Assessing the Associative Deficit of Older Adults in Long-Term

and Short-Term/Working Memory

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By

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The undersigned, appointed by the dean of the Graduate School,

have examined the thesis entitled

ASSESSING THE ASSOCIATIVE DEFICIT OF OLDER ADULTS IN LONG-TERM AND SHORT-TERM/WORKING MEMORY

Presented by Tina Chen

A candidate for the degree of

Master of Arts

And hereby certify that, in their opinion, it is worthy of acceptance.

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ABSTRACT

Older adults exhibit a deficit in associative long-term memory relative to younger adults. However the associative deficit of older adults is less apparent in short-term memory or working memory; the literature is inconclusive regarding whether this deficit is attenuated or consistent with the deficit in long-term memory. In order to help elucidate the issue, three experiments assessed younger and older adults' item and associative memory and the effects of several variables that might have potentially contributed to the inconsistent pattern of results in previous studies. In Experiment 1, participants were tested on item and associative recognition memory with both long-term and short-term retention intervals in a single, continuous recognition paradigm. There was an associative deficit for older adults in the short-term as well as the long-term intervals. To examine the potential effect of test event salience discrepancies between the item and associative tests, Experiment 2 utilized mixed and blocked test designs of the same paradigm of Experiment 1, using only short-term intervals. Blocking the test did not attenuate the age-related associative deficit seen in the mixed test blocks. Finally, in Experiment 3, study material was presented sequentially, as in Experiments 1 and 2, or simultaneously. An age-related associative deficit was found in both conditions. Even while accounting for some methodological discrepancies, the associative deficit of older adults is evident in short-term/working memory.

INTRODUCTION

Research shows that while semantic memory remains intact in normal, healthy aging (e.g., Kausler & Puckett, 1980), episodic memory declines with age (e.g., Old & Naveh-Benjamin, 2008a; Zacks, Hasher, & Li, 2000). In particular, this decline is more pronounced in instances where the task requires memory for associations (Old & Naveh-Benjamin, 2008a).

The Associative Memory Deficit of Older Adults

The associative memory deficit of older adults has been observed in many long-term memory experiments and is quite a robust phenomenon (see Old & Naveh-Benjamin, 2008a for a meta-analysis).

Chalfonte and Johnson (1996) suggested that older adults were less able, relative to younger adults, to bind feature information together into a complex memory. Because memory for associations is unavoidably comprised of memory for the to-be-associated items in addition to their association to each other, measuring both types of memory is necessary to elucidate the deficit specifically in associative memory separate from item memory. As such, Chalfonte and Johnson (1996) utilized a paradigm in which both younger and older participants saw objects in different colors in different locations. Under intentional learning, participants were given an item recognition test (e.g., on a color), or an associative recognition test (e.g., on the color of a given object). By comparing the measure of associative memory to that of the item memory between younger and older adults, they were able to show that, relative to younger adults, older adults were more impaired in their memory for associations in comparison to items.

Naveh-Benjamin (2000) extended the findings of Chalfonte and Johnson (1996) beyond feature information and posited the associative deficit hypothesis (ADH), which proposes that the age-related decrease in episodic memory is due to difficulties in binding the individual components together to form new associations, and in retrieving those bound components. Several studies using different types of components (e.g., name-face, word pairs, picture pairs, person-activity) support the ADH, showing a differential age-related decline in associative memory (e.g., Bastin & Van der Linden, 2006; Castel & Craik, 2003; Naveh-Benjamin, Guez, Kilb, & Reedy, 2004; Naveh-Benjamin, Hussain, Guez, & Bar-On, 2003; Old & Naveh-Benjamin, 2008b). While the long-term associative memory deficit of older adults is a robust phenomenon (e.g., Old & Naveh-Benjamin, 2008a), finding a similar age-related associative memory in short-term/working memory has led to some inconclusive results.

The Potential Importance of Demonstrating an Associative Deficit in Short-Term/Working Memory

Finding an age-related associative memory deficit in short-term/working memory could serve to elucidate the locus of the deficit. If the deficit is already exhibited in short-term/working memory, it would point to potential age-related differences in the encoding of associations as the locus of the deficit. However, if the deficit is not apparent in short-term/working memory, then the demonstrated long-term age-related associative deficit could be a result of differing age-related consolidation rates and forgetting rates of associations over time. In addition, demonstrating a general, age-related associative memory deficit in short-term/working and long-term memory, would serve towards the

”unification of cognitive aging theories across cognitive systems” (Bopp & Verhaeghen, 2009).

However, no consensus has yet been reached in regards to the existence of an age-related associative deficit in short-term/working memory. Some experiments demonstrate the associative deficit, while others find that no such deficit exists. An example of a study assessing associative deficits in short-term/working memory is one by Brockmole, Para, Della Sala, and Logie (2008) which utilized the Luck and Vogel (1997) change detection task to test for an associative memory deficit in older adults. Both younger and older adults saw an array for 1,000 ms where four items had a given color and shape, followed by 900 ms of a blank screen. The polygonal shapes did not allow for any immediate semantic labels. A second array was then presented in a different spatial pattern in which an item change or a binding change may have occurred, with these changes being presented in a blocked manner. An item change occurred when the color or the shape of the object changed to a novel one not presented in the array at encoding. A binding change occurred when two objects switched colors, presented in the original array, but not in that particular pairing. Brockmole, et al. (2008) found that older adults' performance on the binding trials was not lower than on the item trials in comparison to the younger adults; no associative deficit was found. They concluded that an associative deficit in working memory may be specific to certain types of information, but not with color and shape information.

Methodological Differences within the Literature on the Associative Deficit in Short-Term/Working Memory

One difficulty in examining the empirical evidence concerning the associative deficit of older adults in the working memory literature arises from the distinct methodologies used. The methodologies used in different experiments vary from each other in many aspects, including the retention interval, the associative nature of the stimuli in addition to the stimuli themselves, the paradigms used, the presentation of study stimuli, and the design of test conditions.

Cataloguing these differences within these experiments offers no specific insight into what methodologies might or might not lead to an associative deficit in working memory (see Table 1). The methodologies do not differ systematically across experiments that demonstrate an associative deficit in contrast to experiments that do not demonstrate an associative deficit.

One commonality of the experiments that do not find an associative deficit in working memory is that they all use a blocked test design, where the item test and associative test events are not intermixed (Bopp & Verhaeghen, 2009; Brockmole, et al., 2008). However, this fails to unequivocally explain why some studies might lead to the conclusion that an associative deficit of older adults exists in working memory and others to the conclusion that it does not exist. This is so since the commonality of demonstrating no associative deficit and utilizing a blocked test design fails to hold true in the reverse: an associative deficit may still be found, even when using a blocked test design. While Cowan et al. (2006) used a mixed test design in their first experiment and found an associative deficit, other experiments found an associative deficit, even though they used a blocked test design (Bopp & Verhaeghen, 2009; Brown & Brockmole, 2010; Cowan, et al., 2006; Mitchell, Johnson, Raye, Mather, & D'Esposito, 2000).

Table 1 catalogues the experiments mentioned and their characteristics, with the last column on the right indicating whether an associative deficit was found.

Table 1. ***Experiments Assessing an Associative Deficit in Short-Term/Working Memory***

Study authors	Retention Intervals (time between study/test)	Stimuli complexity	One Study event or multiple study events before test	Test type (item/assoc) blocked or mixed	Associative Deficit?
Mitchell et al. (2000)	8 seconds	Object (clip art like) and location	Multiple study events	Blocked test	**yes**
Bopp and Verhaeghen (2009) Expt. 1	Self-paced	Number and locations	Multiple study events	Blocked test	**In one condition, yes, no in the other**
Bopp and Verhaeghen (2009) Expt. 2	Self-paced	Number and locations	Multiple study events	Blocked test	**no**
Brown and Brockmole (2010) Expt.1	1 second	Color and shape	1 study event	Blocked test	**no**
Brown and Brockmole (2010) Expt.2	1 second	Color and shape	1 study event and multiple study events	Blocked test	**yes**
Cowan et al. (2006) Expt. 1	1 second	Color and location	1 study event	Mixed test	**yes**
Cowan et al. (2006) Expt. 2	1 second	Color and location	1 study event	Blocked test	**yes, slight**
Parra et al. (2009a) Expts. 1 and 2	900 msec	Color and color	1 study event	Blocked test	**no**
Brockmole et al. (2008) Expt. 1	1 second	Color and polygonal shape	1 study event	Blocked test	**no**
Brockmole et al. (2008) Expt. 2	1 or 5 seconds	Shape and location	1 study event	Blocked test	**no**

From this table, no obvious pattern emerges for why some experiments find an associative deficit and others do not. The body of research therefore remains inconclusive as to the phenomenon of an age-related associative deficit in short-term/working memory.

How to Address the Discrepancy between the Patterns of Age-Related Associative Deficits in Short- and Long-term Memory?

