adults (OA) each of which contributed data to the two memory tests (item and associative). The design is not factorial however, because attention is manipulated only in the young group. All pairwise comparisons among groups are associated with a priori predictions.

Materials

The experiment was run with the DMASTR software developed at Monash University and at the University of Arizona by K. I. Forster and J .C. Forster.

Primary Task. Sixty-four pictures of common objects from the internet served as the stimuli for the primary memory task. Object pictures were standardized to a particular height or width and location of presentation. Objects were randomized to create a study list of twenty-eight pairs (four pairs serve as buffers, two at the beginning and two at the end of the list) and a list of eight lures for the item memory test. Two versions of pairings and lures were created.

Secondary Tasks. Stimuli for the standard divided attention secondary task were 112 semi-randomly ordered numbers (1-9) spoken by a computer generated female voice (voiceforge.com, Callie). Stimuli for the MTL divided attention secondary task were 64 common, concrete nouns spoken by a computer generated female voice (voiceforge.com, Callie). All auditory stimuli were recorded and edited with the program Audacity (audacity.sourceforge.net). Words were randomly paired to create two versions of a study list of 32 pairs (four pairs serve as buffers, two at the beginning and two at the end of the list).

The list of object pictures and the list of words were matched on frequency, objects *M* = 38 per million and words *M* = 41 per million, according to $SUBTLEX_{US}$ (Brysbaert, & New, 2009), and all pairs were unrelated and matched on association, Forward and Backward Strength, *M* = 0, according to List Checker Pro (Nelson, McEvoy, & Schreiber, 1998).

Procedure

All participants received a brief practice task before beginning so that the nature of the task was understood. All stimuli and instructions were presented via computer. The experimenter read the instructions aloud to participants, remained present for any questions, and recorded all oral responses. Young adults were randomly assigned to one of three conditions: full attention (FA), divided attention (DA), MTL divided attention (MTL DA). All older adults performed the task under full attention. The order of the item and associative memory tests were counterbalanced across all participants. Additionally, all participants were given a post-test questionnaire that inquired about the nature of their strategy use (if any) during the study phase of the object picture task.

Full Attention. Young adults in the FA condition and all older adults completed the primary task—memory for object pairs—under full attention conditions. They were instructed to study the objects carefully because they would later be asked to remember individual objects and pairs of objects. Object pairs were presented at a rate of one every four seconds and in a different random order for each participant. The study phase was followed by a 60 second interpolated activity in which participants counted backwards by threes from a three-digit number. The retrieval phase consisted of an item and associative recognition memory test. The item test contained eight old and eight new objects, presented in a different random order for each participant, and participants were to press a “yes” key for old items and a “no” key for new items. The associative test contained eight intact pairs (as originally presented) and eight recombined pairs (objects seen before but rearranged into new pairs), presented in a different random order for each participant, and participants were to press a “yes” key for intact pairs and a “no” key for recombined pairs.

Divided Attention. Young participants in the DA condition first completed a digit-monitoring task under full attention to establish a baseline. In this task, participants said, “Yes,” every time three odd digits were consecutively presented (e.g., 3-9-7). Participants then performed the digit-monitoring task (with differently ordered numbers) during the study phase of the primary task—the object-picture task described above. The study phase was followed by a 60 second interpolated activity in which participants counted backwards by threes from a three-digit number. Participants then received the object-picture item and associative memory tests described above.

