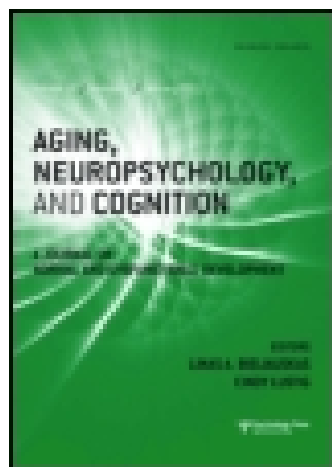


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Aging, Neuropsychology, and Cognition: A Journal on Normal and Dysfunctional Development

Publication details, including instructions for authors and
subscription information:

<http://www.tandfonline.com/loi/nanc20>

Improving associative memory in older adults with unitization

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Published online: 14 Nov 2014.

To cite this article: Fahad N. Ahmad, Myra Fernandes & William E. Hockley (2014): Improving associative memory in older adults with unitization, *Aging, Neuropsychology, and Cognition: A Journal on Normal and Dysfunctional Development*, DOI: [10.1080/13825585.2014.980216](https://doi.org/10.1080/13825585.2014.980216)

To link to this article: <http://dx.doi.org/10.1080/13825585.2014.980216>

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Improving associative memory in older adults with unitization

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(Received 22 July 2014; accepted 20 October 2014)

We examined if unitization inherent preexperimentally could reduce the associative deficit in older adults. In Experiment 1, younger and older adults studied compound word (CW; e.g., *store keeper*) and noncompound word (NCW; e.g., *needle birth*) pairs. We found a reduction in the age-related associative deficit such that older but not younger adults showed a discrimination advantage for CW relative to NCW pairs on a yes–no associative recognition test. These results suggest that CW compared to NCW word pairs provide schematic support that older adults can use to improve their memory. In Experiment 2, reducing study time in younger adults decreased associative recognition performance, but did not produce a discrimination advantage for CW pairs. In Experiment 3, both older and younger adults showed a discrimination advantage for CW pairs on a two-alternative forced-choice recognition test, which encourages greater use of familiarity. These results suggest that test format influenced young adults' use of familiarity during associative recognition of unitized pairs, and that older adults rely more on familiarity than recollection for associative recognition. Unitization of pre-experimental associations, as in CW pairs, can alleviate age-related associative deficits.

Keywords: associative recognition; age-related associative deficit; schematic support; unitization; familiarity; compound word pairs; two-alternative forced-choice test

Aging is associated with a differential decline in memory abilities. This memory decline is differential because with increasing age some memory functions remain intact whereas others decline. In particular, older adults' semantic memory (i.e., for facts and content information) is largely preserved, whereas their episodic memory (i.e., for context and specific events) is impaired (Spencer & Raz, 1995). Different theories attribute the episodic memory deficit in old age to a failure of meta-memory (Hertzog, Kidder, Powell-Moman, & Dunlosky, 2002), a failure of inhibitory processing (Hasher & Zacks, 1988), or a reduction in processing speed (Salthouse, 1996; see Light, 1991 for a review).

Naveh-Benjamin (2000) proposed an associative-deficit hypothesis (ADH) to account for age-related differences in episodic memory. According to ADH, older adults have difficulty forming relations between items and subsequently retrieving them. The deficit in older adults is shown by their relatively similar performance to young adults on item recognition (i.e., recognition of studied versus nonstudied individual words), but significantly lower performance than younger adults on tests of memory for pairs of items in a yes–no associative recognition test.

For example, in Naveh-Benjamin's (2000) study, older and young adults were presented with a list of unrelated word pairs and were then tested on their recognition

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memory for item information (i.e., studied versus nonstudied individual words) and associative information (i.e., intact versus rearranged word pairs). When examining corrected recognition (hit rate minus false alarm rate), Naveh-Benjamin showed older adults had significantly lower performance than younger adults for associative information, but similar recognition discrimination for item information. Thus, older adults' decline in recognition memory performance was restricted to associative information. In addition, older adults' impaired associative memory performance was observed not only for unrelated word pairs but also for word and font relationships. Researchers have since shown that older adults' associative deficit extends to unrelated picture pairs, name–face, face–context, and name–context associations (Naveh-Benjamin, Brav, & Levy, 2007; Naveh-Benjamin, Hussain, Guez, & Bar-On, 2003).

It is generally assumed that item recognition typically relies to a greater extent on familiarity than recollection. In contrast, it is presumed that associative recognition relies more heavily on recollection (e.g., Hockley & Consoli, 1999; see Yonelinas, 2002). In associative recognition, both familiarity and recollection would support the identification of old or intact pairs. To reject new or rearranged pairs, however, recollection is needed to oppose the familiarity of the individual items of these pairs (recall-to-reject; Rotello & Heit, 2000). Several researchers have suggested that the age-related associative deficit found by Naveh-Benjamin (2000) is present because older adults have reduced recollection and rely more on familiarity for associative recognition of unrelated word pairs (e.g., Bender, Naveh-Benjamin, & Raz, 2010; Brubaker & Naveh-Benjamin, 2014; see Light, 2012 for a review). A lower hit rate and higher false alarm rate shown by older compared to younger adults for associative recognition of unrelated pairs indeed suggests that older adults have reduced recollection for the associations and a greater reliance on the familiarity of the individual items.

Recently, however, researchers have examined ways to alleviate the age-related associative deficit. One way is by providing a suitable encoding strategy to promote ease of encoding of unrelated pairs for older adults. Two different encoding strategies have been shown to help alleviate the age-related associative deficit and thereby improve associative memory. One involves using a sentence or visual image to find or force a relationship between unrelated word pairs (Naveh-Benjamin et al., 2007). This is an example of an active encoding strategy, whereby the participant must generate a relationship between two unrelated word pairs. Another strategy is to use one's semantic memory to facilitate better encoding of word pairs. This is an example of a passive strategy, since schematic support is provided by information in one's semantic store. In line with this, Naveh-Benjamin et al. (2003) examined if the age-related associative deficit could be reduced for semantically related word pairs (i.e. articles of clothing) on an associative recognition test. Results showed no age-related associative memory deficit for the semantically related, compared to unrelated, pairs. Naveh-Benjamin et al. (2003) concluded older adults may be relying on their intact semantic memory, rather than their episodic memory, to aid performance on the associative recognition task with the semantically related word pairs. The age-related associative deficit was reduced because the inherent semantic structure in related word pairs supported cohesion in associative memory, which was not present for unrelated pairs.

Findings from recent studies provide further support that the age-related associative deficit is reduced or even eliminated when participants study pairs of categorically related items (Badham, Estes, & Maylor, 2012; Naveh-Benjamin, Craik, Guez, & Kreuger, 2005). Naveh-Benjamin et al. (2005) suggested the preexisting semantic relations provided a schematic framework for learning the pairs and minimizing the need for initiating effortful

encoding strategies. In addition, recognition of semantically related, compared to unrelated, pairs may provide an age-related benefit because the pairs afford greater use of familiarity for memory judgments. Familiarity is a relatively fast process and allows a recognition decision to be made even though no specific details of a prior presentation of an item have been retrieved (Yonelinas, 2002). In contrast, recollection is a relatively slow process, described as a search for specific details associated with prior presentation of an item. It is a process similar to that involved in a recall task (Yonelinas, 2002). In support, Greve, Rossum, and Donaldson (2007) provided evidence that semantically related pairs promote greater use of familiarity during associative recognition. They used a process dissociation procedure to show familiarity was used more for recognition of semantically related than unrelated pairs. Further, Greve et al. (2007) found the mid-frontal event related potential old/new effect was larger for semantically related compared to unrelated pairs.