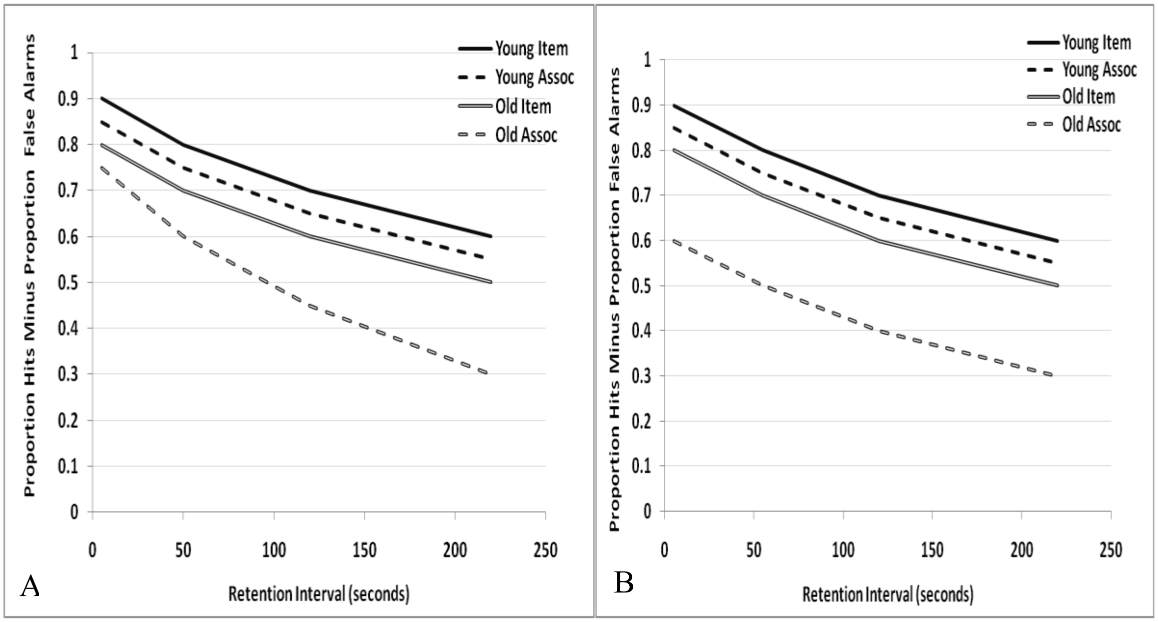
Because there is an age related associative deficit in long-term memory, but no resolution on an age related associative deficit in short-term/working memory, one approach to experimentally determine whether such an associative deficit exists in short-term/working memory is to assess potential discrepancies in long-term memory and short-term/working memory methodologies. Because the paradigms used in long-term and short-term/working memory attempt to address different aspects of memory, it's no wonder the paradigms differ so vastly. With long-term memory paradigms, the retention interval is longer, visual stimuli tend to be more meaningful and complex (e.g., faces, scenes, or common household objects), and the study and test phases are often distinct series of events separated by an interpolated activity. On the other hand, short-term/working memory paradigms utilize a short retention interval, visual stimuli are simple (e.g., polygons, single colors, spatial locations in a grid), and often the study and test phase are not series of events grouped together, but rather alternate such that after each study and test trial, another trial begins.

We can begin to reconcile some of the discrepancies in the two general paradigms by holding constant some of the differences, and manipulating others. To do so, we used a single paradigm: the continuous recognition paradigm. This is a long-term memory paradigm that lends itself well to retention interval variation, and indeed this has been done with regards to item and associative memory (e.g., Hockley, 1992; Jones & Atchley, 2002). The paradigm has also been used to look at short-term and long-term aging memory (Ishihara, Gondo, & Poon, 2002). However, using the continuous recognition paradigm to address the associative deficit of older adults has not yet been done. With this paradigm, the study and test are intermixed, approximating a working memory paradigm. In Experiment 1, w varied the retention interval by using four main study-test intervals to assess both short-term and long-term memory in one experiment. These study-test intervals varied from 0 to 220 seconds (see details below). Experiment 2 utilized the same paradigm to examine the short-term interval in more detail, using retention intervals of 0, 2, 4, and 6 seconds. We also manipulated the presentation of test trials in a mixed (as presented in Experiment 1) or blocked fashion (where item test trials are separate from associative test trials) to examine what role the salience of test events might play in the associative deficit in these intervals (see later discussion). Finally, in Experiment 3, we utilized a variation of the paradigm and examined the role of a sequential or simultaneous presentation of study material (see later discussion).

Experiment 1

Using the continuous recognition paradigm and manipulating the study-test retention interval of face-scene stimuli, we would expect to find an age-related associative memory deficit in long-term memory (the long retention intervals). If there is an associative deficit in short-term memory, it should appear in the short-term interval of 5 seconds (see Figure 1B). If there is no associative deficit in short-term memory, the associative deficit of older adults should be absent in the short retention interval and increase as the retention intervals get longer (see Figure 1A).

Figure 1. Predicted Patterns of Results for Experiment 1



Predicted patterns of results for Experiment 1: On the left (A), the predicted results should an associative deficit not be demonstrated in the short-term interval, and on the rght (B), the predicted results with an associative deficit throughout.

Methods

Participants

The participants included 25 undergraduates with an average age of 18.96 years (*SD* = 1.49, range of 18-24 years) enrolled in a psychology course at the University of Missouri who were offered credit for their participation. Their mean education level was 13.00 years (*SD* = 1.08), and 16 of them were female. The participants also included 24 older adults with an average age of 70.38 years (*SD* = 4.56, range of 65-79 years) from the mid-Missouri area who were healthy with no known memory impairments and were paid $15 for their participation. Their mean education level was 14.17 years (*SD* = 1.90), and 17 of them were female. Older adults had significantly more education than younger adults, t (47) = 2.66, p = 0.01. Participants were run individually by the researcher.

Design

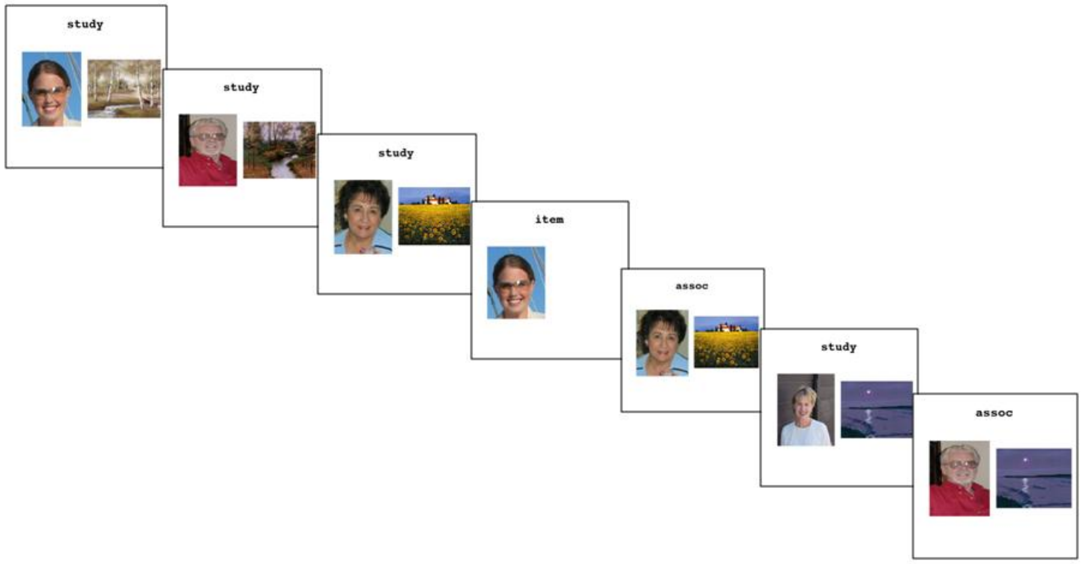
This experiment used a 2 (age: younger adults and older adults) x 2 (test: item including both faces and scenes, and associative) x 4 (main retention interval: short term, short-long term, mid-long term, and long-long term intervals) design. Each of the main retention intervals were further divided into three sub-intervals. Test and retention interval were within-subjects factors.

Materials

Using the E-Prime program and a 15 inch monitor with resolution set at 640x480 pixels (the E-Prime default), an instruction word appeared centered above image pairs consisting of one face on the left and one scene on the right. Two blocks were presented to each subject with 168 events in each block; study and test events each lasted 5 seconds for a block length of 14 minutes. Each block included 72 study pairs, 48 item test images, and 48 associative test pairs evenly distributed across the retention intervals. There were an equal number of targets and distractors for both tests. Stimuli were counterbalanced between the configurations, in type of test, and in target or distractor status.

The color images were 200 x 250 pixels large in portrait orientation for faces and landscape orientation for scenes (see Figure 2). The scenes were taken from Luo, Sakuta, & Craik (2008) and the face images were taken from Kilb and Naveh-Benjamin (in press). There was an equal distribution of older and younger faces, and male and female faces.

Figure 2. **Example of Stimuli from Experiment 1**



The instruction word was presented centered at the top of the screen in bold, lowercase, Courier font in size 18. The different, intermixed instruction words were "study," "item," and "assoc," short for "associative" to equate the amount of text to be read. Because the experiment utilized a variation of the continuous recognition paradigm, a "study" instruction indicated that the pair on that screen should be remembered for a later test in that trial, either an item test or an associative test. An "item" instruction indicated that the participant should make a recognition response (yes or no) to the single image on the screen, i.e., the item was recognized as having been seen at any time prior. An "assoc" instruction indicated that the participant should make a recognition response (yes or no) to the pairing of the face and scene on the screen; associative test pairs were either intact or recombined from their original pairing at study. An intact pair consisted of a face and a scene that were presented together at study. A recombined pair consisted of a face and a scene that were not originally presented together, though both had been presented previously.

The interval between the presentation of the pair and the test on that particular pair (or item in a pair) fell into four main categories: the short term interval, the short-long term interval, the mid-long term interval, and the long-long term interval. Each of these main interval groups consisted of 3 sub-intervals. The short term interval included lags of 0 seconds, 5 seconds, and 10 seconds. A 0 second interval meant that the pair (or item from the pair) was tested immediately after it was presented as a study pair, and a 5 second interval meant that there was one intervening event with a presentation rate of 5 seconds between the study and test instructions. Similarly, a 10 second interval meant that there were two intervening events, each presented for 5 seconds; these intervening events could be either a study or a test event.

The short-long term interval included lags of 50 seconds, 55 seconds, and 60 seconds. The mid-long term interval included lags of 115 seconds, 120 seconds, and 125 seconds. The long-long term interval included lags of 215 seconds, 220 seconds and 215 seconds. In other words, on average, the short term interval was 5 seconds, the short-long term interval was 55 seconds, the mid-long term interval was 2 minutes, and the long-long term interval was 3 minutes and 40 seconds.

Procedure

Participants were instructed to pay close attention to the instruction that was presented at the top of each screen. A "study" probe indicated that the participant should try to remember each of the items presented (face and scene) as well as the items together in that pair for a later test. An "item" probe indicated that the participant would be presented one image (face or scene) and should decide whether he or she had seen the item at any point during the trial; a "yes" response was made by pressing "1" at the top of the keyboard and a “no” response was made by pressing “0” at the top of the keyboard. An “assoc” probe indicated that the participant would be presented with a pair of images and should decide whether he or she has seen the two images together in that particular pairing during the trial; a “yes” response (for intact) was made by pressing “1” at the top of the keyboard and a “no” response (for recombined) was made by pressing”0” at the top of the keyboard. The participants had 5 seconds to respond to each test event during which the image(s) remained on the screen, and they were encouraged to respond within that time, because the screen moved on automatically after 5 seconds and was not contingent on a response.

Since the presentation of study and test events was intermixed and did not follow any apparent pattern, participants were instructed to pay close attention to the instruction at the top of the screen for an indication of what response to make to the image(s) on the screen. They were informed about the approximate number of study or test events, and about the fact that the correct response to the tests was evenly divided between a “yes” response and a “no” response. Participants also saw a text example of several intermixed study and tests events on one instruction screen in a downward flowchart, and the correct response to the test events.