MTL Divided Attention. Young participants in the MTL DA condition first completed the study phase of the word-pair task. In this task, participants heard a word pair presented every six seconds. In order to facilitate relatively uniform and deep encoding (Craik & Lockhart, 1972), participants were asked to quickly say a sentence using each word in the pair. The study phase was followed by a 60 second interpolated activity in which participants counted backwards by threes from a three-digit number. The retrieval phase consisted of an associative recognition test in which 14 intact pairs (as originally presented) and 14 recombined pairs (words heard before but rearranged into new pairs) were presented in a predetermined random order at an average rate of one pair every four seconds (the presentation time varied randomly among three rates: 3.5 s, 4.0 s, 4.5 s, to avoid synchronization of word and picture presentations). Participants said, "Yes," to intact pairs and, "No," to recombined pairs. The retrieval phase of the word pair task was completed simultaneously with the study phase of the object pair task, such that participants responded "Yes" or "No" aloud for the auditory word pair associative recognition test while studying the object pictures on a computer monitor. (FA young participants also completed the word-pair task alone for comparison purposes).

At the end of the test session, participants were asked whether they had used a strategy during the study phase of the object-picture task. Strategy users were queried as to the kind of strategy, an example of the strategy, and the percentage of pairs for which the strategy was used. If the strategy was used on less than 100% of the pairs, participants were asked if any other strategies had been employed, followed by the same subsequent questions. Strategies were coded as relational (e.g., imagined objects interacting, created a sentence with object names) or non-relational (e.g., rote rehearsal, noticed a perceptual similarity of objects).

RESULTS

Memory performance

Table 2

Means and Standard Deviations for Proportion of Hits and False Alarms

	Hits		False Alarms	
Test and group	*M*	*SD*	*M*	*SD*
Item				
FA	0.95	0.09	0.02	0.04
DA	0.69	0.20	0.10	0.15
OA	0.92	0.10	0.07	0.09
MTL DA	0.79	0.21	0.13	0.13
Associative				
FA	0.91	0.13	0.30	0.27
DA	0.70	0.19	0.40	0.22
OA	0.90	0.11	0.44	0.27
MTL DA	0.74	0.24	0.51	0.21

Note: FA = Young Full Attention; DA = Young Divided Attention; OA = Older Adults; MTL DA = Young MTL Divided Attention

Corrected recognition scores (proportion hits minus proportion false alarms) were used as measures of item and associative recognition memory and are displayed in Figure 1. The proportion of hits and false alarms are reported in Table 2. Preplanned analyses of the data included six 2 (Group) x 2 (Test) ANOVAS, making all possible pairwise comparisons across groups on the item and associative memory test scores.

To first test for the associative deficit in older adults compared to young under full attention, a 2 (FA and OA) x 2 (Test) ANOVA was performed. As predicted, results indicated a significant effect of Group, $F(1, 46) = 5.45$, $p = .024$, such that young adults under FA had higher overall performance (.77) than older adults (.65), and Test, $F(1, 46) = 56.31$, $p < .001$, such that performance on the item test (.89) was greater than performance on the associative test (.53). However, the interaction of the two variables was not significant, $F(1, 46) = .60$, $p = .44$, which is contrary to my prediction and to what the ADH would predict, meaning that the OA group did not show an associative deficit relative to the FA group.

Next, to test if young adults under DA showed an associative deficit compared to young adults under FA, a 2 (FA and DA) x 2 (Test) ANOVA was performed. As predicted, results indicated a significant effect of Group, $F(1, 46) = 33.34$, $p < .001$, such that young adults under FA had higher overall performance (.77) than young adults under DA (.46), and Test, $F(1, 46) = 35.58$, $p < .001$, such that performance on the item test (.76) was greater than performance on the associative test (.46). Additionally, the interaction of the two variables was not significant, $F(1, 46) = .112$, $p = .74$, which is in line with my prediction and with what the ADH would predict.

Third, to test if young adults under MTL DA showed an associative deficit compared to young adults under FA, a 2 (FA and MTL DA) x 2 (Test) ANOVA was performed. As predicted, results indicated a significant effect of Group, $F(1, 46) = 41.78$, $p < .001$, such that young adults under FA had higher overall performance (.77) than young adults under MTL DA (.44), and Test, $F(1, 46) = 50.62$, $p < .001$, such that performance on the item test (.80) was greater than performance on the associative test (.42). However, the interaction of the two variables was not significant, $F(1, 46) = 1.05$, $p = .31$, which is contrary to my prediction, and indicates that MTL DA did not show an associative deficit relative to FA.