Rather than presenting categorically related word pairs at study, greater schematic support at encoding can also be provided by promoting unitization. This can be achieved either by varying encoding instructions or by presenting stimulus pairs containing strong preexperimental associations that can be unitized. Unitization occurs when different components of an association are processed in such a way that they become integrated into a coherent whole (Bastin et al., 2013; Graf & Schacter, 1989). The end product of unitization is that the well-integrated whole becomes more familiar than its constituents (Bastin, van der Linden, Schnakers, Montaldi, & Mayes, 2010). Several studies have shown associative memory in young adults and amnesic patients can be improved with unitization at encoding (Ahmad & Hockley, 2014; Diana, Yonelinas, & Ranganath, 2008; Giovanello, Keane, & Verfaellie, 2006; Haskins, Yonelinas, Quamme, & Ranganath, 2008; Quamme, Yonelinas, & Norman, 2007; see Murray & Kensinger, 2013 for a review). For example, Quamme et al. (2007) found that amnesic patients showed a discrimination advantage for unrelated word pairs that were unitized using compound definitions compared to unrelated word pairs encoded in sentences. Quamme et al. concluded based on receiver operating characteristic (ROC) curves that associative recognition of unitized pairs relied more on familiarity than recollection, and this benefited amnesic patients' discrimination in associative recognition.

Given this, unitization should benefit older adults' associative recognition of pairs because when unrelated pairs are unitized to form a single item, the unified pair should be more familiar than its individual components. As a result, older adults can use the familiarity of the unitized pairs (not the familiarity of the individual items) as the basis of their associative recognition decisions. The familiarity associated with unitized study pairs would exceed the familiarity associated with rearranged test pairs and lead to increased associative recognition discrimination.

Recently, unitization has been shown to alleviate older adults' associative deficit in a source memory task (Bastin et al., 2013) and a yes–no associative recognition task (Kilb & Naveh-Benjamin, 2011). Bastin et al. (2013) examined if encoding instructions that encouraged unitization would reduce older adult's associative deficit on a source memory task. They found that older adults showed improved source memory when words were unitized with the background color at encoding (i.e., the item detail condition) compared to when they were not unitized (the context detail condition). In contrast, young adults showed similar source memory performance in the item detail and context detail conditions. In a second experiment, ROC curves for older participants indicated familiarity contributed more to source memory performance in the item detail condition. Bastin et al. concluded unitization promoted greater use of familiarity at retrieval and as a result improved older adults' source memory performance. Evidence for unitization benefiting

older adults in a yes–no associative recognition test comes from a study by Kilb and Naveh-Benjamin (2011) examining the effect of pair repetition at study on the age-related associative deficit. Older adults showed higher discrimination for repeated pairs compared to pairs consisting of repeated items leading the authors to conclude that the age-related benefit in associative recognition for repeated unrelated pairs resulted from unitization promoted by pair repetition that allowed older adults to rely more on familiarity-based judgments at test.

The effect of unitization on associative recognition can, perhaps, be best examined by presenting compound word (CW) pairs which are created by presenting the two lexemes of a CW as two individual items (e.g., land scape). A CW is formed when two or more words are put together to form a new word with a new meaning. One important feature of CW pairs is that they represent unitized preexisting associations. That is, words in a CW pair can be integrated to form a unitized representation based on their preexisting relationship. Recently, Ahmad and Hockley (2014) examined young adults' associative recognition of CW compared to noncompound word (NCW) pairs (i.e., unrelated word pairs) on a yes–no associative recognition task under standard associative memory instructions. Young adults showed both higher hits and false alarms for CW compared to NCW pairs with no difference in discrimination (i.e., a concordant effect). Ahmad and Hockley concluded the higher hit and false alarm rates for CW pairs were due to a greater contribution of familiarity for the associative recognition of unitized compared to non-unitized pairs.

Overview of experiments

In the present study, our goal was to examine whether studying CW pairs for a later yes–no associative recognition task would alleviate the associative deficit in older adults. Three aspects of the current study distinguish it from previous studies examining the effects of unitization on the age-related associative deficit. Firstly, instead of using encoding instructions that promoted unitization of unrelated pairs (Bastin et al., 2013) or repeating unrelated pairs (Kilb & Naveh-Benjamin, 2011), CW pairs that represent preexperimental associations were presented. Secondly, in contrast to semantically related word pairs that are related categorically, CW pairs are preexperimental associations providing schematic support and opportunity for unitization. Thirdly, we wanted to examine if unitization could also benefit younger adults when presentation time of the word pairs was reduced from 4 s to 1.5 s. Three experiments were conducted. In Experiment 1, younger and older adults studied CW and NCW pairs and were tested on yes–no associative recognition for each type of pair. Experiment 2 was conducted in order to determine if young adults also benefitted from the unitization of CW pairs when encoding time was limited. Experiment 3 was carried out in order to determine if test format had an influence on the CW effect in both younger and older adults, by measuring performance on two-alternative forced-choice recognition test.

Experiment 1

CW and NCW pairs were presented to young and older adults for a later associative recognition test, to determine whether there was a discrimination advantage for CW pairs in older adults. Three predictions were made for Experiment 1. Firstly, we predicted a replication of the associative age deficit (Naveh-Benjamin, 2000) with poorer performance in older than younger adults. Secondly, there would be a replication of Ahmad and

Hockley (2014) concordant effect for CW pairs with younger adults' hit and false alarm rates being greater for CW than NCW pairs with no difference in discrimination. Lastly, we predicted that the associative age deficit would be reduced for older adults, that is, older adults would show a greater discrimination advantage for CW than NCW pairs than younger adults. Thus, there would be an age-related benefit for associative recognition of CW pairs. There are two interrelated reasons to make such a prediction. Firstly, older adults would have a greater benefit in using semantic knowledge than younger adults, leading to enhanced memory for the CW pairs. That is, CW pairs provide a schematic framework similar to categorically related word pairs for older adults to learn the pairs and minimize the need for initiating effortful encoding strategies. Secondly, unitization of CW pairs at study supports greater use of familiarity for the later recognition judgments (Ahmad & Hockley, 2014).

If unitization of CW pairs provides schematic support, which increases the ease of encoding for older adults and also allows greater use of familiarity during associative recognition, then, similar to younger adults, older adults should also show a CW concordant effect. Based on the framework of dual process theory (Yonelinas, 2002), older adults should show higher hit rates for CW compared to NCW pairs, because of high preexperimental and study-induced familiarity. They would also show higher false alarm rates for CW pairs than NCW pairs, because of the high preexperimental familiarity of CW pairs. However, older adults should show a discrimination advantage for CW pairs, because the increase in hit rates would be greater than the increase in false alarm rates due to the greater familiarity of intact CW compared to rearranged CW pairs.