Participants then completed a practice block which was modeled after the experimental blocks, after which, if there were no further questions, they began the first block. A short break was taken between the two trials, and participants were told that the second block’s tests would be over only the material presented in that second block and would not include any overlap from the first block. A reminder of the basic instructions of study, item, and assoc was restated before the second block began.

After both blocks, participants were asked to answer some post-test questions and then were debriefed.

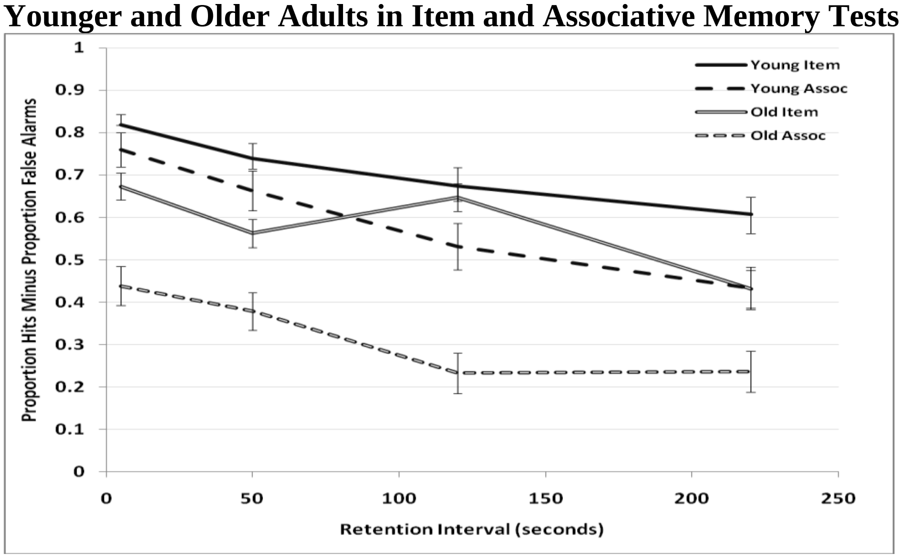
Results

Memory accuracy was recorded in the form of the proportion of hits (proportion of yes responses to targets) minus the proportion of false alarms (proportion of yes responses to distractors), hereafter written as proportion hits minus false alarms. The means and standard deviations for younger and older adults can be found in Table 2. The means and standard errors are presented in graphical form in Figure 3.

Table 2. ***Proportion Hits Minus False Alarms Means and Standard Deviations -- Experiment 1***

		STM		ShortLTM		MidLTM		LongLTM	
		item	assoc	item	assoc	item	assoc	item	assoc
Young	**Mean**	**0.82**	**0.76**	**0.74**	**0.66**	**0.67**	**0.53**	**0.61**	**0.43**
	SD	0.13	0.20	0.18	0.23	0.22	0.27	0.21	0.25
Old	**Mean**	**0.67**	**0.44**	**0.56**	**0.38**	**0.65**	**0.23**	**0.43**	**0.24**
	SD	0.15	0.23	0.16	0.22	0.16	0.23	0.22	0.24

Figure 3. **Mean Proportion Hits minus False Alarms (with Standard Errors) for Younger and Older Adults in Item and Associative Memory Tests -- Experiment 1**



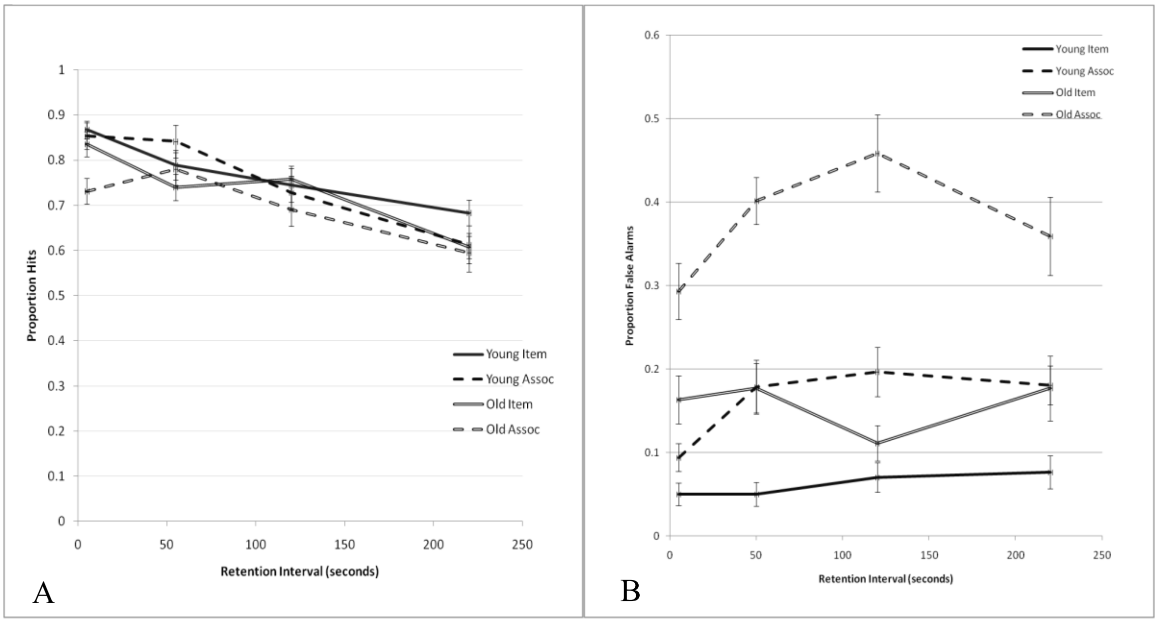
A three-way ANOVA was performed with age, retention interval, and test as the independent variables and proportion of hits minus false alarms as the dependent variable. As expected, there was a significant main effect of age (F (1, 47) = 25.22, $p <$ 0.001, $\eta_p^2 = .35$) showing that younger adults (M = .65, SD = .24) performed better than older adults (M = .45, SD = .26). There was a significant main effect of test (F (1, 47) = 114.65, $p < 0.001$, $\eta_p^2 = .71$) with item test performance (M = .65, SD = .21) being higher than associative test performance (M = .46, SD = .29). There was also a significant main effect of retention interval (F (3, 141) = 41.26, $p < 0.001$, $\eta_p^2 = .47$). As retention interval increased, memory performance decreased; follow-up paired t-tests indicated that performance was better on the short term interval than the short long-term interval (t (97) = 3.83, $p < 0.001$), which was better than the mid long-term interval (t (97) = 2.59, p = 0.01), which was better than the long long-term interval (t (97) = 3.46, $p < 0.001$).

There was a significant interaction of test and interval (F (3, 141) = 3.64, p = 0.001, $\eta_p^2 = .07$). Follow-up paired t-tests indicated that item memory performance was significantly better than associative memory performance in the short-term interval (t (97) = 4.11, $p < 0.001$), the short long-term interval (t (97) = 3.73, $p < 0.001$), the mid long-term interval (t (97) = 7.50, $p < 0.001$), and the long long-term interval (t (97) = 4.79, $p < 0.001$).

Evident of an overarching age-related associative deficit, there was a significant interaction of age and test (F (1, 47) = 17.64, $p < 0.001$, $\eta_p^2 = .27$). Follow-up t-tests indicated that younger adults performed significantly higher in the item test (M = 0.71, SD = 0.20) than older adults (M = 0.58, SD = 0.20), t (47) = 3.31, p = 0.001. Younger adults also performed significantly higher to a larger degree in the associative test (M =

0.60, *SD* = 0.27) than older adults (*M* = 0.32, *SD* = 0.24), t (47) = 5.76, $p < 0.001$. Notably, a three-way interaction of age, test, and interval was only marginally significant (F (3, 141) = 2.36, $p = 0.07$).

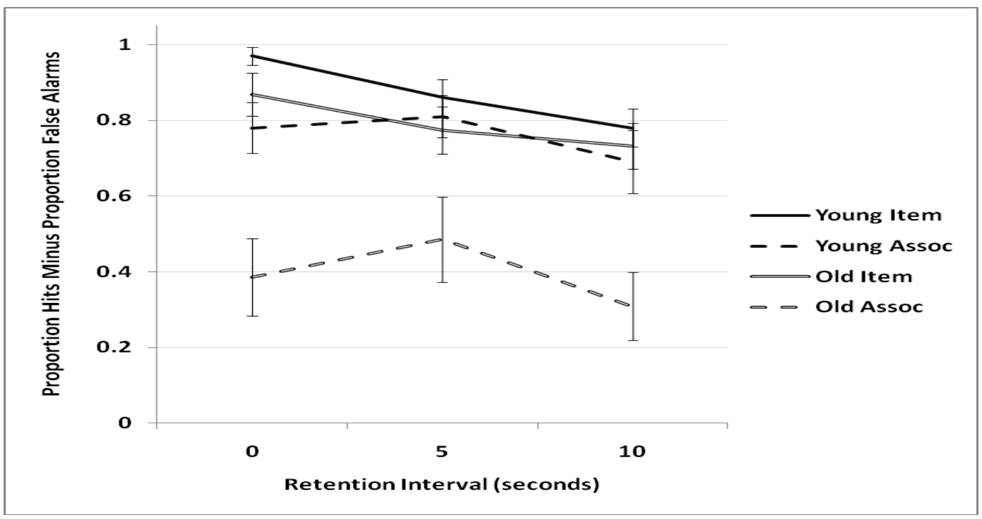
Figure 4. **Item and Associative Memory Test Hits (A) and False Alarms (B) for Younger and Older Adults --Experiment 1**



Next, hits and false alarms were examined separately. Examining proportion hits (Figure 4A), there was a significant main effect of interval (F (3, 141) = 43.98, $p < 0.001$, $\eta_p^2 = .48$) and a significant interaction of test and interval (F (3, 141) = 3.26, $p = 0.02$, $\eta_p^2 = .06$). Notably, there was no significant interaction of age and test (F (1, 47) = 0.61, $p = 0.44$).