Fourth, young adults under DA were compared to older adults using a 2 (DA and OA) x 2 (Test) ANOVA. Results indicated a significant effect of Group, $F(1, 46) =$

16.15, $p < .001$, such that young adults under DA had lower overall performance (.45) than older adults (.65), and Test, $F(1, 46) = 59.34$, $p < .001$, such that performance on the item test (.72) was greater than performance on the associative test (.39). Additionally, the interaction of the two variables was not significant, $F(1, 46) = 1.05$, $p = .23$, which is contrary to my prediction, i.e., the OA group had better overall performance, but the pattern of item and associative memory for the two groups was similar. Fifth, young adults under DA were compared to young adults under MTL DA using a 2 (DA and MTL DA) x 2 (Test) ANOVA. As predicted, results showed a significant effect of Test, $F(1, 46) = 52.07$, $p < .001$, such that performance on the item test (.62) was greater than performance on the associative test (.27). However, contrary to my predictions, there was not a significant effect of Group, $F(1, 46) = .009$, $p = .92$, such that young adults under DA did not differ in performance (.45) from that of young adults under MTL DA (.44), and the interaction of the two variables was not significant, $F(1, 46) = 2.04$, $p = .16$, indicating that the two groups' memory performance were not different from each other.

Finally, young adults under MTL DA were compared to older adults using a 2 (MTL DA and OA) x 2 (Test) ANOVA. Contrary to my prediction, results indicated a significant effect of Group, $F(1, 46) = 21.55$, $p < .001$, such that young adults under MTL DA had lower overall performance (.44) than older adults (.65). As predicted, results indicated a significant effect of Test, $F(1, 46) = 79.35$, $p < .001$, such that performance on the item test (.75) was greater than performance on the associative test (.34) and the interaction of the two variables was not significant, $F(1, 46) = .133$, $p = .72$, i.e., the OA group had better overall performance, but the pattern of item and associative memory for the two groups was similar.

