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The impact of aging on associative memory for preexisting unitized associations

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ABSTRACT

Aging is accompanied by a decline in associative memory that can, however, be attenuated when associations are unitized at encoding, that is, when they form an integrated entity. Unitization is thought to promote familiarity-based recognition memory, which is preserved in aging. We examined whether pre-experimentally unitized associations (compound words (CWs)) do indeed reduce age differences in memory, and whether preexperimental unitization promotes familiarity. In Experiment 1, we assessed the memory of 20 young and 20 older participants for compound versus unrelated word pairs using a yes/no recognition test with Remember/Know/Guess judgments. In Experiment 2, we tested 20 young and 20 older participants using the same procedure, except for the use of a two-alternative forced-choice recognition paradigm, which is thought to enhance the contribution of familiarity. The results of both experiments corroborated the greater contribution of familiarity to recognition of unitized associations. In Experiment 1, however, the use of CWs did not attenuate the age-related associative decline. We suggest that preexisting knowledge associated with recombined compounds induced high absolute familiarity and illusory recollection, leading to high false-recognition rates for the older adults. By contrast, the two groups performed similarly across both conditions in Experiment 2. Thus, the forced-choice procedure facilitates the use of familiarity in such a way that it improves older adults' associative memory to the level of young participants. These results suggest that the modulation of associative memory in aging by preexisting unitization varies according to methodological parameters, such as the nature of the lures and the test format.

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Introduction

Episodic memory relies on the ability to bind information together into a single event. According to the associative deficit hypothesis (Bender, Naveh-Benjamin, & Raz, 2010; Brubaker & Naveh-Benjamin, 2014; Naveh-Benjamin, 2000; Naveh-Benjamin, Brav, & Levy, 2007; Naveh-Benjamin, Hussain, Guez, & Bar-On, 2003; Old & Naveh-Benjamin, 2008), the well-known age-related decline in episodic memory is thought to be due at least in part to an associative memory deficit, that is, difficulty binding together the

components of a memory episode and retrieving bound units. In associative memory tasks, participants study pairs of items and subsequently either have to recall the association from a cue, or else have to distinguish intact pairs from recombined ones (i.e., studied items in new combinations). Older adults' associative deficit is typically illustrated by relatively similar performances of younger and older adults on individual item recognition, but significantly poorer performances among older adults on associative memory tests. Moreover, it has been suggested that memory for associations mostly relies on recollection (i.e., the controlled retrieval of the stimulus and qualitative details about its encoding context; see Yonelinas, 2002, for a review) which is impaired in aging, as opposed to familiarity (i.e., more automatic retrieval based on stimulus strength; see Davidson & Glisky, 2002, for a review). Familiarity generally underlies individual item recognition, but does not allow for a "recall-to-reject" strategy that has to be used in associative recognition tests to reject recombined pairs where both items are familiar (Daselaar, Fleck, & Cabeza, 2006; Hockley & Consoli, 1999). In aging studies, the intact use of familiarity, combined with reduced use of recollection hindering recall-to-reject strategies, is thought to induce a higher false-alarm rate in older adults when they are confronted with associative memory decisions (Cohn, Emrich, & Moscovitch, 2008; Healy, Light, & Chung, 2005).

The unitization of associations has been put forward as a way of alleviating older adults' associative deficit. Unitization allows associations to be encoded as single, coherent entities (Graf & Schacter, 1989) that are more familiar than their individual components (Yonelinas, 2002). In contrast to nonunitized associations, unitized ones can be recognized on the basis of familiarity (Parks & Yonelinas, 2009, 2015; Yonelinas, 1999). For example, using the remember/know paradigm (Gardiner & Java, 1990), Giovanello, Keane, and Verfaellie (2006) found that familiarity contributed more to associative memory performance for compound words (CWs) (preexperimentally unitized in memory) than for unrelated word pairs, although there was no difference in overall discrimination performances. Moreover, they showed that amnesic patients with impaired recollection but preserved familiarity benefited significantly from unitization at encoding. Unlike healthy participants whose overall performances scarcely varied across the two conditions, amnesic patients had higher associative memory performances in the CW pair condition than in the unrelated word pair condition (Giovanello et al., 2006). Quamme, Yonelinas, and Norman (2007) also tested healthy controls' and amnesic patients' associative memory for word pairs considered either as newly created CWs (i.e., two words put together to form a new compound with a new meaning) in a unitization condition or as separate units in a nonunitization condition. Like Giovanello et al. (2006), they recorded equivalent performances across the two conditions in control participants, but an advantage for unitized versus nonunitized word pairs in amnesic patients, as well as in those healthy participants who restricted their answers to familiarity judgments. When Rhodes and Donaldson (2007) studied the involvement of familiarity in associative retrieval across different types of associations, they highlighted a higher hit rate and an early frontal old/new event related potential (ERP) effect associated with familiarity in an *association* condition (newly created CWs) as opposed to a *semantic relationship* condition (semantically related word pairs), with no difference in the false-alarm rate across conditions. In another ERP study, electrophysiological evidence also converged to show an early frontal old/new effect associated with familiarity specifically for experimentally unitized CWs