Examining the false alarms (Figure 4B), on the other hand, yielded identical significant effects as the hits minus false alarms analyses, and most notably, there was a significant interaction of age and test (F (1, 47) = 12.45, $p < 0.001$, $\eta_p^2 = .21$). Follow-up t-tests indicated that for younger adults there were no significant differences in false alarms in the item test (*M* = 0.05, *SD* = 0.07) and the associative test (*M* = 0.09, *SD* = 0.08), *t* (24) = 1.88, *p* = .07. However, older adults had significantly fewer false alarms in the item test (*M* = 0.16, *SD* = 0.14) than the associative test (*M* = 0.29, *SD* = 0.16), *t* (23) = 3.76, *p* = 0.001.

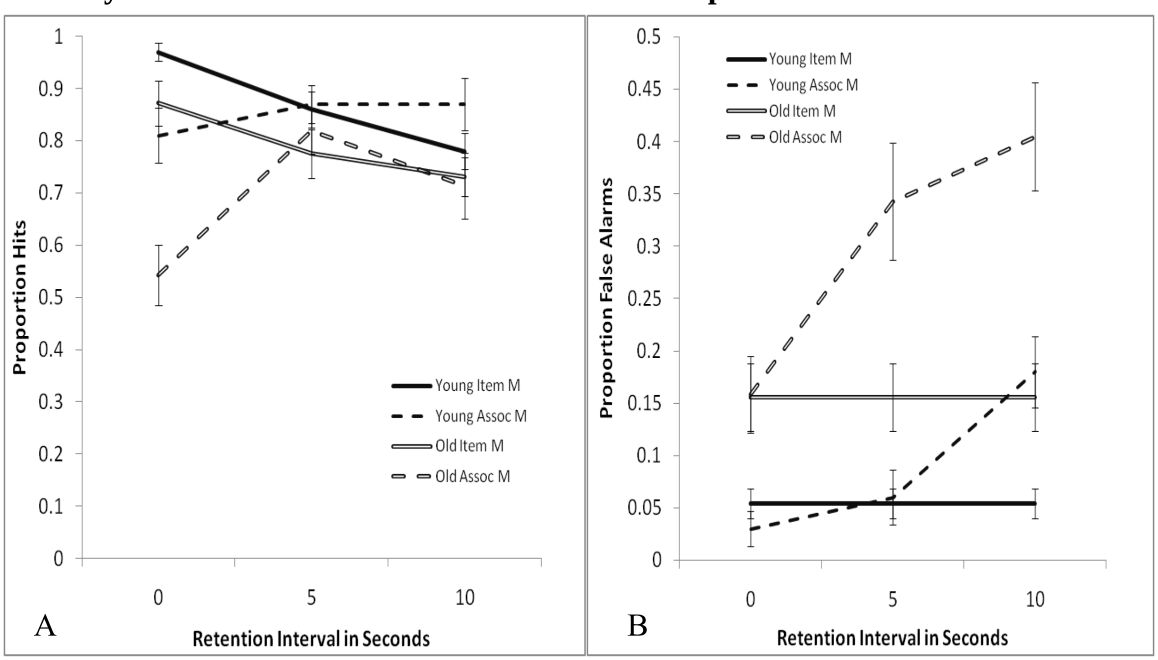
***Figure 5.* Mean Proportion Hits minus False Alarms (with Standard Errors) for Younger and Older Adults in the Item and Associative Memory Tests – Short-Term Sub intervals from Experiment 1**



Examination of the short retention interval

Examining the proportion hits minus false alarms in the three sub-intervals in the short-term interval yielded similar results to the findings across all intervals (Figure 5); there was a significant main effect of age (F (1, 47) = 28.15, p < 0.001, η_p^2 = .37), of test (F (1, 47) = 79.84, p < 0.001, η_p^2 = .63), and of retention interval (F (2, 94) = 7.20, p = 0.001, η_p^2 = .13). Evident of an overarching age-related associative deficit, there was a significant interaction of age and test (F (1, 47) = 26.68, p < 0.001, η_p^2 = .36), and of test and interval (F (2, 94) = 3.48, p = 0.04). Follow-up paired t-tests on the age by test interaction indicated that younger adults performed significantly higher in the item test (M = .87, SD = .15) than the associative test (M = .76, SD = .22), t (49) = 3.34, p = 0.002. Older adults to a greater extent performed significantly higher in the item test (M = .79, SD = .22) than the associative test (M = .39, SD = .30), t (47) = 8.40, p < 0.001. Follow-up t-tests on the test by retention interval interaction indicated that for the 0 second interval, performance was significantly higher in the item test (M = .92, SD = .22) than the associative test (M = .56, SD = .47), t (97) = 7.17, p < 0.001. This significance was also found in the 5 second interval, with item test performance (M = .82, SD = .28) higher than associative test performance (M = .65, SD = .47), (t (97) = 3.58, p < 0.001), and in the 10 second interval, with item test performance (M = .76, SD = .27) significantly higher than associative test performance (M = .50, SD = .47), t (97) = 4.92, p < 0.001. Notably, a three-way interaction of age, test, and interval was not significant (F (2, 94) = 0.23, p = 0.80).

***Figure 6.* Mean Proportion Hits (A) and Mean Proportion False Alarms (B) (with Standard Errors) for Younger and Older Adults in the Item and Associative Memory Tests – Short-Term Sub Intervals from Experiment 1**



Examining the proportion hits (Figure 6A), there was a significant main effect of age (F (1, 47) = 9.34, $p < 0.003$, $\eta_p^2 = .17$), of test (F (1, 47) = 8.34, $p = 0.006$, $\eta_p^2 =.15$), and a significant interaction of test and interval (F (2, 94) = 16.73, $p < 0.001$, $\eta_p^2 = .26$). Notably, there was a marginally significant interaction of age and test (F (1, 47) = 3.85, $p = 0.06$). Follow-up t-tests indicated that younger adults did not perform significantly higher in the item test ($M = .87$, $SD = .15$) than the associative test ($M = .85$, $SD = .17$), t (49) = .65, $p = .52$, but older adults performed significantly higher in the item test ($M = .79$, $SD = .22$) than the associative test ($M = .69$, $SD = .23$), t (47) =, $p = 0.008$. There was a marginally significant triple interaction of age, test, and interval (F (2, 94) = 2.33, $p = 0.10$). A post-hoc follow-up comparison demonstrated that there was a significant age and test interaction in the hits in the 0 second sub-interval (F (1, 47) = 4.99, $p = 0.03$, $\eta_p^2 = .10$), but not in the 5 second (F (1, 47) = 0.24, $p = 0.63$) or 10 second sub-intervals (F (1, 47) = 1.75, $p = 0.19$).

The proportion false alarms are shown in Figure 6B. However, since only one false alarm rate was used across all three sub-intervals in the item test, no analyses on the false alarm rates were done.

Discussion

Overall, when utilizing a single paradigm to measure both long-term and short-term/working memory, the results demonstrated a clear age-related associative memory deficit in the short-term interval, in addition to that in the long-term intervals. The effect was driven by an increase in false alarms in the older adults' associative memory performance. Even upon closer examination of the short-term retention interval, the associative memory deficit of older adults was apparent. Interestingly, while there was evidence of forgetting with lower memory performance as retention intervals increased, this forgetting was not differentially larger for older adults' associative memory.

However, the hit rate results drew concern due to the associative memory performance in the 0 second sub-interval. Specifically, in the 0 second interval, the hit rate was much lower than on the longer retention sub-intervals of 5 and 10 seconds for younger and especially older adults. This was possibly due to methodological issues. In the experiment, the only cue to indicate that a new event was being presented was a change in the instruction word at the top of the screen every five seconds. Especially in the 0 second interval, which did not have an inter-stimulus interval, it is possible that an intact pair in an associative test event was not made sufficiently distinct from the study event. Perhaps older adults in particular perceived these study and test events as one long study event, rather than a test event of the intact pair, resulting in a lack of response.

Still, even excluding the potentially problematic data of the 0 second interval, there is clear evidence for an associative memory deficit of older adults in the short-term interval.

Experiment 2

Because there was an associative deficit even in the short-term interval in the data of Experiment 1, we investigated the role of the salience of test events in this short-term/working memory deficit. While, as mentioned before, no obvious pattern emerges in the literature for why an associative deficit of older adults is evident in some short-term/working memory experiments but not in others, the salience of test events does differ in these experiments in that some test events may appear more obvious than others, and this difference may shed some light on the varying results. In other words, because the participant is unaware of which type of test they will be completing at any given point in a mixed design, they may find the associative test to be less salient because it looks similar to a study presentation and includes material that they have seen before (in contrast to an item test in which only one image is presented, and it may even be a new image). A binding change, therefore, may appear less obvious. Blocking the test type would increase the salience of test events relative to each other, such that an associative test is not less salient than an item test. In such blocking, the associative test no longer blends into the study events in comparison to the more salient item tests which spatially look very different; in the associative block, the associative tests have only the study events to contrast with.

Not all experiments that demonstrated an associative deficit of older adults in short-term/working memory utilized one test type (blocked or mixed); Cowan et al. (2006) utilized both test types. In the first experiment, they used a mixed test type and found an associative deficit. In a follow-up experiment conducted to take into consideration the possibility of differential salience of change trials affecting the results, they implemented a blocked test type. The results from this experiment led to a smaller associative deficit.

Therefore in order to investigate whether the associative deficit in older adults found in Experiment 1 in the short-term/working memory retention intervals was due to the differential salience of the test events, we blocked the test type in Experiment 2 in addition to having a mixed test (as done in Experiment 1). In the mixed condition, study, item, and associative test events were presented in one block (as in Experiment 1). In the blocked condition, study and item test events were presented in a different block than the study and associative test events.

Because we demonstrated a general associative deficit across the retention intervals using this modified continuous recognition paradigm in Experiment 1, we continued to vary the retention interval, but focused on the short-term interval (0-6 seconds) ,which reflects short-term/working memory. Some other methodological changes were also implemented based on feedback and analysis of the first experiment; some participants responded during the post-test questionnaire that some of the stimuli looked too similar to each other, so new stimuli were used. Also, because of the potential issue of older adults having a particular problem with distinguishing intact pairs in the 0 second sub-interval in Experiment 1, we presented more salient external cues to signal that a new event was occurring. Study events had a white background and test events had a grey background, and each was presented with an auditory cue to indicate there was a new event.

We expected to find that there would be an associative deficit in the mixed condition throughout the intervals, as this would replicate the results of the first experiment. Should salience of test events be the main issue in finding an associative deficit in short-term memory, no associative deficit would be seen in the blocked condition.