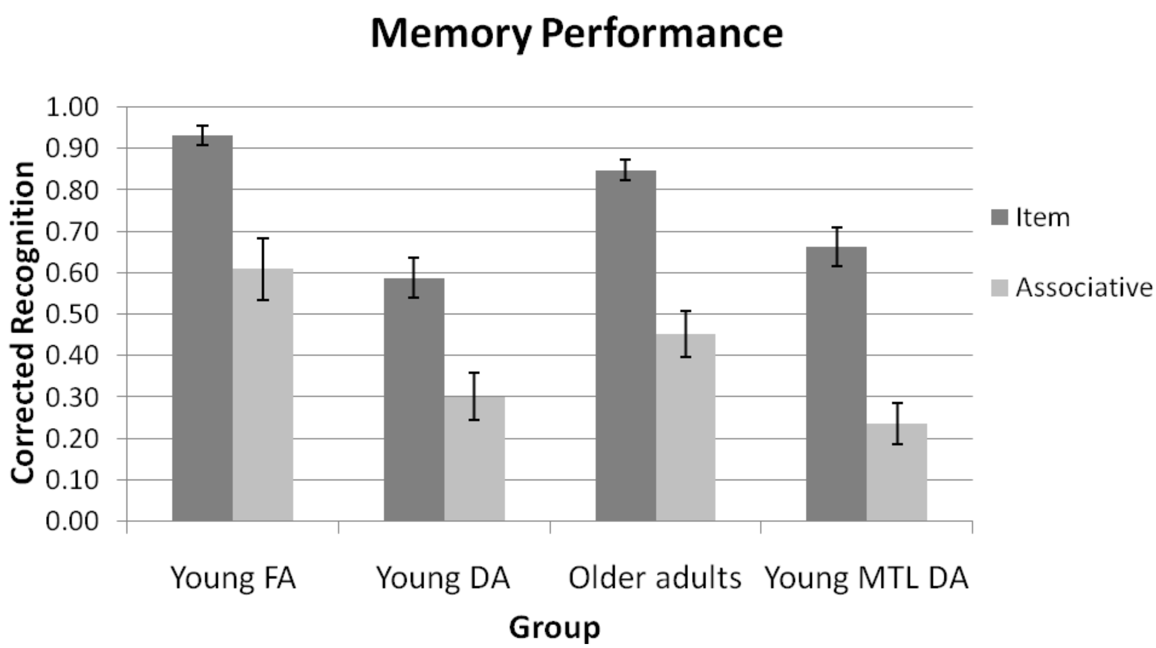

Figure 1. Corrected Recognition scores for the item and associative recognition memory tests. Bars represent standard errors. FA = Full Attention; DA = Divided Attention; MTL DA = MTL Divided Attention

Follow-up analyses were conducted to investigate the unique absence of an associative deficit in older adults. The divergence of this study compared to previous research appeared to be in the younger adults' performance under FA, as the difference between their item and associative memory scores was much greater than differences previously reported (e.g., Naveh-Benjamin et al., 2003b). Naveh-Benjamin, Brav, & Levy (2007) found that 100% of the young adults in their study used a relational strategy. In the present study in the young FA group, half of the 24 participants indicated that they used a relational strategy at least 50% of the time, but the other half of the participants did not. T-tests comparing the scores of the two groups found no significant difference in item memory, $t(22) = -1.67$, $p = .11$, between relational strategy users (.97) and non-relational strategy users (.90), but did show a significant difference, $t(17) = -3.74$, $p = .002$, in associative memory such that young using a relational strategy had higher performance (.84) than young using a non-relational strategy (.39). Additionally, the relational strategy users' scores are similar to previous research.

To retest for the associative deficit in older adults now compared to the young FA relational strategy users, a 2 (Group) x 2 (Test) ANOVA was performed. Results indicated a significant effect of Group, $F(1, 34) = 24.40$, $p < .001$, such that young FA relational strategy users had higher overall performance (.90) than older adults (.65), and Test, $F(1, 34) = 33.22$, $p < .001$, such that performance on the item test (.91) was greater than performance on the associative test (.65). Importantly, the interaction of the two variables was significant, $F(1, 34) = 8.10$, $p = .007$, such that older adults had disproportionately lower associative scores with respect to item scores when compared to young FA relational strategy users, meaning that they displayed an associative deficit. Mean scores are reported in Table 3.

Table 3
Means for Corrected Recognition

	Young Strategy Users	Older Adults
Item	0.97	0.85
Associative	0.84	0.46

The contrast between FA and DA was repeated using only the relational strategy FA group in a 2 (Group) x 2 (Test) ANOVA. Results indicated a significant effect of Group, $F(1, 34) = 56.11$, $p < .001$, such that young FA relational strategy users had higher overall performance (.90) than young DA (.45), and Test, $F(1, 34) = 16.06$, $p < .001$, such that performance on the item test (.78) was greater than performance on the associative test (.57). The interaction of the two variables was not significant, $F(1, 34) = 2.12$, $p = .15$, as in the original contrast, showing that young under DA did not display an associative deficit relative to young FA strategy users. Mean scores are reported in Table 4.

Table 4

Means for Corrected Recognition

	Young Strategy Users	Young DA
Item	0.97	0.59
Associative	0.84	0.30

The contrast between FA and MTL DA was also repeated using only the relational strategy FA group in a 2 (Group) x 2 (Test) ANOVA. Results indicated a significant effect of Group, $F(1, 34) = 83.23$, $p < .001$, such that young FA relational strategy users had higher overall performance (.90) than young MTL DA (.44), and Test, $F(1, 34) = 25.37$, $p < .001$, such that performance on the item test (.81) was greater than performance on the associative test (.53). Importantly, the interaction of the two variables was significant, $F(1, 34) = 6.97$, $p = .012$, such that young MTL DA had disproportionately lower associative scores with respect to item scores when compared to young FA relational strategy users, meaning that they showed an associative deficit, as was originally predicted. Mean scores are reported in Table 5.