Method

Participants. The younger participants were 24 undergraduate students enrolled in a psychology course at the University of Waterloo who participated for course credit. Older participants were 24 adults over the age of 60 years recruited from the Waterloo Research in Aging Pool (WRAP) and received CAD\$10 remuneration in appreciation of their time. WRAP consists of a database of senior citizens from the Kitchener–Waterloo community recruited through newspaper advertisements, flyers in senior centers, and television segments. All participants were fluent English speakers and had normal or corrected-to-normal vision and hearing. The mean age was 20 years ($SD = 0.56$; range = 20–25 years) for younger and 78.2 years ($SD = 6.6$, range = 60–91 years) for older adults. The mean number of years of education was 14.33 ($SD = .96$) for younger and 15.42 ($SD = 2.69$) for older adults, which did not differ significantly, $t(46) = 1.86$, $p = .07$. All older participants reported being in good health and lived independently in the community. The Mini-Mental Status Exam (MMSE; Folstein, Folstein, & McHugh, 1975) was administered to older adults; all had MMSE scores greater than 27/30 ($M = 29.22$, $SD = 0.85$), indicating there were free from major cognitive and neurological impairments. All older adults had good hearing and vision.

Materials and apparatus. The experiment was run on a PC compatible laboratory computer equipped with 17" LCD monitor. SuperLab 4.0 software (Cedrus Corp.) was used to control stimulus presentation and response recording. From a list of 160 CWs provided by Jones (2005), 48 CW pairs and 48 NCW pairs were constructed. CWs and NCWs were both presented as word pairs (e.g., *heartbeat, death-clap*). The two members of the word pair were separated by six spaces. To create the NCW pairs, the left member from one CW pair was paired with the right component from another CW pair. This was

Table 1. Examples of the counter-balanced compound word (CW) and noncompound word (NCW) pair sets used in each associative recognition experiment.

Study		Test	
Set A		Set A	
CW	NCW	CW	NCW
<i>Bath robe</i>	<i>Fire bridge</i>	Intact	Intact
<i>News letter</i>	<i>Tea kick</i>	<i>Bath robe</i>	<i>Fire bridge</i>
<i>Child birth</i>	<i>Star cut</i>	<i>News letter</i>	<i>Tea kick</i>
<i>Brother hood</i>	<i>Crew bag</i>	Rearranged	Rearranged
		<i>Child hood</i>	<i>Star bag</i>
Set B		Set B	
CW	NCW	CW	NCW
<i>Fire place</i>	<i>Bath mail</i>	Intact	Intact
<i>Tea leaf</i>	<i>Room robe</i>	<i>Fire place</i>	<i>Bath mail</i>
<i>Star dust</i>	<i>Stock shop</i>	<i>Tea leaf</i>	<i>Room robe</i>
<i>Sword fish</i>	<i>Brother birth</i>	Rearranged	Rearranged
		<i>Star fish</i>	<i>Stock birth</i>

done to equate the individual words of the CW and NCW pairs. To create a rearranged CW pair, the first member of the parent CW pair was paired with the second member of the other CW pair. For example, the rearranged CW pair *check-point* was made from the parent CW pairs *check-list* and *needle-point*. Two sets (A and B) were constructed to counterbalance the components of the CW and NCW pairs. These were the same set of CW and NCW pairs used by Ahmad and Hockley (2014). Examples of the intact and rearranged CW and NCW pairs in sets A and B are shown in Table 1.

Procedure. At the beginning of the study phase, participants were told they would be presented with a list of word pairs presented one at a time on the screen. They were asked to try to form a relation between the words in the word pair by using a sentence combining the two words in the pair and that this would help them remember the word pair at test. The critical portion of the study list consisted of 48 CW and 48 NCW pairs. In addition, there were two buffer pairs, one CW pair and one NCW pair, at the beginning and end of each study list to minimize primacy and recency effects. The order of the study pairs (excluding buffers) was random, with a different random order for each subject. Each word pair appeared in the center of the screen for 4 s with no interval between successive pairs. After the study phase was completed, for approximately 1-m duration, the experimenter presented the test instructions to the participants. Participants were informed of the difference between old (intact) and new (rearranged) test pairs and instructed to press the “/” and “z” keys for old and new judgments, respectively. They were also instructed to respond as accurately as possible; response time (RT) was not mentioned.

During the test phase, each trial began with a test pair displayed in the center of the screen and remained on the screen until the participant responded. RT was measured from the onset of the test pair until the response. There were 16 intact and 16 rearranged CW pairs and 16 intact and 16 rearranged NCW pairs presented in random order.

Design. A 2 (group: young vs. old) × 2 (test probe type: old or new) × 2 (word pair type: CW or NCW) mixed factorial design was used. The between-subject variable was the age group. The dependent variables were accuracy and RT.

Results

Initial analyses showed that there were no differences in the pattern of results between sets A and B item lists; thus, the reported results are collapsed over counterbalanced stimulus sets within each age group. The mean proportion of hits (correct old responses to intact pairs) and false alarms (incorrect old responses to rearranged test pairs) are presented in Table 2. Signal detection theory estimates of discrimination (d') and criterion (C) for CW and NCW pairs for each age group are presented in Figure 1. The .05 level of significance was used to evaluate all statistical outcomes.

Proportion of old responses. A 2 (group: young vs. older adults) × 2 (pair type: CW vs. NCW) × 2 (probe type: intact vs. rearranged) mixed factor analysis of variance (ANOVA)

Table 2. Experiments 1 and 2: Mean hit (HR) and false alarm (FAR) rates for compound word (CW) and noncompound word (NCW) pairs for young and older adults.

Pair type		HR	FAR
<i>Experiment 1</i>			
Young	CW	.89 (.10)	.32 (.16)
Adults	NCW	.71 (.17)	.17 (.13)
Older	CW	.89 (.11)	.47 (.19)
Adults	NCW	.59 (.23)	.29 (.17)
<i>Experiment 2</i>			
Young	CW	.79 (.13)	.45 (.18)
Adults	NCW	.64 (.16)	.26 (.28)

Note: Standard deviations of the means are given in parentheses.

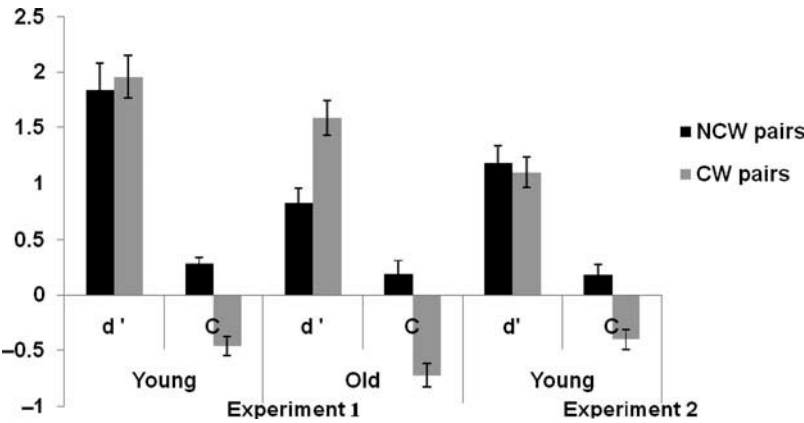


Figure 1. Mean signal detection theory estimates of d' and C for both compound word (CW) and noncompound word (NCW) pair types for younger and older adults in Experiment 1 (4 s presentation rate) and younger adults in Experiment 2 (1.5 s presentation rate).

was conducted on the proportions of old responses. There was a significant main effect of test probe, $F(1, 46) = 296$, $MSE = .033$, $p < .001$, $\eta^2 = .865$. The hit rate was significantly higher than the false alarm rate showing that overall discrimination performance was above chance. There was also a significant main effect of word pair type, $F(1, 46) = 115$, $MSE = .017$, $p < .05$, $\eta^2 = .715$, as participants showed a higher proportion of old responses for CW pairs ($M = .64$) compared to NCW pairs ($M = .44$). The hit and false alarm rates were both higher for the CW than the NCW pairs reflecting a concordant effect for CW pairs. This main effect was qualified by a significant interaction between word pair type and test probe, $F(1, 46) = 5.5$, $MSE = .011$, $p < .05$, $\eta^2 = .107$, as the increase in hits for CW (.23) was greater than false alarms (.11).