Methods

Participants

The participants included 30 undergraduates with an average age of 20.4 years (*SD* = 1.92, range of 18-25 years) enrolled in a psychology course at the University of

Missouri who were offered credit for their participation. Their mean education level was 14.13 years (SD = 1.72), and 20 of them were female. The participants also included 29 older adults with an average age of 70.79 years (SD = 4.95, range of 64-80 years) from the mid-Missouri area who were healthy with no known memory impairments and were paid $15 for their participation. Their mean education level was 15.31 years (SD = 2.29), and 19 of them were female. Older adults had significantly more education than younger adults, t (57) = 2.24, p = 0.03. Participants were run individually by the researcher.

Design

This experiment used a 2 (age: younger adults and older adults) x 2 (test: item including both faces and scenes, and associative) x 2 (list type: mixed and blocked tests) x 4 (retention interval: 0, 2, 4, and 6 second intervals) design. Test, list type, and retention interval were within-subjects factors.

Materials

The lists were presented using the E-Prime program and appeared very similar to that of Experiment 1 with a face and a scene side by side with an instruction at the top. Three mixed lists and four blocked lists (two each of item and associative only blocks) for a total of seven short-term memory lists were presented to each subject, with one long-term memory test list at the end of all trials (which was added to assess final overall performance). Order of the seven short-term memory lists was counterbalanced. Each list lasted on average 5.5 minutes. Study events were presented on a white background for 2 seconds (to resemble standard short-term/working memory parameters) and test events were presented on a grey background for 4 seconds.

Each mixed list had 62 study pairs, 48 of which were tested in that list. There were 24 item test events and 24 associative test events with an equal number of targets and distractors evenly distributed across the four retention intervals (similar to Experiment 1). Each blocked item list had 40 study pairs, 24 of which were tested in that list. There were also 24 distractor items that were tested, and half of the tests were faces and the other half were scenes. These were evenly distributed across the four retention intervals. The blocked associative list had 68 study pairs, 48 of which were tested in that list. There were 24 intact target pairs and 24 recombined distractor pairs. These were evenly distributed across the four retention intervals. Note that for all conditions, there were several extra study pairs that were never tested in order to ensure that the list, with its randomly ordered intervals and events, always presented images, rather than have any blank screens to fill in the retention interval. These randomly ordered lists minimized the amount of extra study pairs while keeping the total time the same for each type of list. Due to limitations in number of stimuli, the item blocks had fewer extra study pairs than the associative blocks.

Untested pairs were used for the final recognition test, which tested over two items, two intact pairs, and two recombined pairs from each of the lists. With 14 additional item distractors not shown at any point prior in the study, there were a total of 28 item test events and 28 associative test events.

The 362 pairs of color images were 250 x 250 pixels. The face images were taken from both the web (Veer.com, 2009) and the face database from Minear and Park (2004). The faces were equally male and female and ranged in age from mid 20s to 80 year olds with a roughly similar number of older and younger adults. The faces were more ethnically diverse than in Experiment 1, including mostly white, but also black, and some Asian faces. The scenes included mountains, forests, open country, beaches, houses, city scenes, skyscrapers, and roads (Oliva & Torralba, 2001). Stimuli were counterbalanced to list type and to type of test, target or distractor status, and retention interval in each configuration.

The instruction words were the same as in Experiment 1; they included “study,” “item,” and “assoc,” and instructed the same response from the participant as in Experiment 1. The interval between the presentation of the pair and the test event on that particular pair varied in four intervals: 0, 2, 4, and 6 seconds. A 0 second interval meant that the pair was tested immediately after it was presented as a study pair. A 2 second interval could only have another 2 second study event in the intervening time, whereas a 4 second or 6 second interval could include any combinations of 2 second study events or 4 second test events. This slight restriction was because the 4 second presentation rate of test events required that it not be an intervening event in a 0 or 2 second interval.

Procedure

Participants’ instructions were the same as in Experiment 1 with a few changes. They were told that there would be three different trial types: a) “mixed” in which all three instructions appear intermixed (as in Experiment 1), b) “item” in which only the “study” and “item” instructions appear intermixed, and c) “assoc” in which only the “study” and “assoc” instructions appear intermixed. Participants pressed “v” for a “yes” response and “n” for a “no” response to the recognition test. As in Experiment 1, participants were told that each list’s test would include only material from that list and there would be no overlap in stimuli from any other list. They were also informed that they would be told of the upcoming list type just before doing the list.

Study pairs were presented for 2 seconds on a white background and test pairs were presented for 4 seconds on a grey background. At the beginning of each event, a brief clap sound played to indicate that this event was a new event. Thus, in the case of a 0 second interval target associative test event in which the pair was intact and tested immediately after the study, the subject had both the clap sound and the background color change in addition to the instruction word change to cue that this was a test event and not just an extended study event. The participant had 4 seconds to respond to the test during which the image(s) remained on the screen; they were encouraged to respond within that time as the screen moved on automatically after the 4 seconds.

Again, they were instructed given to pay close attention to the instruction at the top of the screen for an indication of what response to make to the image(s) on the screen. They were informed about the approximate number of study or test events, and about the fact that the correct response to the tests would be evenly divided between a "yes" response and a "no" response. Participants also saw a visual example of what a study pair might look like and an item, or an associative test pair, shown side by side for ease of comparison and clarity regarding what the correct response should be. The text example from Experiment 1 was also shown, with indications to the correct key ("v" and "n" instead of "1" and "0").

Participants then completed practice lists, in the order of item list, associative list, and then mixed list. Before each list, on screen instructions said which one they would be doing, which instructions they would see, and what kind of response the instruction word should elicit.

Short breaks were encouraged throughout the experiment, and one break was taken for all participants after 4 lists. After the 7^{th} list, participants were given a self-paced final recognition test over the material that they saw throughout the experiment. They were not told about the test until they were about to take it and the item test was presented before the associative test. After the final recognition test, participants were asked to answer some post-test questions and then were debriefed.

Results

As in Experiment 1, memory accuracy was recorded in the form of proportion hits minus false alarms. The means and standard deviations for younger and older adults can be found in Tables 3 (mixed lists) and 4 (blocked lists). The means and standard errors are presented in graphical form in Figure 7.

Table 3. ***Proportion Hits minus False Alarms Means and Standard Deviations for the Mixed Condition in Experiment 2***

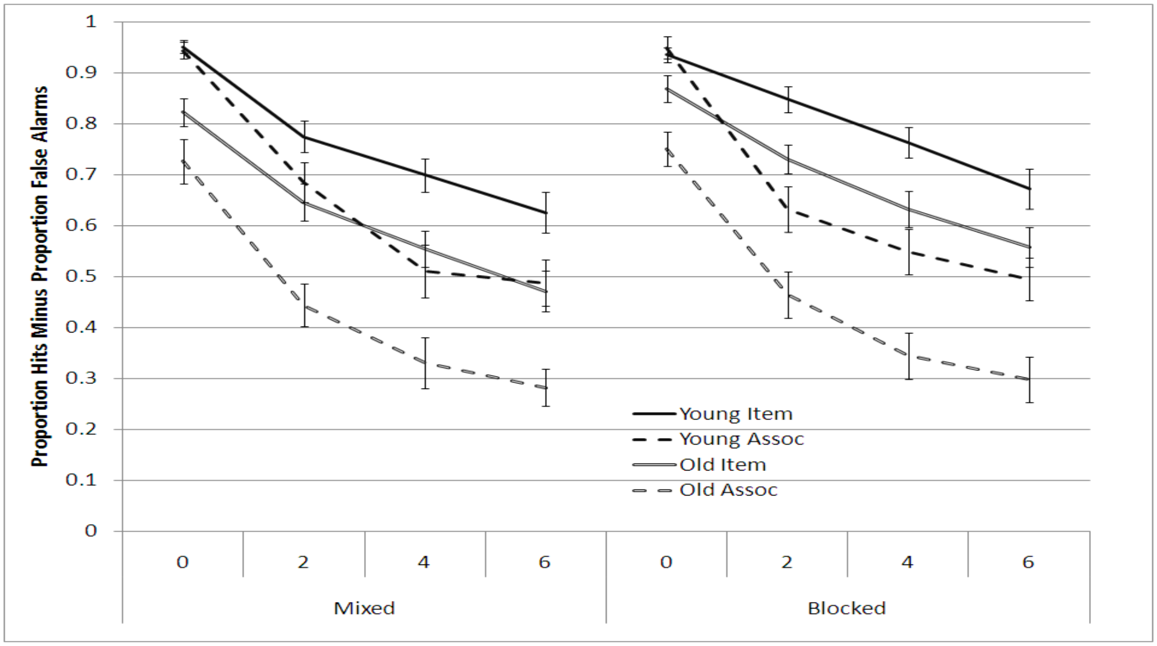
		0 seconds		**2 seconds**		**4 seconds**		**6 seconds**	
		Item	**Assoc**	**Item**	**Assoc**	**Item**	**Assoc**	**Item**	**Assoc**
Young	**Mean**	**0.95**	**0.94**	**0.78**	**0.69**	**0.70**	**0.51**	**0.63**	**0.49**
	SD	0.07	0.09	0.17	0.22	0.18	0.28	0.22	0.25
Old	**Mean**	**0.82**	**0.73**	**0.65**	**0.44**	**0.55**	**0.33**	**0.47**	**0.28**
	SD	0.15	0.24	0.19	0.22	0.19	0.27	0.21	0.20

Table 4. ***Proportion Hits minus False Alarms Means and Standard Deviations for the Blocked Condition in Experiment 2***

		0 seconds		**2 seconds**		**4 seconds**		**6 seconds**	
		Item	**Assoc**	**Item**	**Assoc**	**Item**	**Assoc**	**Item**	**Assoc**

Young	**Mean**	**0.94**	**0.95**	**0.85**	**0.63**	**0.76**	**0.55**	**0.67**	**0.49**
	SD	0.08	0.12	0.14	0.24	0.16	0.24	0.21	0.23
Old	**Mean**	**0.87**	**0.75**	**0.73**	**0.46**	**0.63**	**0.34**	**0.56**	**0.30**
	SD	0.14	0.18	0.15	0.25	0.19	0.25	0.21	0.24

***Figure 7.* Mean Proportion Hits minus False Alarms (with Standard Errors) for Younger and Older Adults in the Item and Associative Memory Tests – Experiment 2**



A four-way ANOVA was performed with age, test, list type, and retention interval as the independent variables and proportion of hits minus false alarms as the dependent variable. As expected, there was a significant main effect of age (F (1, 57) = 27.23, $p < 0.001$, $\eta_p^2 = .32$) showing that younger adults ($M = .72$, $SD = .25$) performed better than older adults ($M = .56$, $SD = .28$). There was a significant main effect of test (F (1, 57) = 147.44, $p < 0.001$, $\eta_p^2 = .72$) with item test performance ($M = .72$, $SD = .22$) being higher than associative test performance ($M = .56$, $SD = .30$). There was a significant main effect of list type (F (1, 57) = 10.04, $p = 0.002$, $\eta_p^2 = .15$) with blocked test performance ($M = .66$, $SD = .27$) being higher than mixed test performance ($M = .62$, *SD* = .28). There was also a significant main effect of retention interval (F (3, 171) =165.34, $p < 0.001$, $\eta_p^2 = .74$). As retention interval increased, memory performance decreased; follow-up paired t-tests indicated that performance was better in the 0 second interval than the 2 second interval (t (235) = 15.90, $p < 0.001$), which was better than the 4 second interval (t (235) = 7.06, $p < 0.001$), which was better than the 6 second interval (t (235) = 3.80, $p < 0.001$).