compared with nonunitized ones. A qualitatively different late old/new effect was seen for nonunitized word pairs only (Bader, Mecklinger, Hoppstädter, & Meyer, 2010). Zheng, Li, Xiao, Broster, Jiang, et al. (2015) also examined the contributions of recollection and familiarity to the recognition of preexperimentally unitized CWs versus unrelated word pairs through ERPs. Results showed a significant early frontal old/new effect for intact CW pairs, but not for unrelated pairs. They also evidenced a late parietal old/new effect that was greater for CWs than for unrelated word pairs, thereby suggesting that unitization enhances the contribution of both familiarity and recollection to associative recognition. Moreover, functional magnetic resonance imaging (fMRI) studies have shown that the recognition of preexisting CWs (Ford, Verfaellie, & Giovanello, 2010), as well as experimentally unitized CW pairs (Haskins, Yonelinas, Quamme, & Ranganath, 2008), is correlated with the activation of a region (perirhinal cortex) thought to underlie familiarity, and that this activity predicts subsequent familiarity-based associative recognition memory (Haskins et al., 2008). Furthermore, Ahmad and Hockley (2014; Exp. 1 & 2) demonstrated that the yes–no recognition of preexperimentally unitized CWs increases hit and false-alarm rates compared with the recognition of noncompound word (NCW) pairs (concordant effect), with no difference in overall discrimination. In Experiments 3A and 3B, they further tested memory for these same compound versus NCWs through a two-alternative forced-choice memory task thought to increase the contribution of familiarity at retrieval (Bastin & Van der Linden, 2003). Results revealed a recognition advantage for CWs compared with NCWs. Importantly, this effect of unitization on the use of familiarity in associative recognition memory extends beyond word pairs, and has also been observed for word-background color associations combined with instructions promoting unitization (Diana, Van den Boom, Yonelinas, & Ranganath, 2011; Diana, Yonelinas, & Ranganath, 2008), pairs of objects (Tibon, Gronau, Scheuplein, Mecklinger, & Levy, 2014), pairs of faces (Jäger & Mecklinger, 2009; Jäger, Mecklinger, & Kipp, 2006), and face-context associations (Guillaume & Etienne, 2015).

In aging, findings on memory for unitized entities are conflicting. Jäger, Mecklinger, and Kliegel (2010) failed to find any benefit of unitization in aging, reporting instead that older adults' associative memory performances were poorer for unitized versus nonunitized face pairs. Bastin et al. (2013), on the other hand, found improved source memory when encoding instructions promoted unitization, compared with a condition that did not promote unitization at encoding. By contrast, young adults' source memory performances did not differ according to encoding instructions. In addition, this study examined the contribution of familiarity to the recognition of unitized versus nonunitized associations through receiver operating characteristic (ROC) curves (Exp. 2), which showed greater involvement of familiarity in the unitization versus nonunitization condition. Along the same lines, Ahmad, Fernandes, and Hockley (2015) studied the impact of aging on recognition memory for preexperimentally unitized compound versus NCW pairs. A yes–no recognition memory test revealed a discrimination advantage among older – but not younger – adults for CWs compared with NCW pairs (Exp. 1). In Experiment 3, they demonstrated an advantage for CWs among both younger and older adults, using a two-alternative forced-choice test promoting greater use of familiarity. Similarly, in an ERP study, Zheng, Li, Xiao, Broster, and Jiang (2015) highlighted a reduction in the age-related associative deficit in preexperimentally unitized compound versus NCW pairs. Only the recognition of CWs was accompanied by an early frontal old/new effect in the older adults, thought to reflect

familiarity-based recognition. Furthermore, this effect was positively correlated with associative discrimination accuracy in the CW condition. However, there was no evidence of the actual contribution of familiarity, as there was no direct measure of the processes underlying correct recognition.

In this context, the goal of the current study was to test the hypothesis that the use of preexperimentally unitized entities (here, CWs) improves associative memory performance in normal aging by favoring greater reliance on familiarity-based discrimination. We therefore built on the studies by Giovanello et al. (2006), Ahmad et al. (2015), and Zheng et al. (2015), but, for the first time, assessed this hypothesis using a direct measure of the processes underlying recognition memory; the Remember/Know/Guess (RKG) paradigm. As in Ahmad et al. (2015), we used a yes/no recognition memory test in Experiment 1, and a two-alternative forced-choice test in Experiment 2.