There was no significant main effect of group, $F(1, 46) = 1.73$, $MSE = .041$, $p = .194$, $\eta^2 = .36$. However, the interaction between group and word pair type was significant, $F(1, 46) = 4.15$, $MSE = .017$, $p < .05$, $\eta^2 = .083$, reflecting the fact that age-related differences were larger for CW pairs (young adults = .60; older adults = .68) than for NCW pairs (young adults = .44; older adults = .44). There was also a significant interaction between group and test probe, $F(1, 46) = 13.6$, $MSE = .003$, $p < .05$, $\eta^2 = .001$. Younger adults showed higher overall hit rates (.80) compared to older adults (.73), and they showed lower overall false alarm rates (.25) compared to older adults (.38). There was no significant interaction between group, pair type, and probe, $F(1, 46) = 2.23$, $MSE = .011$, $p = .142$, $\eta^2 = .046$.

Discrimination. A 2 (group: young vs. older adults) $\times$ 2 (pair type: CW vs. NCW) mixed factor ANOVA was conducted on mean estimates of d' . There was a main effect of group, $F(1, 46) = 7.96$, $MSE = 1.27$, $p < .01$, $\eta^2 = .148$. Young adults showed higher discrimination for both word pair types than older adults. There was a significant effect of word pair type, $F(1, 46) = 9.69$, $MSE = .382$, $p < .01$, $\eta^2 = .174$. There was also a significant interaction between group and word pair type, $F(1, 46) = 4.66$, $MSE = .382$, $p < .05$, $\eta^2 = .092$. Follow-up paired t -tests indicated older adults showed higher discrimination for CW than NCW pairs, $t(23) = 4.10$, $p < .001$, $d = 0.92$. However, young adults showed no significant difference in discrimination between CW and NCW pairs, $t(23) = .623$, $p = .540$, $d = 0.11$. The same analysis based on corrected recognition scores (hits minus false alarms) showed the same pattern of results. Importantly, the increase in hit rate from NCW to CW pairs was significantly greater for older (.30) than younger adults (.18), but the increase in false alarm rate was similar for both age groups (.18 and .15, respectively), resulting in older adults showing a discrimination advantage for CW over NCW pairs.

Criterion. The same analysis based on estimates of criterion placement revealed a main effect of word pair type $F(1, 46) = 147$, $MSE = .110$, $p = .001$, $\eta^2 = .761$. Criterion placement was significantly higher for NCW than CW pairs. There was no main effect of group, $F(1, 46) = 2.08$, $MSE = .347$, $p = .156$, $\eta^2 = .043$, and no interaction between group and word pair type, $F(1, 46) = 1.47$, $p = .231$, $MSE = .110$, $\eta^2 = .031$, indicating both young and older adults showed a more liberal criterion for CW pairs.

Response time. Table 3 also shows the mean of participants' median RTs for hits and correct rejections for each group and pair type. The same analysis as above based on median RTs revealed a significant main effect of age group, $F(1, 46) = 30.1$, $MSE = 431512$, $p < .001$, $\eta^2 = .396$. Younger adults showed overall faster RTs than older adults. There was a significant main effect of test probe, $F(1, 46) = 34.7$, $MSE = 281963$, $p < .001$, $\eta^2 = .349$. Mean RT for hits was significantly faster than for correct rejections. There was also a main effect of pair type, $F(1, 46) = 44.5$, $MSE = 118412$, $p < .001$, $\eta^2 = .492$. Mean

Table 3. Experiments 1 and 2: Mean reaction times (RT, in ms) for hits and correct rejections for young and older adults are presented for compound word (CW) and noncompound word (NCW) pairs.

	Pair type	RT (HR)	RT (CR)
<i>Experiment 1</i>			
Young adults	CW	929 (157)	1338 (261)
	NCW	1244 (260)	1528 (397)
Older adults	CW	1261 (238)	1890 (624)
	NCW	1744 (456)	2227 (963)
<i>Experiment 2</i>			
Young adults	CW	1479 (539)	2332 (1097)
	NCW	1822 (748)	2123 (556)

Note: Standard deviations of the means are given in parentheses.

RTs were faster for CW than NCW pairs. The interactions between probe and age, $F(1, 46) = 1.86$, $MSE = 281963$, $p = .179$, $\eta^2 = .039$, pair type and age, $F(1, 46) = 2.51$, $MSE = 118412$, $p = .120$, $\eta^2 = .052$, pair type and probe, $F(1, 46) = 1.87$, $MSE = 118162$, $p = .178$, $\eta^2 = .039$, and the three-way interaction, $F(1, 46) = .011$, $MSE = 118162$, $p = .91$, $\eta^2 = .000$, were not significant. For both younger and older adults, mean RT for hits and correct rejections were faster for CW pairs compared to NCW pairs.

In summary, younger adults showed better overall discrimination in associative recognition than older adults. Young adults also showed the expected concordant effect for CW pairs as evidenced by higher hits and false alarms for CW pairs compared to NCW pairs along with no difference in discrimination, replicating the findings of Ahmad and Hockley (2014). Older adults also showed a concordant effect, but more importantly, they demonstrated a discrimination advantage for CW compared to NCW pairs. Both young and older adults showed a similar increase in false alarm rates for CW pairs, but older adults showed a higher increase in hit rates for CW pairs. As predicted, the ease of unitization of the CW pairs served to significantly reduce the associative deficit of the older adults.

Experiment 2

In Experiment 1, older adults' discrimination advantage for CW pairs could alternatively be explained by more time needed to encode NCW compared to CW pairs. In contrast, younger adults did not show a discrimination difference, because the presentation duration was long enough to encode NCW pairs in a manner that was as memorable as CW pairs.

A recent study by Brubaker and Naveh-Benjamin (2014) examined if the age-related associative deficit in younger adults can be simulated when both presentation time of study pairs and retrieval time were reduced, and retention interval between study and test increased. In three experiments, participants studied face-scene pairs and were tested for item and associative recognition. The time allotted at encoding and retrieval was manipulated to replicate strategic age-related deficits, and the length of retention interval was manipulated to replicate automatic deficits. Strategic age-related deficits relate to an inability to use appropriate strategies to form associations such as with unrelated words in a word pair. In contrast, automatic deficits relate to an inability to bind all conscious information together at any point of time, in the absence of intentional control (Cohn, Emrich, & Moscovitch, 2008).

Brubaker and Naveh-Benjamin (2014) found overall recognition performance of young adults decreased as presentation time was reduced and when the retention interval

was lengthened. Importantly, Brubaker and Naveh-Benjamin showed reducing presentation time in younger adults resulted in a simulation of older adults' associative memory deficit in all three experiments, in particular mimicking the differential increase in false alarms in the associative than in the item test. In the current experiment, we examined if the reduction in the age-related deficit due to unitization could be explained by a strategic benefit associated with the CW pairs. That is, we wanted to determine if younger adults would show similar associative memory as older adults when presentation time of word pairs was reduced to 1.5 s from 4 s. With less time to form a relation between words in the study pairs, younger adults might take greater advantage of the preexisting associations present in CW pairs. That is, with reduced presentation time, it would be easier for younger adults to encode the CW compared to NCW pairs. There would be a strategic benefit associated with CW compared NCW pairs.