Table 5

Means for Corrected Recognition

	Young Strategy Users	Young MTL DA
Item	0.97	0.66
Associative	0.84	0.23

Because strategy appeared to be an important factor in young FA performance, the older adult group was also split into relational strategy users (n = 9) and non-relational strategy users (n = 15). A t-test did not find a significant difference in item memory, $t(22) = 1.20$, $p = .24$, between relational strategy users (.89) and non-users (.83), but there was a significant difference in associative memory, $t(22) = 2.74$, $p = .012$, between strategy users (.63) and non-users (.35).

Further, to test for an associative deficit in the older adult relational strategy users compared to young FA relational strategy users, a 2 (Group) x 2 (Test) ANOVA was performed. Results indicated a significant effect of Group, $F(1, 19) = 6.11$, $p = .023$, such that young strategy users had higher overall performance (.90) than older adult strategy users (.76), and Test, $F(1, 19) = 14.72$, $p = .001$, such that performance on the item test (.93) was greater than performance on the associative test (.73). Importantly, the interaction of the two variables was not significant, $F(1, 19) = 1.55$, $p = .23$, indicating that older adult strategy users did not show an associative deficit relative to the young strategy users. Mean scores are reported in Table 6.

Table 6
Means for Corrected Recognition

	Young Strategy Users	Older Strategy Users
Item	0.97	0.89
Associative	0.84	0.63

Older adult item and associative scores were run in a correlation with the FL and MTL composite scores. Results showed a significant correlation of the MTL composite score with item memory, $r(22)= .44$, $p = .03$ and a marginally significant correlation with associative memory, $r(22)= .38$, $p = .065$. The FL composite score was not significantly correlated with item, $r(22)= -.37$, $p = .074$, or associative memory, $r(22)= -.06$, $p = .789$. Additionally, the MTL and FL scores were not correlated with each other, $r(22)= -.32$, $p = .13$. With regard to the FL score correlations, it is important to note that because the MTL score was of most interest in the present study, the range of FL scores was intentionally restricted (±.50), with one exception (.93), while the MTL score was allowed to vary in the selection of participants. This limitation may have affected the FL correlations.

Secondary task performance

Young adult accuracy performance (within-subject) on the DA secondary task, digit-monitoring, averaged 93% when performed alone and 82% when performed during the study phase of the object picture task. This difference was statistically significant, $t(41) = 2.50$, $p = .017$. Young adult corrected recognition performance (between-subject) on the MTL DA secondary task, word pair associative recognition, averaged 92% when performed alone by young under FA and 90% when performed during the study phase of the object picture task by young under MTL DA. This difference was not statistically significant, $t(46) = .90$, $p = .37$. A t-test showed that there was not a significant difference between the DA and MTL DA groups in the self-reported amount of attention devoted to the primary task, $t(45) = -1.68$, $p = .10$, and the secondary task, $t(45) = 1.68$, $p = .10$.

DISCUSSION

This experiment intended to replicate a robust finding in the literature and extend the understanding of older adults' associative deficit by including an additional, novel young adult condition. However, replication of the associative deficit did not occur because some of the young adults behaved in a unique fashion. They appeared to have an associative deficit, i.e., a much greater difference between item and associative memory than has been seen in the literature. Upon investigation, it was found that half (50%) of the young adults under FA did not use a relational strategy, whereas, a previous study (Naveh-Benjamin et al., 2007) found that all (100%) young adults used a relational strategy. When the young adult FA group was spilt into relational strategy users versus non-users, there was a significant difference in associative memory, such that strategy users had much higher performance and looked like what has been reported in the literature. When only the relational strategy users of the FA group were used in the planned comparisons, results were as originally predicted such that OA and young MTL DA showed an associative deficit compared to young adult FA, but young DA did not show an associative deficit. That the young MTL DA group displayed an associative deficit, but the DA group did not, lends indirect support to the idea that inefficient processing in the MTL contributes to older adults' associative deficit. Further support of this was found with the older adult group in that the MTL composite score had a marginally significant correlation with associative memory performance.