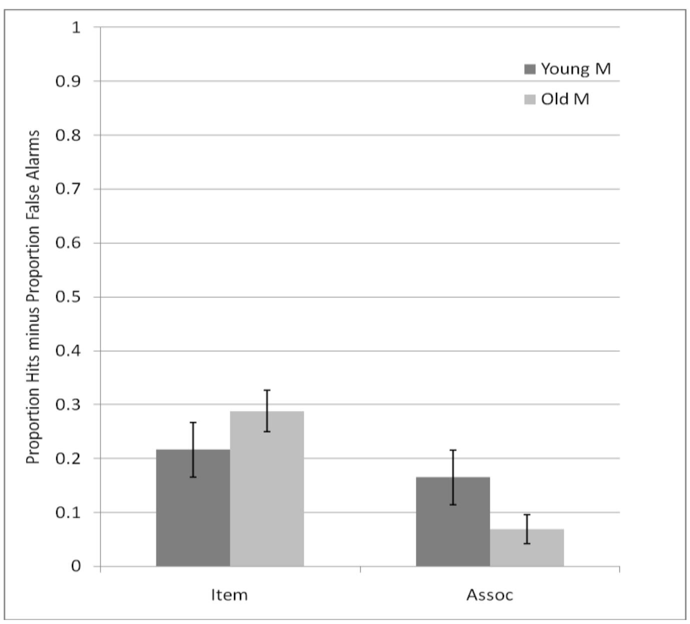
There was a significant interaction of test and list type (F (1, 57) = 4.76, $p = 0.03$, $\eta_p^2 = .08$). Follow-up paired t-tests indicated that item memory performance was significantly higher in the blocked list condition than the mixed list condition, t (235) = 4.87, $p < 0.001$. On the other hand, associative memory performance was not significantly different in the blocked and mixed list conditions, t (235) = .56, $p = .58$.

There was a significant interaction of test and interval (F (3, 171) = 16.43, $p < 0.001$, $\eta_p^2 = .22$). Follow-up paired t-tests indicated that item memory performance was significantly higher than associative memory performance in the 0 second interval (t (117) = 2.97, $p = 0.004$), although this advantage was smaller than in the 2 second interval (t (117) = 9.52, $p < 0.001$), the 4 second interval (t (117) = 9.71, $p < 0.001$), and the 6 second interval (t (117) = 8.67, $p < 0.001$).

Evident of an overarching age-related associative deficit, there was a significant interaction of age and test (F (1, 57) = 8.20, $p = 0.006$, $\eta_p^2 = .13$). Follow-up t-tests indicated that younger adults performed significantly higher in the item test ($M = .78$, $SD = .11$) and the associative test ($M = .66$, $SD = .16$), t (29) = 8.86, $p < 0.001$. Older adults performed significantly higher to a larger degree in the item test ($M = .66$, $SD = .11$) than the associative test ($M = .45$, $SD = .13$), t (28) = 8.76, $p < 0.001$. Notably, no other interactions were significant; the age, test and list type interaction (*F* (1, 57) = 0.08, *p* = 0.78), the age, test, and interval interaction (*F* (1, 57) = .30, *p* = 0.82), nor the age, test, list type, and interval interaction (*F* (3, 171) = 0.47, *p* = 0.70).

Analysis of the final recognition memory test (the results of which are shown in Figure 8) yielded a significant main effect of test (*F* (1, 55) = 20.95, *p* < 0.001, η_p^2 = .28) and a significant interaction of age and test (*F* (1, 55) = 7.36, *p* = 0.009, η_p^2 = .12). Follow up paired t-tests indicated that there was no significant effect of test with younger adults (*t* (28) = 1.20, *p* = 0.24), but there was a significant effect of test with older adults (*t* (27) = 6.15, *p* < 0.001).

***Figure 8.* Mean Proportion Hits minus False Alarms (with Standard Errors) for Younger and Older Adults in the Item and Associative Memory Tests – Final Recognition in Experiment 2**



Discussion

The results from Experiment 2 converged with those from Experiment 1, in that an age-related associative memory deficit was found when a mixed test design was used in retention intervals comparable to those used in short-term/working memory experiments.

Interestingly, this associative deficit was demonstrated in the blocked test design, as well. The lack of differential results may provide further evidence for an age-related associative deficit in short-term/working memory. Relative to the mixed list condition associative memory performance did not increase in the blocked list condition for either younger or older adults as hypothesized, but item memory performance did increase consistently for both younger and older adults so that an age-related associative deficit was still found. This increase in item memory performance was most likely due to the lack of associative strategic resources needed in the item memory test list. In other words, participants did not need to use any resources to bind the images together into a pair in the item test list because they knew they would only be tested over individual images. In the mixed list condition, because a given pair could be tested over either the individual image or the pairing, participants needed to remember the associations of each pair presented at study, which might have been at the expense of paying attention to the individual items.

To measure the potential effects on long-term memory using a long-term memory paradigm (with the test administered after the study phase is completed), the final recognition test was administered. As further support to the above-reported results, an age-related associative deficit was found in this test, as well.

Overall, the results showed an unequivocal age-related associative memory deficit in both the blocked and mixed list conditions, in each retention interval. Despite the evidence from Cowan et al. (2006) that blocking the test conditions might yield a diminished associative deficit of older adults, implementing such a manipulation in this experiment did not yield similar results.

These results not only provide converging evidence to those reported in Experiment 1, but also provide further support for a general age-related associative deficit in short-term memory, irrespective of at least one potential methodological confound of blocked test type.

Experiment 3

Manipulating the trial type (mixed vs. blocked) in Experiment 2 did not result in a change in older adults' the associative deficit in short-term/working memory. As a result, in this experiment, we examined the role of another potential mediating methodological factor. The sequential presentation of study items is the most common method used in long-term memory studies (and was also used in Experiments 1 and 2), while a simultaneous presentation of study items is prevalent in short-term/working memory studies (for example, the often used paradigm by Luck & Vogel, 1997). Perhaps the sequential nature of the study presentation used in Experiments 1 and 2 may make the associations more difficult for older adults to remember resulting in an apparent associative memory deficit. Indeed, there is evidence that sequential presentation of items affects binding performance of younger adults specifically in a working memory task (Allen, Baddeley, & Hitch, 2006). While a sequential presentation introduces a temporal component to study of items, a simultaneous presentation provides for potentially smaller binding load for older adults because they may rely on holistic processing. Though the images themselves still need to be bound together in their pairing, they may appear to be parts of a whole on one screen. On the other hand, a simultaneous presentation may require a more effective strategy in allocation of attention to the pairings, such that sufficient attention is given to both pairs. Since there is some evidence that simultaneous presentation may result in smaller age-related associative deficit in short-term working memory than a sequential one (Brown & Brockmole, 2010; Cowan, et al., 2006), we examined in this experiment the effects of a sequential presentation (as seen in the continuous recognition paradigm of Experiments 1 and 2) versus a simultaneous one on the associative memory deficit of older adults.

We presented the study stimuli in Experiment 3 in a sequential or simultaneous manner. In the sequential condition, one study pair was presented on the screen followed by a second study pair, before a test over any of those two pairs. In the simultaneous condition, two study pairs were presented together on the screen at the same time before the test. The spatial orientation of the images was never the same for two events in a row. Images at study were either in an array, or presented either on top or bottom. Images at test were always presented in the middle. The participant therefore needed to make several eye movements (saccades) for each event.

In Experiments 1 and 2, recombined pairs included an item from a given interval recombined with an untested item from any previous event. While the lag between the presentation of one test item and the second test item was consistent across the intervals, this would prove problematic for Experiment 3. In working memory paradigms, recombined pairs consist of items within a given array (in a simultaneous presentation) or within a short series of study items (in a sequential presentation). In long-term memory paradigms, however, the recombination may consist of items within a long list. As such, this was the approach of Experiments 1 and 2: the lag between presentations of the recombined items at study was not manipulated. Therefore, to examine the effect of within-array (as in working memory paradigms) and between-array (as in long-term paradigms and Experiments 1 and 2) recombinations of pairs, a within-array recombined pair recombined a face and a scene from that given trial of two pairs. In contrast, a between-array recombined pair did recombine a face and a scene, one of which was presented in that given trial of two pairs, and the other of which was presented at a time prior to that block (as in Experiments 1 and 2).

Because we established an associative deficit using a blocked test design, we continued to use a blocked test design here. In addition, to eliminate any potential factor of task-switching that may have arisen in Experiment 2, the order of blocks was counterbalanced such that all item tests were presented first, and all associative tests were presented after, or vice versa.

We expected to find that there would be an associative deficit in the sequential condition, as this would be a replication of the results of Experiment 1 and 2. If a simultaneous presentation was less detrimental to binding, a reduced or possibly no age-related associative deficit would be seen in the simultaneous condition. If a between-array recombined pair was a more salient cue, performance for between-array recombinations would be higher than for within-array recombinations.

Methods

Participants

The participants included 24 undergraduates with an average age of 19.08 (*SD* = 1.47, range of 18-25 years) enrolled in an introductory psychology course at the

University of Missouri, 13 of whom were female. They had on average 12.8 years of education (*SD* = 0.85). There were also 24 older adults with an average age of 69.46 (*SD* = 5.15, range of 63-79 years) from the mid-Missouri area who were healthy with no known memory impairments and were paid $15 for their participation, 13 of whom were female. They had on average 14.3 years of education (*SD* = 1.98). Older adults had significantly higher levels of education than older adults, t (46) = 3.41, p = 0.001.