We predicted younger adults' discrimination for both CW and NCW pairs would decrease with reduced presentation time, because they would have less time to unitize CW pairs or relate the two words of NCW pairs. Moreover, younger adults, similar to older adults, would show an increase in false alarm rate for both CW and NCW pairs. Importantly, we predicted younger adults would perform similar to older adults, because with less time younger adults would be unable to form associations of similar strength or relatedness for CW and NCW pairs. Thus, younger adults would take advantage of the preexperimental familiarity of the CW pairs and be better able to encode the CW compared to NCW pairs. They would show a discrimination advantage for CW pairs similar to older adults.

Method

Participants. The participants were 24 undergraduate students enrolled in a psychology course at Wilfrid Laurier University who participated for course credit.

Materials and apparatus. The materials and apparatus were the same as in Experiment 1.

Procedure. The procedure was the same as Experiment 1; however, during the study phase, each word pair was presented for 1.5 s on the screen. In addition, participants provided a confidence judgment for their old and new responses. That is, after participants entered their old or new response, they made a confidence judgment by pressing 1 for "not sure", 2 for "sure," and 3 for "very sure."

Design. A 2 (test probe type: old or new) $\times$ 2 (word pair type: CW or NCW) repeated measures design was used.

Results

The mean proportion of hits and false alarms for each test condition are presented in Table 2. Signal detection theory estimates of d' and C for CW and NCW pairs for each test condition are shown in Figure 1.

Proportion of old responses. A 2 (pair type: CW vs. NCW) $\times$ 2 (probe type: intact vs. rearranged) within factor ANOVA was conducted on the proportions of old responses. There was a significant main effect of test probe, $F(1, 23) = 114$, $MSE = 3.13$, $p < .001$, $\eta^2 = .833$. The hit rate was significantly higher than the false alarm rate showing that overall discrimination performance was above chance. There was also a significant main

effect of pair type, $F(1, 23) = 26$, $MSE = .643$, $p < .001$, $\eta^2 = .532$. Overall old responses were higher for CW compared to NCW pairs. There was no interaction between probe and pair type, $F(1, 23) = 1.2$, $MSE = .008$, $p = .280$, $\eta^2 = .051$.¹

Discrimination. A paired t -test showed discrimination to be the same for CW and NCW pairs, $t(23) = .59$, $p = .560$. As in Experiment 1, young adults showed no difference in discrimination for CW and NCW pairs.

Criterion. A paired t -test showed a more liberal criterion for CW compared to NCW pairs, $t(23) = 4.98$, $p < .001$. Participants again showed a more liberal bias for discrimination of CW compared to NCW pairs.

Response time. Table 3 shows the mean of younger adults median RT for hits and correct rejections for pair type in Experiment 2. A repeated measures ANOVA based on median RTs. revealed a main effect of probe, $F(1, 23) = 23.7$, $MSE = 335825$, $p < .001$, $\eta^2 = .451$. Mean RT for hits was significantly faster than for correct rejections. There was no main effect of pair type, $F(1, 23) = .903$, $MSE = 161007.2$, $p = .352$, $\eta^2 = .052$. There was a trend for an interaction between probe and pair type, $F(1, 23) = 3.65$, $MSE = 1598697.21$, $p = .07$, $\eta^2 = .213$. Paired t -tests showed mean RT for hits to be significantly faster for CW compared to NCW pairs, $t(23) = 3.23$, $p = .004$. However, there was no significant difference in mean RT for correct rejections for CW and NCW pairs, $t(23) = .877$, $p = .389$.

In summary, even with a reduced presentation time of 1.5 s, younger adults showed a pattern of results similar to when word pairs were presented for 4 s during encoding. With reduced presentation time, young adults showed a CW concordant effect (i.e., higher hit rates and false alarm rates for CW compared to NCW pairs) and similar discrimination for CW and NCW pairs. In addition, they showed a more liberal bias in recognition of CW pairs. Moreover, young adults showed a trend for faster RT for correct recognition of CW than NCW pairs. In order to evaluate similarities and differences in associative recognition of CW and NCW pairs, we compared associative recognition performance of young adults in Experiment 2 with that of both young and older adults in Experiment 1.

For the first comparison, yes–no associative recognition performance was compared between young adults in Experiment 1 and young adults in Experiment 2. The key difference between the two groups was the presentation time during the study phase. The design was 2 (presentation time: 4 s vs. 1.5 s) $\times$ 2 (probe type: old or new) $\times$ 2 (pair type: CW or NCW) mixed factorial design. For the second comparison, the design was the same; however, recognition performance was compared between older adults in Experiment 1 and young adults in Experiment 2.

Younger adults: comparison of presentation time

In terms of the comparison of associative recognition performance in younger adults by presentation time, there was a main effect of probe, $F(1, 46) = 285.3$, $MSE = .035$, $p < .001$, $\eta^2 = .861$. The hit rate was significantly higher than the false alarm rate. There was a main effect of pair type, $F(1, 46) = 68.3$, $MSE = .019$, $p < .001$, $\eta^2 = .598$. Overall old responses were higher for CW than NCW pairs. There was no significant effect of group, $F(1, 46) = .361$, $MSE = .025$, $p = .551$, $\eta^2 = .008$. Proportions of old responses were similar for the 4 s and 1.5 s presentation group. However, there was an interaction between probe and group, $F(1, 46) = 11.8$, $MSE = .035$, $p = .001$, $\eta^2 = .205$. Hit rates

were higher and false alarm rates were lower for young adults in Experiment 1 compared to young adults in Experiment 2. There was no interaction between pair type and group, $F(1, 46) = .003$, $MSE = .019$, $p = .959$, $\eta^2 = .000$ or between pair type and probe, $F(1, 46) = .063$, $MSE = .008$, $p = .803$, $\eta^2 = .001$. The three-way interaction between probe, pair type, and group was also not significant, $F(1, 46) = 1.28$, $MSE = .008$, $p = .263$, $\eta^2 = .027$.

In terms of comparison of discrimination by presentation time, a 2 (presentation time: 4 s vs. 1.5 s) $\times$ 2 (pair type: CW vs. NCW) mixed factor ANOVA was conducted on mean estimates of d' . There was a main effect of group, $F(1, 46) = 10.71$, $MSE = 13.72$, $p < .01$, $\eta^2 = .189$. Young adults in the 4 s group showed greater discrimination for both word pair types than young adults in the 1.5 s group. There was no significant effect of word pair type and no significant interaction between group and word pair type; all F s < 1 . The same analysis based on estimates of criterion placement revealed a main effect of criterion, $F(1, 46) = 75$, $MSE = .138$, $p < .001$, $\eta^2 = .620$. Criterion placement was significantly higher for NCW than CW pairs. There was no main effect of group and no interaction between group and pair type, indicating both groups of younger adults showed a more liberal criterion for CW pairs.