Why did some young participants not use a relational strategy? One possibility is that their neural and cognitive functions are not fully developed (Clark.et al., 2006). The

PFC has been implicated in executive function and is known to develop more slowly than other cortical areas (Fuster, 2002). This development may continue into young adulthood (Sowell, Thompson,
Holmes, Jernigan, Toga, 1999). Using a sample from UA similar to that used in the present study, Glisky & Kong (2008) found that the young adults did not differ from older adults on the FL composite score. Furthermore, the average age of the young adults in this study was 18.8 years, whereas, the average age of young adults used in many (though not all) studies of the associative deficit is > 20 years (Naveh-Benjamin, 2000; Naveh-Benjamin et al., 2003b; Naveh-Benjamin et al., 2004; Naveh-Benjamin et al., 2005; Kilb & Naveh-Benjamin, 2007; Naveh-Benjamin et al., 2007; Overman & Becker, 2009; Craik et al., 2010), including a meta-analysis (Old & Naveh-Benjamin 2008) of the differential effects of age on item and associative memory (M = 21.46). This difference in age could be developmentally significant.

Further, as has been discussed in the background, there are changes in PFC activity associated with aging. These changes may contribute to a lack of strategy initiation in older adults. Naveh-Benjamin et al. (2007) found that when the associative deficit was present, only 11% of older adults had spontaneously used a relational strategy. However, when older adults were given a relational strategy to use at encoding and retrieval, the associative deficit diminished. In the present study, 37.5% of older adults used a relational strategy. Strategy users were significantly different from non-strategy users on associative, but not item memory. Additionally, the OA strategy users did not show an associative deficit when compared to young FA strategy users. Thus, lack of relational strategy use may be a large contributor to the associative deficit in older adults.

One reasonable deduction is that younger young adults and older adults may be similar in strategy use and subsequent associative memory performance because the PFC is not at its peak (still maturing in young and declining in old). If this is true, then an associative memory deficit may also be present in young adults with immature PFC regions, which would mean this deficit is not unique to older adults. Additionally, the fact that older adults engaging in spontaneous strategy use did not show an associative deficit relative to young FA strategy users implies that the associative deficit may not be existent in all older adults.

In sum, it is likely that PFC and MTL regions both contribute to the episodic memory decline associated with aging. The present study provides indirect support for the contributions of both areas to the associative deficit. Young adults under divided attention designed to additionally engage the hippocampus showed an associative deficit, giving credence to the MTL's role. On the other hand, the performance of young FA non-relational strategy users was similar to older adults' performance, which provides evidence for the role of PFC in the associative deficit, as these young participants' neural functions may not be fully developed.

The concurrent results are an illustration of the complexity involved in memory processes and make way for many potential future experiments to help satisfy remaining questions. Prospective research possibilities include the following. Test an additional 24 young participants to confirm that a lack of strategy use in some young participants is not an anomalous finding. Next, a useful comparison would be to test a group of older young adults to see if they differ from younger young adults in strategy use and memory performance, in order to corroborate a developmental difference between the two age groups. In addition, obtaining FL and MTL factor scores for the young and using neuropsychological tests associated with the strategy/organization aspect of executive functioning may be valuable to further characterize the young adult groups. Furthermore, including tests of episodic memory would be useful to assess whether some young adults do have an episodic memory deficit and if strategy and poor associative memory is associated with the deficit. Another direction future research might explore is direct manipulation of strategy use in young and older adults, i.e., does the associative deficit appear for certain strategies but not others in the young and old alike or are they differentially affected.

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