Design

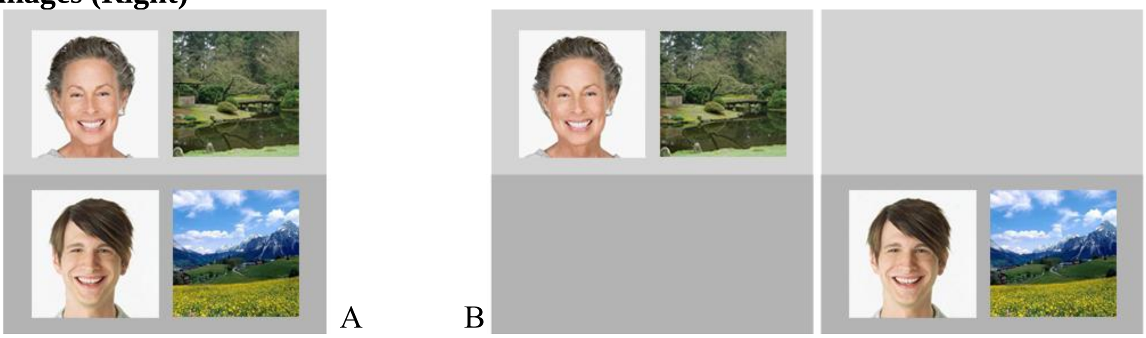
This experiment was a 2 (age: younger adults and older adults) x 2 (test: item including both faces and scenes, and associative) x 2 (study presentation type: sequential and simultaneous) design with an additional factor of recombination type (within-array and between-array) manipulated only in the recombined pairs in the associative test. Test, study presentation type, and recombination type were within-subjects factors.

Materials

The blocks were presented using the E-Prime program. Six blocks were presented to each subject (sequential: one item and two associative blocks; simultaneous: one item and two associative blocks). The reason for the larger number of associative blocks was in order to accommodate the number of within-array and between-array recombinations. Order of the blocks was counterbalanced, such that either the sequential or the simultaneous condition was presented first, and that either the item condition or the associative condition was presented first for a given participant.

The stimuli were the same as in Experiment 2. In the simultaneous condition, two pairs of images were presented on one screen with one pair on top and one pair on bottom for 4 seconds (see Figure 9A). To encourage binding within each of the pairs, the top half of the screen was one shade of grey and the bottom half of the screen a darker shade of grey, to ensure a gestalt processing of the four images as two pairs.

Figure 9. **Examples of Simultaneous Study Images (Left) and Sequential Study Images (Right)**



In the sequential condition, two pairs of images were presented temporally staggered. One pair of images was in the top half of the screen for 2 seconds and the other in the bottom half for 2 seconds (see Figure 9B), and position order was randomized. The total study time spent on each two pairs was therefore the same as in the simultaneous condition. Again, the top half of the screen was one shade of grey and the bottom half a darker shade. Test events were presented on a white background for 3 seconds. A clap noise sounded at the beginning of each event as an auditory cue.

For each condition (simultaneous and sequential), 220 study pairs were presented. The item test consisted of 20 targets and 20 distractors (half faces and half scenes). The associative test consisted of 40 intact pairs and 40 recombined pairs. Within the recombined pairs, 20 were recombined within-array, and 20 recombined between-array.

Procedure

Participants' instructions differed from Experiments 1 and 2. They were told that there would be two different types of blocks. In the sequential condition, they saw for each event one pair of images on the screen, either on top or bottom (the position of which they were told was not important to remember). Then they were tested immediately after the second pair. In the simultaneous condition, they saw two pairs of images on the screen, either on top or bottom and were tested immediately after with no interstimulus interval. If the block was an item block, they were asked if the item was presented (in either of those two pairs), and they should respond "v" for yes and "n" for no. In an associative block, they were asked if the pair was presented together originally, and they should respond "v" for yes and "n" for no. As in Experiments 1 and 2, participants were told that each trial's test would include only material in that trial and there was no overlap in stimuli from any other trial. They were also informed of the trial type immediately prior to the trial.

The participant had 3 seconds to respond to the test during which the image(s) remained on the screen; they were encouraged to respond within that time because the screen moved on automatically after the 3 seconds. They were not informed of the fact that recombined pairs would be between-array or within-array, as this was manipulated within blocks.

They were informed that the correct response to the tests would be evenly divided between a "yes" response and a "no" response. Participants also saw a visual example of what a study pair, an item test, and an associative test might look like, shown side by side for ease of comparison and clarity, as well as the correct response.

Participants then completed practice sequential and simultaneous trials. Before each trial, on screen instructions indicated which trial they would be doing and which instructions they would see. After completing the last trial, participants were asked to answer some post-test questions and then debriefed.

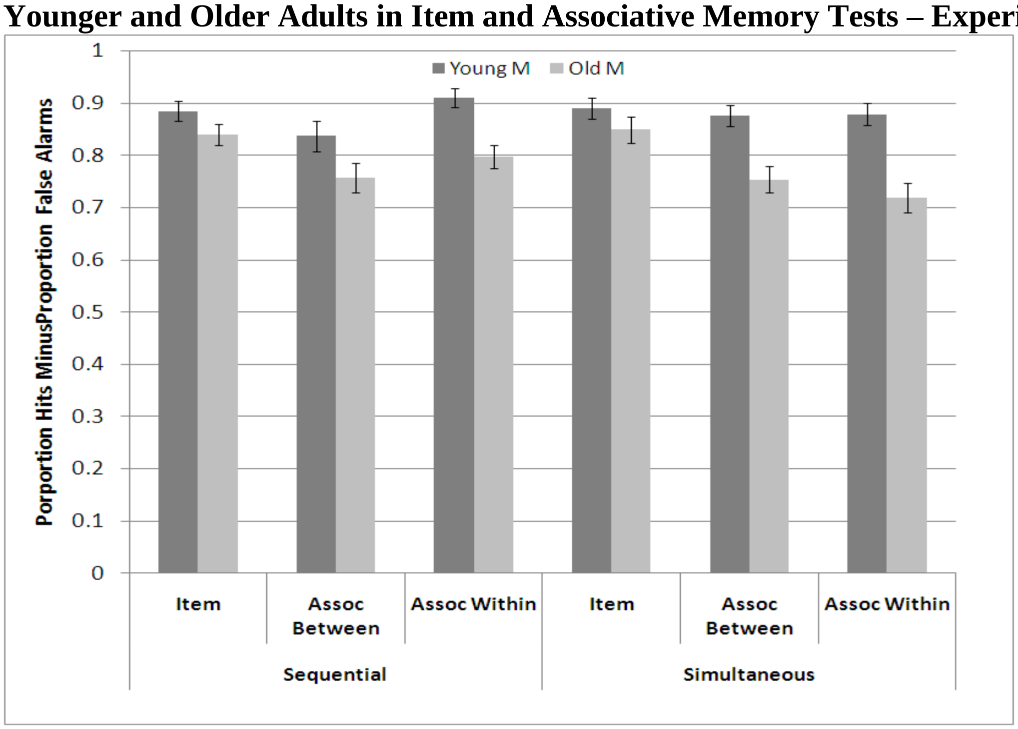
Results

Memory accuracy was recorded in the form of proportion hits minus false alarms. The means and standard deviations for younger and older adults can be found in Table 5. The means and standard errors are presented in graphical form in Figure 10.

Table 5. ***Proportion Hits minus False Alarms Means and Standard Deviations for Experiment 3***

		Sequential			Simultaneous		
		Item	Assoc		Item	Assoc	
			Between	Within		Between	Within
Young	**M**	**0.89**	**0.84**	**0.91**	**0.89**	**0.88**	**0.88**
	SD	0.10	0.14	0.09	0.10	0.10	0.10
Old	**M**	**0.84**	**0.76**	**0.80**	**0.85**	**0.75**	**0.72**
	SD	0.10	0.14	0.11	0.12	0.12	0.14

Figure 10. **Mean Proportion Hits minus False Alarms (with Standard Errors) for Younger and Older Adults in Item and Associative Memory Tests – Experiment 3**



A three-way ANOVA was performed with age, test, and study presentation type as the independent variables and proportion of hits minus false alarms as the dependent variable. As expected, there was a significant main effect of age (F (1, 46) = 20.76, $p <$ 0.001, $\eta_p^2 = .31$) showing that younger adults (M = .88, SD = .11) performed better than older adults (M = .79, SD = .13). There was a significant main effect of test (F (1, 46) = 11.06, p = 0.002, $\eta_p^2 = .19$) with item test performance (M = .87, SD = .10) being higher than associative test performance (M = .82, SD = .13). There was no main effect of condition (F (1, 46) = .65, p = 0.42), with sequential condition performance (M = .84, SD = .12) not different from simultaneous condition performance (M = .83, SD = .13).

There was a significant interaction of age and test (F (1, 46) = 6.39, p = 0.01, η_p^2 = .12). Follow-up t-tests indicated that there was no significant effect of test for younger adults (t (46) = .48, p = 0.64), with item test performance at .89 (SD = .10) and associative test performance at .88 (SD = .11), but there was a significant effect of test for older adults (t (46) = 3.53, p < 0.001), with item test performance at .84 (SD = .11) and associative test performance at .76 (SD = .13). Notably, a three-way interaction of age, test, and condition was not significant (F (1, 46) = 1.34, p = 0.25).

An additional three-way ANOVA was performed with age, study presentation type, and recombination type as the independent variables and proportion of hits minus false alarms in the associative test as the dependent variable. As expected, there was a significant main effect of age (F (1, 46) = 22.68, p < 0.001, $\eta_p^2 = .33$) showing that younger adults (M = .88, SD = .11) performed better than older adults (M = .76, SD = .13). There was no main effect of condition (F (1, 46) = 1.45, p = 0.24) with sequential condition performance at .83 (SD = .13) and simultaneous condition performance at .81

(*SD* = .14). There was also no main effect of recombination type (*F* (1, 46) = 2.52, *p* = 0.12) with between-array performance at .81 (*SD* = .13) and simultaneous condition performance at .83 (*SD* = .13).There was a significant interaction of condition and recombination type (*F* (1, 46) = 8.65, *p* = 0.005, η_p^2 = 16). Follow-up t-tests indicated that in the simultaneous condition, between-array performance (*M* = .82, *SD* = .13) was not significantly different from within-array performance (*M* = .80, *SD* = .15), *t* (47) = .95, *p* = 0.34, but in the sequential condition, between-array performance (*M* = .80, *SD* = .14) was significantly lower than within-array performance(*M* = .85, *SD* = .11), *t* (47) = 3.06, *p* = 0.003.