Younger versus older adults

For the comparison of associative recognition performance between older adults in Experiment 1 and younger adults in Experiment 2, there was a main effect of probe, $F(1, 46) = 240$, $MSE = .026$, $p < .05$, $\eta^2 = .839$. Hit rate was greater than false alarm rate. There was a main effect of pair type, $F(1, 46) = 84.6$, $MSE = .023$, $p = .648$, $\eta^2 = .84.6$. Overall old responses were higher for CW than NCW pairs. There was no main effect of group, $F(1, 46) = .576$, $MSE = .052$, $p = .452$, $\eta^2 = .012$. There was no significant interaction between probe and group, $F(1, 46) = .022$, $MSE = .026$, $p = .881$, $\eta^2 = .000$, or between pair type and group, $F(1, 46) = 3.02$, $MSE = .023$, $p = .088$, $\eta^2 = .062$. However, there was a three-way interaction between probe, pair type, and group, $F(1, 46) = 7.3$, $MSE = .010$, $p < .05$, $\eta^2 = .137$. Both groups showed an increase in hit rates and false alarm rates for CW compared to NCW pairs, but older adults showed a greater increase in hit rate than false alarm rate for CW pairs compared to younger adults.

For the comparison of discrimination performance between older adults in Experiment 1 and younger adults in Experiment 2, there was no main effect of group, $F(1, 46) = MSE = .278$, $p = .537$, $\eta^2 = .008$. Young adults in the 1.5 s presentation time group showed similar discrimination for both word pair types as older adults. There was a significant effect of word pair type. Higher discrimination was shown for CW than NCW pairs, $F(1, 46) = 6.72$, $MSE = .295$, $p < .05$, $\eta^2 = .128$. There was also a significant interaction between group and word pair type, $F(1, 46) = 11.6$, $MSE = .295$, $p = .001$, $\eta^2 = .201$. Follow-up independent sample t -tests revealed that younger adults showed lower discrimination for CW pairs than older adults, $t(46) = 2.31$, $p < .05$. However, younger adults showed similar discrimination for NCW pairs as older adults, $t(46) = 1.34$, $p = .187$.

The same analysis based on estimates of criterion placement revealed a main effect of word pair type, $F(1, 46) = 99.1$, $MSE = .641$, $p < .001$, $\eta^2 = .683$. Criterion placement was significantly higher for NCW than CW pairs. There was no main effect of group, $F(1, 46) = 1.54$, $MSE = .593$, $p = .220$, $\eta^2 = .032$. However, there was a significant interaction between group and word pair type, $F(1, 46) = 4.9$, $p < .05$, $MSE = .641$, $\eta^2 = .095$, indicating older adults showed a more liberal criterion for CW pairs. Follow-up

independent sample *t*-tests showed younger adults had a more conservative response bias for CW pairs than older adults, $t(46) = 2.25, p = .029$. However, younger adults showed a similar response bias for NCW pairs, $t(46) = .967, p = .967$.

In summary, with a presentation time of 1.5 s during the study phase, younger adults still showed a CW effect. However, younger adults displayed significantly lower discrimination for both CW and NCW pairs at test compared to a presentation time of 4 s for both pair types. Importantly, younger adults displayed similar discrimination for CW and NCW pairs even when presentation time was reduced. Thus, reducing presentation time did not result in younger adults taking advantage of the easier associations of CW compared to NCW pairs. There are two possible reasons for younger adults showing no discrimination difference between CW and NCW pairs. Firstly, younger adults, in general, tend to rely more on recollection than familiarity, and unlike older adults, recollection-based processes are unimpaired (e.g., Bender et al., 2010; Cohn et al., 2008). Secondly, the yes–no associative recognition test encourages the use of recollection and as a result led to a greater reliance on recollection by younger adults even under reduced encoding time conditions. A discrimination advantage for CW pairs can only be shown when there is a greater reliance on familiarity as evidenced by older adults' discrimination of CW pairs in a yes–no associative recognition test.

Experiment 3

As indicated earlier, one explanation for the similar discrimination for CW and NCW pairs shown by younger adults with reduced encoding time is that younger adults still relied more on recollection than familiarity on the yes–no associative recognition test, whereas older adults rely more on familiarity. Perhaps, if a test was used that encouraged greater use of familiarity than recollection, young adults would rely more on familiarity similar to older adults and show a discrimination advantage for CW pairs.

In Experiment 3, we used a two-alternative forced-choice test, since some researchers (e.g., Bastin & van der Linden, 2003; Patterson & Hertzog, 2010) have suggested familiarity contributes more to associative recognition in a forced-choice test than in the yes–no associative recognition test and as a result would attenuate age differences in associative recognition. In two experiments using a two-alternative forced-choice test, Ahmad and Hockley (2014) found younger adults showed a discrimination advantage for CW pairs. They concluded younger adults showed a discrimination advantage for CW pairs in the forced-choice test but not in the yes–no test because familiarity contributed to a greater extent to the discrimination advantage for unitized pairs in the forced-choice test. If younger adults also show a CW discrimination advantage similar to older adults on a forced choice test, this finding would support further the view that unitization of pre-experimental associations at encoding in the case of CW pairs allows for the greater use of familiarity during a recognition test.

The second goal of Experiment 3 was to compare recognition for CW and NCW pairs in a task that eliminates response bias based on the nature of the stimulus pairs. Instead of comparing the familiarity of single test probe to an established criterion as in the case of yes–no associative recognition test, in a forced-choice test, participants can base their recognition decisions on the relative familiarity of the two alternatives (e.g., Patterson & Hertzog, 2010). Response bias for one pair type over the other is eliminated when the target and distractors pairs are the same pair type. Response bias can still be present, however, when the target and distractor pairs are different pair types.

Following Ahmad and Hockley's (2014) forced-choice test procedure, two types of forced-choice test trials were compared in the current experiment. In the pure pair test condition, intact CW pairs were tested with rearranged CW pairs and intact NCW pairs were tested with rearranged NCW pairs. Since both test alternatives are the same type of pair in the pure test condition, response bias favoring one pair type cannot play a role. Therefore, any differences in recognition performance between these two types of tests must be due to differences in familiarity. However, in the mixed pair test condition where intact pairs of one pair type were tested with rearranged pairs of the other type, response bias could play a role. In these tests, a response bias to choose the CW test pair would increase the proportion of correct responses when CW pairs were the correct alternative and decrease performance when NCW pairs were the correct choice. Thus, a comparison of accuracy in the pure and mixed test conditions provides a measure of response bias in associative recognition of CW and NCW pairs (Ahmad & Hockley, 2014).

Method

Participants. A total of 20 undergraduate students and 20 older adults participated in Experiment 2. The younger participants were undergraduate students enrolled in a psychology course at the University of Waterloo who participated for course credit. As in Experiment 1, older participants were adults over the age of 60 years recruited from the WRAP. All participants were fluent English speakers and had normal or corrected-to-normal vision and hearing. The mean age was 20 years ($SD = 0.54$; range = 20–25 years) for younger and 77.4 years ($SD = 5.3$, range = 60–87 years) for older adults. The mean number of years of education was 14.4 ($SD = .85$) for younger and 15.2 ($SD = 2.50$) for older adults, which did not differ significantly, $t(46) = 1.54$, $p = .09$. All older participants reported being in good health and lived independently in the community. The MMSE (Folstein et al., 1975) was administered to older adults; all had MMSE scores greater than 27/30 ($M = 29.5$, $SD = 0.82$), indicating they were free from major cognitive and neurological impairments.

Materials and apparatus. The apparatus and stimuli were the same as in Experiment 1.

Procedure. The study phase was exactly the same as in Experiment 1. The test pairs were also the same as in Experiment 1. However, during the test phase, two word pairs were presented, and participants were to select which pair had been presented at study. They were informed before the test phase started, that they would be presented with word pairs in a two-alternative forced-choice test for which an intact word pair would be presented with a rearranged word pair and they would select which word pair they saw at study. There were four discrimination conditions represented at test. Studied CW pairs were paired with rearranged CW pairs in one condition, and with rearranged NCW pairs in another. Similarly, intact NCW pairs were paired with rearranged NCW pairs and with rearranged CW pairs in separate test conditions. For each test presentation, one pair was presented in the top half of the screen and one in the bottom half. A random half of the intact pairs were presented in the top portion of the screen and half in the bottom portion. The order of test presentation was random with a different random order for each participant. Participants pressed the “1” key to choose the top pair and the “2” key for the bottom pair. The test phase was subject-paced.

Table 4. Experiment 3: Mean proportion of correct responses and mean d' estimates for the different combinations of intact and rearranged compound word (CW) and noncompound word (NCW) forced-choice test pair alternatives.

Forced-choice recognition	Young adults		Older adults	
	Proportion correct	d'	Proportion correct	d'
Intact CW and rearranged CW	0.84 (.09)	1.87 (.82)	0.77 (.14)	1.15 (.69)
Intact CW and rearranged NCW	0.91 (0.10)	2.59 (1.71)	0.78 (.14)	1.30 (.96)
Intact NCW and rearranged CW	0.73 (0.18)	0.91 (1.62)	0.64 (.19)	0.55 (.78)
Intact NCW and rearranged NCW	0.79 (0.13)	1.53 (.80)	0.68 (.13)	0.74 (.61)

Note: Standard deviations of the means are given in parentheses.

Results and discussion

The proportion of correct responses and estimates of d' for each test condition are presented in Table 4. As the analyses of proportion of correct responses and d' showed similar patterns of results, we only report the analyses of d' . The d' values for the forced-choice task were computed from the proportion of correct responses corrected for this procedure (Macmillan & Creelman, 1991).²

A 2 (target pair type: intact CW vs. intact NCW) $\times$ 2 (distractor pair type: rearranged CW vs. rearranged NCW) $\times$ 2 (group) mixed factor ANOVA revealed a significant main effect of group, $F(1, 38) = 12.8$, $MSE = 1.96$, $p = .001$, $\eta^2 = .252$. Older adults showed overall lower memory performance compared to young adults. There was a significant main effect of target, $F(1, 38) = 35.3$, $MSE = .704$, $p < .001$, $\eta^2 = .482$. Both young and older adults showed a discrimination advantage for CW pairs. There was also a significant main effect of distractor, $F(1, 38) = 11.81$, $MSE = .593$, $p = .001$, $\eta^2 = .237$. When CW pairs were the distractors, both younger and older adults showed lower memory performance. There was a significant interaction between distractor and group, $F(1, 38) = 4.29$, $MSE = .704$, $p < .05$, $\eta^2 = .101$. Compared to older adults, younger adults showed a greater increase in discrimination when NCW pairs were distractors. There were no significant interactions between target and distractor, $F(1, 38) = .009$, $MSE = .753$, $p = .924$, $\eta^2 = .009$, or between target and group, $F(1, 38) = 1.38$, $MSE = .704$, $p = .118$, $\eta^2 = .063$. There was also no significant three-way interaction, $F(1, 38) = .067$, $MSE = .753$, $p = .756$, $\eta^2 = .067$.

Response time. Mean correct median RTs are shown in Table 5. The above analysis was conducted on RT. There was a significant main effect of target, $F(1, 38) = 8.47$,

Table 5. Experiment 3: Mean response time (ms) of correct responses for the different combinations of intact and rearranged compound word (CW) and noncompound word (NCW) forced-choice test pair alternatives.

Forced-choice recognition	Young adults	Older adults
	Proportion correct RT	Proportion correct RT
Intact CW and rearranged CW	2391 (701)	3358 (1071)
Intact CW and rearranged NCW	2296 (698)	3197 (1089)
Intact NCW and rearranged CW	2638 (698)	3645 (1702)
Intact NCW and rearranged NCW	2667 (732)	3878 (1389)

Note: Standard deviations of the means are given in parentheses.

$MSE = 694230$, $p = .006$, $\eta^2 = .182$. This effect indicates both young and older adults showed significantly faster mean correct RT for CW compared to NCW pairs. There was also a significant main effect of group, $F(1, 38) = 12.4$, $MSE = 41750238$, $p = .001$, $\eta^2 = .245$. Overall, older adults displayed slower RTs than younger adults for recognition of both pair types. No interactions were significant, all $F_s < 1$.

Both older and younger adults showed a discrimination advantage for CW pairs that was also mirrored in RT. These results replicate Ahmad and Hockley's (2014) finding of younger adults showing a discrimination advantage for CW pairs in forced-choice recognition. There was also an effect of type of distractor. Discrimination was reduced for both young and older adults when the distractor was a CW rather than a NCW rearranged pair, and this difference was greater for younger adults. These effects could, at least in part, represent a response bias for CW pairs. Note that such a response bias would increase performance for CW targets tested with NCW distractors and decrease performance for NCW targets tested with CW distractors, but would not adversely affect performance for CW targets tested with CW distractors nor NCW targets tested with NCW distractors. The fact that the interaction between target type and distractor type was not significant suggests that response bias did not have a large influence on forced-choice performance in this experiment.

In summary, a CW discrimination advantage was shown by both younger and older adults on a two-alternative forced-choice test. Younger adults showed a discrimination advantage for CW pairs in a forced-choice test, likely because the use of familiarity to guide memory was encouraged in this test.

General discussion

The main goal of the current study was to determine whether schematic support in the form of unitization of CW pairs could reduce the associative deficit in older adults. Older adults showed poorer discrimination of NCW pairs compared to young adults, replicating the associative deficit found by Naveh-Benjamin (2000). Importantly, only older adults demonstrated a significant discrimination advantage for CW relative to NCW pairs on our yes–no associative recognition. In Experiment 2, with presentation time reduced, younger adults still showed no difference in discrimination for CW and NCW pairs. Finally, in Experiment 3, both age groups showed a CW discrimination advantage when the memory was probed using a forced-choice associative recognition test.

As an explanation for the findings of Experiment 1, we suggest the ease of encoding of CW relative to NCW pairs at study allowed greater use of familiarity at test, facilitating older adults' associative recognition of CW pairs. Familiarity has been associated with fast RTs whereas recollection has been associated with slower RTs (e.g., Yonelinas, 2002; see Hockley, 2008 for a review). The fact that RTs for both hits and correct rejections of CW pairs were faster than for NCW pairs suggests that both young and older adults used familiarity in discrimination of unitized pairs to a greater extent than for nonunitized pairs. We also replicated the concordant effect for CW pairs in a yes–no associative recognition task found by Ahmad and Hockley (2014) with younger adults. That is, there were higher hit and false alarm rates for CW pairs compared to NCW pairs, suggesting familiarity contributed more to recognition of CW (i.e., unitized) compared to NCW (i.e., nonunitized) pairs.

Older adults showed similar hit rates as younger adults for intact CW pairs, but false alarm rates for NCW and CW pairs were significantly higher for older adults. Similar patterns of high false alarms shown by older adults on associative recognition have been

reported in other studies (e.g., Bender et al., 2010; Cohn et al., 2008; Kilb & Naveh-Benjamin, 2011; Light, Patterson, Chung, & Healy, 2004; Rhodes, Castel, & Jacoby, 2008) and have been interpreted to mean that older adults' associative deficit is due to impaired recollection (i.e., the recall-to-reject strategy; Rotello & Heit, 2000) in the face of spared familiarity of the components of pairs. Moreover, the magnitude of the increase of the hit rates for CW compared to NCW pairs was significantly greater for older (HR: .30, FAR: .18) than younger adults (HR: .18, FAR: .15), indicating older adults relied more on familiarity (of the pairs) than recollection for recognition of unitized CW pairs.