There was no significant interaction of age, condition, and recombination type (*F* (1, 46) = .0057, *p* = 0.94). However, we were interested in older adults specifically with the recombination type and there was a marginally significant interaction of condition and recombination type for older adults, *F* (47) = 3.62, *p* = 0.07.

Discussion

The results from Experiment 3 converged with those from Experiments 1 and 2, in that an age-related associative memory deficit was found in the sequential condition in which the study pairs were presented in temporal sequence as in the previous experiments. More importantly, this associative deficit was also seen in the simultaneous condition in which the study pairs were presented in one array. Minimizing the potential temporal source memory problems in older adults failed to reduce the associative memory deficit. The associative memory deficit remained in a typical presentation type used in the short-term/working memory literature (a simultaneous presentation). We believed that the recombination type could have a differential effect in the memory performance of older adults in the two different conditions; more specifically, that a between-array recombination would help their performance in the simultaneous condition, but would hurt their performance in the sequential condition. However, this result was not significant. Instead, there was a general interaction of the condition and recombination type regardless of age; in the sequential presentation, a within-array recombination led to higher performance than a between-array recombination. The reasoning for this trend had been hypothesized, i.e., that the temporal component of the between array recombination in conjunction with the temporal component of the sequential presentation would prove to be more detrimental, and this appeared to be occurring in both age groups.

Overall, the results of this experiment showed a clear age-related associative memory deficit, regardless of study presentation mode, which further support a general age-related associative deficit in short-term/working memory.

General Discussion

Naveh-Benjamin (2000) proposed that the age-related decline in episodic memory is due to a difficulty for older adults to bind information into new associations and later retrieve those associations. As evidence, an extensive literature on the associative memory deficit of older adults in long-term memory exists (see Old & Naveh-Benjamin, 2008a). However, the extrapolation of the associative memory deficit to working memory has proven to be more controversial.

While some experiments have demonstrated an age-related associative memory deficit in working memory (Bopp & Verhaeghen, 2009; Brockmole, et al., 2008; Brown

& Brockmole, 2010; Parra, Abrahams, Logie, & Sala, 2009), others have used similar paradigms to demonstrate no such deficit (Bopp & Verhaeghen, 2009; Brockmole, et al., 2008; Cowan, et al., 2006; Mitchell, et al., 2000). These experiments, while generally similar, do have variations in their methodologies, though all attempt to measure item and associative recognition in working memory.

The approach taken in the current research was to attempt to bridge the discrepancy in the literature by using a single paradigm to measure both long-term memory and short-term/working memory. We varied the retention interval to measure both types of memory in one paradigm, though we remained agnostic as to whether the paradigm would be considered measuring working memory specifically, mostly because it was not a traditional working memory paradigm. In Experiment 1, retention intervals comparable to those used in both long-term memory and short-term/working memory research yielded a general age-related associative deficit. This pattern of results suggests that the associative deficit found in long-term memory is not a result of a slower consolidation rate or increased forgetting rate in older adults. This effect was driven by an increased false alarm rate rather than a decreased hit rate; older adults were more likely to respond that they had seen a recombined pair as having appeared in that pairing at study. The pattern of results was seen on a macro level across intervals from 5 seconds to 3 minutes and 40 seconds, and also on a micro level, as seen in the short-term intervals of 0, 5, and 10 seconds.

However, there was a decrease in associative hits in the 0 second retention interval for older adults which highlighted some methodological drawbacks to Experiment 1 which were remedied in Experiment 2. Specifically, older adults may have failed to recognize that the associative test presented immediately after the test was a distinct event that required a response, as the only indicator was a change in the instruction word presented at the top of the screen. The issue was that there was a decrease in test event salience in comparison to an item test event, for example, in which not only the instruction word changed, but the visual array also had only one element (either a face or a scene) rather than the usual two (both a face and a scene). Test salience in other retention intervals could also be a potential factor in the results from Experiment 1, and in the inconsistent results in the working memory literature, one that could explain why the one experiment without high associative test salience led to an associative deficit (see Cowan, et al., 2006). Therefore, we manipulated test event salience in Experiment 2 by blocking the test, in addition to using the mixed test design of Experiment 1.

The manipulation of test salience failed to yield a smaller associative deficit in any of the retention intervals used; associative memory performance was not affected for either younger or older adults. In fact, instead, item memory performance increased for both groups. Rather than any particular increase in test salience for item tests, we believe that the nature of an item block allowed both younger and older adults to not waste their cognitive resources on binding or retrieving these bindings. While this particular methodological manipulation did not shed light on the inconsistent associative deficit in working memory literature, it did provide further support for a general age-related associative deficit.

Experiment 2 examined only one methodological factor, and not all of the different methodological factors have yet been ruled out. The next most likely methodological factor was related to the paradigm used in Experiments 1 and 2. Utilizing a paradigm that involved a temporal component to its study material may have led to an associative deficit. By including a non-explicit secondary source memory component of time in a sequential design, older adults may have been at a particular disadvantage, since their temporal memory is also impaired in comparison to younger adults (e.g., Newman, Allen, & Kaszniak, 2001). Thus, we manipulated the presentation of the study in Experiment 3 by using either a sequential or simultaneous presentation mode. However, while the temporal component of the study material was manipulated, we also needed to assess the potential effect of time in the recombinations in the associative test. If a recombination occurred with an image presented from a previous array, this knowledge could benefit a participant in the simultaneous condition (e.g., that face was not in either pair on the previous screen), but hurt a participant in the sequential condition because it would be more difficult to distinguish there. The opposite would be true for a recombination within the array; there would be no benefit in the simultaneous condition, but there could be a benefit in the sequential condition (e.g., that scene was on the previous screen, but not with that face).

The manipulation of presentation type in Experiment 3 failed to reduce the associative deficit. A simultaneous presentation did not improve older adults' associative memory performance, even with a between array recombination type, which should have provided an extra cue to reject the recombined pair. This may have been due to the potential issue of resource allocation in the simultaneous condition. When both study pairs were presented in the simultaneous condition in one array, a subject would need to be sure to encode each pair sufficiently, allocating resources and/or time to each pair equally. An older adult might not be as efficient or strategic when viewing both pairs simultaneously (Dunlosky & Connor, 1997), but the nature of a sequential presentation would force a more equal allocation of resources and/or time to each pair. Indeed, the working memory literature indicates that a simultaneous presentation may still produce an associative deficit (Brown & Brockmole, 2010; Cowan, et al., 2006). Again, the particular methodological manipulation used in Experiment 3 did not settle the overall unclear literature on a working memory associative deficit, but it did provide further evidence for a general age-related associative deficit. Indeed, given that the older adults in all three experiments had significantly higher level of education than the younger adults, the associative deficit measured in all three experiments may be an underestimation of a true associative deficit given equated education levels.

The experiments reported here have some limitations, however. As mentioned before, there was an issue in Experiment 1 with the lack of salience between events. This was remedied in Experiment 2 with additional cues to indicate new events, but an interstimulus interval was not introduced. We specifically remained agnostic about whether the experiments measured working memory as a conceptual memory structure, or just short-term memory, but there may be some concern that in Experiment 2, the 0-second interval was measuring iconic memory and neither short-term nor working memory because a participant could rely on that sensory memory to answer an associative test. In other words, the associative test in a 0-second interval may be answered based on a more perceptual level than a true working memory level, because there was no interstimulus interval. In particular, older adults' relatively low memory score may reflect a sensory memory decline for this retention interval. However, since the pattern of age-related associative decline was demonstrated in the other retention intervals (of 2, 4, and 6 seconds) as well, it seems to indicate a general age-related deficit for associations in short-term/working memory. One future direction would be to replicate Experiment 2, but with an added inter-stimulus interval to ensure that no sensory memory could be utilized when answering at test at the shortest retention interval. Another option would be to eliminate location binding concerns, as was implemented in Experiment 3 where the test images were presented in a different location from the study images.

Another potential concern is that the performance levels in Experiment 3 may have been high. While including longer retention intervals would have led to an especially complicated design in Experiment 3, the evidence for an associative deficit in both conditions would be further strengthened with more and longer retention intervals and performance coming down from close to ceiling.

In the current set of experiments, we did not encourage any particular strategy. Most participants reported in the post-test questionnaire that they used visual strategies to bind the information, but the role of strategy was not manipulated nor controlled for. Some participants may have used verbal strategies to learn the information, in which case an articulatory suppression condition might assist in standardizing the strategy use. In addition, the presentation rate in both Experiments 2 and 3 was only 2 seconds, which may have affected strategy use, particularly in older adults. However, note that such rates of presentation are commonly used in working memory paradigms. A future experiment could specifically look at what role strategy use might have, as it was shown to partially mediate older adults' associative long-term memory decline (Naveh-Benjamin, Brav, & Levy, 2007).

One direction to pursue concerns the general approach of this set of experiments, which was to approximate working memory from a long-term memory paradigm; we started from a paradigm measuring long-term memory, in which an associative deficit is known to be robust. Another approach would be to start from an established paradigm measuring working memory and approximate long-term memory. This was considered, but stimuli complexity in working memory studies is much lower than in long-term memory studies, and attempting to implement an experiment in which participants remembered simple colors in long-term memory was a less feasible option. However, the approach is not impossible. Of course, using different stimuli and retention intervals would provide further support for the findings here.

Another future direction would be to look at whether an associative deficit in working memory was a result of older adults' difficulties in binding at encoding or retrieval. Implementing a divided attention manipulation at either encoding or retrieval might help elucidate the issue. Also, decay and interference were intentionally confounded in the current experiments, as it was not within the scope of the experiments to measure the contribution of decay or interference separately. Doing so might also be a future direction to consider.

Overall, support was found for a general age-related associative deficit, consistent with a robust long-term associative memory deficit of older adults, and across multiple methodological manipulations in the short-term/working memory retention intervals. These results suggest that indeed, the associative deficit seen in long-term memory is not due to differential forgetting rates in older adults, but rather exists even immediately, perhaps at encoding in addition to retrieval as the associative deficit hypothesis proposes (Naveh-Benjamin, 2000). Given these results, perhaps an overarching age-related associative deficit may exist, lending credence to more parsimonious cognitive aging theories.

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