One could argue that the CW discrimination advantage shown by older adults in Experiment 1 was not due to the high familiarity of the unitized CW pairs, but rather to less time needed to encode the CW compared to the NCW pairs. This explanation would imply that younger adults did not show a CW discrimination advantage, because with a 4 s presentation time, they could encode NCW pairs in a manner as memorable as CW pairs. In Experiment 2, we reduced presentation time for both CW and NCW pairs to 1.5 s to simulate in younger adults the strategic binding deficit found in older adults. Thus, with a short presentation time, younger adults would also have more difficulty forming relations between unrelated pairs and as a result find CW pairs much easier to encode. We found with a presentation time of 1.5 s, young adults had higher hit and false alarm rates for CW compared to NCW pairs. However, discrimination of CW and NCW pairs was significantly reduced compared to a presentation time of 4 s for younger adults indicating that younger adults were less able to encode both types of word pairs when presentation time was reduced. Additionally, younger adults in the 1.5 s group showed similar discrimination for NCW pairs as older adults. This finding shows that younger adults were having difficulty relating two unrelated words together, similar to older adults.

Thus, an age-related associative deficit was simulated in younger adults, similar to Brubaker and Naveh-Benjamin (2014). Importantly, younger adults did not show a discrimination advantage for CW pairs even with a presentation time of 1.5 s. Indeed, they showed lower discrimination for CW pairs than older adults. Based on these results, we hypothesized young adults did not show a discrimination advantage for CW pairs because the yes–no recognition test format encouraged greater use of recollection than familiarity. Interestingly, younger adults in Experiment 2 also showed comparable mean RTs as older adults in Experiment 1 for hits and correct rejections to CW pairs, yet they did not show a CW discrimination advantage. This finding may also support the suggestion that the yes–no test format encourages greater use of recollection.

In Experiment 3, we examined both younger and older adults' discrimination for CW and NCW pairs in a two-alternative forced-choice test. According to some researchers, the forced-choice test encourages greater use of familiarity-based than recollection-based judgments (e.g., Bastin & van der Linden, 2003; Patterson & Hertzog, 2010). We showed that both age groups had a CW discrimination advantage.

In both Experiments 1 and 2, younger adults did not show a CW discrimination advantage, because the yes–no associative recognition test encourages greater use of recollection. Quamme et al. (2007) also found based on ROC curves in their first experiment that young adults showed similar discrimination for unitized and nonunitized pairs. Such findings are in contrast to those of Haskins et al. (2008) who found, based on ROC analyses, that young adults had a discrimination advantage for unitized pairs. Importantly, when the use of familiarity was encouraged in a speeded yes–no associative recognition test, Quamme et al. (2007) were able to show a discrimination advantage for unitized pairs in young adults. Similarly in our Experiment 3, when the recognition test

encourages greater use of familiarity than recollection, as in the case of forced-choice, young adults showed a CW discrimination advantage.

Although we have shown unitization of CW pairs benefits both young and older adults associative recognition, some of the effects are different from those shown on tests of associative recognition of semantically (i.e., categorically) related word pairs. There is both a cost and a benefit of testing associative recognition of CW pairs. Due to the high familiarity of rearranged CW pairs, both younger and older adults showed an increased false alarm rate for CW compared to NCW pairs. In contrast, both age groups show similar false alarm rates to categorically related and unrelated word pairs as found by Naveh-Benjamin et al. (2003).

The pattern of results for older adults is similar, in some respects, to the pattern observed for amnesic patients. Giovanello et al. (2006) examined associative recognition for CW and unrelated word pairs in amnesics with medial temporal lobe or diencephalic lesions and nonamnesic patients. During the study phase, the experimenter read a sentence aloud that incorporated either the two words of the unrelated pairs or the CWs and the participants provided a rating of the likelihood of occurrence of the information conveyed in the sentence. Amnesics showed a discrimination advantage for CW compared to NCW pairs on a yes–no associative recognition task. Giovanello et al. (2006) concluded that associative recognition in amnesia was enhanced because it could be supported by study-induced familiarity for the studied pair, similar to what we observed in our older adults for the CW pairs.

We conclude from our findings that unitization of CW pairs led to a greater contribution of familiarity during associative recognition and resulted in reducing the age-related associative deficit. Several researchers have explained the age-related associative deficit within the framework of dual process theory (e.g., Bender et al., 2010; Cohn et al., 2008; Jacoby, 1999; Kilb & Naveh-Benjamin, 2011). In general, these researchers suggest because older adults rely more on familiarity because of impaired recollection, older adults show lower hit rates and higher false alarm rates for unrelated word pairs compared to younger adults in associative recognition. However, older adults show similar levels of item recognition as younger adults because recollection is not essential for item recognition.

The dual process theory provides a straightforward explanation of the reduction in age-related associative deficit in the present study. The greater false alarm rate of CW pairs compared to the false alarm rate of NCW pairs reflects the preexperimental familiarity of the rearranged CW pairs. When the presentation time was 4 s for both age groups, older adults were less able than younger adults to use recollection to correctly reject the CW rearranged pairs as shown by higher false alarm rates for CW pairs. Moreover, older adults showed a discrimination advantage for CW pairs, because they showed a higher increase in hit rate from NCW to CW pairs compared to younger adults, although the increase in false alarm rate was similar.

We acknowledge that we only indirectly assessed the use of familiarity; future work can examine the use of familiarity more directly by using the process dissociation procedure, remember–know paradigm, or ROC curve analysis. Future studies of the neural basis of our effects are suggested. Brubaker and Naveh-Benjamin (2014) reduced both presentation and retrieval time to show that an impairment in the functioning of the frontal lobe (FL) may mediate an age-related strategic binding deficit for unrelated pairs on a yes–no associative recognition test. Unitization of preexperimental semantic associations may attenuate the age-related associative recognition deficit in older adults who specifically show a decline on neuropsychological tests reflecting FL integrity. The

present results also provide a basis for future research to compare the effects of unitization of preexisting associations with the effects of encoding instructions to unitize unrelated word pairs with other methods to induce unitization (e.g., compound definition, pair repetition). Such research would also enable researchers to look for blood oxygen level-dependent signal differences using functional magnetic resonance imaging within the perirhinal cortex (important for familiarity) during older adults' associative recognition of unitized pairs.

To summarize, the findings of the present study are important for two reasons. Firstly, the results lend further support to the argument that older adults compared to younger adults rely more on familiarity than recollection for recognition judgments on an associative recognition task. Secondly, the findings show unitization reduced the age-related associative deficit on a yes–no associative recognition test likely due to the ease of encoding from the schematic support inherent in CW pairs over NCW pairs, which subsequently enabled greater use of familiarity during the associative recognition test.

Notes

1. Mean confidence was significantly higher for hits ($M = 2.07$) compared to correct rejections ($M = 2.07$) and did not reliably differ between CW and NCW pairs. Because confidence judgments cannot be compared between young and older adults, they are not considered further.
2. According to signal detection theory, the two-alternative forced-choice procedure produces a performance advantage over the yes–no procedure of approximately $\sqrt{2}$. Thus, it has been proposed to divide the forced-choice d' score by $\sqrt{2}$ to compensate for this advantage (Hacker & Ratcliff, 1979; Macmillan & Creelman, 1991).

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