We made several predictions. First, we expected to reproduce the classic age-related decline in recollection, with relatively preserved familiarity (see Light et al., 2006) or by increased., 2012, for a review; Yonelinas, 2002). We also predicted that the forced-choice recognition paradigm would enhance the use of familiarity (Bastin & Van der Linden, 2003). Furthermore, we expected to reproduce a concordant effect (i.e., increase in both hit and false-alarm rates for CWs versus NCW pairs; see Ahmad & Hockley, 2014) in younger participants in the yes–no recognition paradigm, leading to similar overall discrimination performances in both conditions. Like Ahmad et al. (2015), we also expected to observe a discrimination advantage in older adults for unitized versus nonunitized associations that would not necessarily be present in younger adults. This would be reflected in a Group \times Condition interaction effect on overall accuracy. By contrast, we predicted better discrimination performances for CWs versus NCW pairs in the forced-choice recognition paradigm in both age groups. As Ahmad et al. (2015) did not find any age-related benefit for the associative recognition of CWs using the forced-choice paradigm, we expected to observe a similar absence of benefit. Moreover, across the two tasks, we predicted that the older adults would make greater use of familiarity than the young adults. One consequence of this enhanced familiarity-based recognition of CWs in older adults would be a concordant effect, with increased hit and false-alarm rates for CWs. Finally, these hypotheses were based on the assumption that previous results showing an age-related benefit for unitized associations, with a greater reliance on familiarity in yes–no recognition memory tasks, can be generalized independently of the procedure that is used.

Experiment 1

Methods

Participants

We recruited 20 young adults (age range = 20–26 years, $M = 22.6$, $SD = 1.7$; 10 women) and 20 healthy older adults (age range = 60–75 years, $M = 66.9$, $SD = 4.4$; 12 women) from the local community. All participants were fluent French speakers and reported having normal or corrected-to-normal vision. None of them reported any neurological or psychiatric disorder that might interfere with their cognitive functioning. The mean

number of years of education was 15 ($SD = 1.92$) for the younger participants and 16.1 ($SD = 4.13$) for the older ones, and the two age groups did not differ significantly on years of education, $t(38) = -1.08$, $p = .29$. Both groups were also matched in terms of vocabulary abilities, as assessed with the Mill Hill Vocabulary test (Part B; Deltour, 1993; young adults: $M = 25.25$ (/33), $SD = 3.04$; older adults: $M = 27.5$, $SD = 4.51$; $t(38) = -1.85$, $p = .07$). The Mattis Dementia Rating Scale was administered to the older adults. None of them displayed any sign of cognitive or neurological impairment (score range: 133–144 out of 144, all within norms; Pedraza et al., 2010). Written informed consent was obtained from all participants, as required by the Ethics Committee of the Psychology Faculty of the University of Liège.

Materials

The experimental task was adapted from Giovanello et al.'s (2006) experiment. Participants completed two associative recognition memory tasks, one consisting of preexperimentally unitized French CW, the other French NCW pairs. For each task, we created 44 word-pair triplets. Each triplet consisted of two pairs of words (AB and CD), and a third pair that was a recombination of the first two pairs (AD). In the CW task, each triplet contained three CWs, where the first two compounds were recombined to form a third compound (e.g., *casse-cou*, *serre-tête* = > *casse-tête*). In the NCW task, the triplets (e.g., *début-mode*, *dormeur-reine* = > *début-reine*) consisted of unrelated words extracted from the Brulex database (Content, Mousty, & Radeau, 1990). The words making up the CW and NCW pairs were matched on frequency, grammatical category, and length. In each task, the study list contained 66 word pairs. Of these, 22 were the first word pair of a triplet and were kept intact in the recognition memory task, while the remaining 44 study word pairs consisted of the first two word pairs from the remaining 22 triplets. In this case, only the third pair in the triplet was presented at retrieval, as a recombination of the first two pairs. The recognition task therefore contained 22 intact pairs and 22 recombined pairs. At study, each word pair was accompanied by a sentence containing the word pair as either two separate words (NCW) or as a CW, following the methodology used in Giovanello et al. (2006). For each task, we created two versions, to counterbalance the status of each word as intact or recombined pairs across participants. Examples of the intact and recombined CW and NCW pairs are provided in Table A1.

Procedure

Participants performed the two tasks (CW vs. NCW) in a single session, with a 10-min break in between, during which participants completed the Mill Hill Vocabulary test. The order of the CW and NCW tasks was counterbalanced across participants. The tasks were presented on a laptop computer. At the beginning of each study phase, participants were instructed to study the associations between the words. They were also asked to make a plausibility judgment concerning the sentence accompanying the word pair. The word pairs and accompanying sentence were presented one at a time in the center of the computer screen. Each study list consisted of 66 word pairs. The study phase was self-paced, and each stimulus remained on the screen until a response was made. The study pairs were presented in randomized order. The study phase was followed by a 10-min interval filled with an arithmetic task. In the test phase, 44 word pairs were presented one at a time in the center of the computer screen in a yes/no recognition

paradigm. Participants were asked to indicate whether or not the two words had been presented together at encoding, thus categorizing pairs as either intact or recombined. Participants were also instructed to provide an RKG judgment for the pairs they considered to be *intact*. Instructions for these judgments were adapted from Naveh-Benjamin and Kilb (2012). The test phase was also self-paced, and test pairs remained on the screen until the participant had responded. A total of 22 intact and 22 recombined pairs were presented in random order to each participant in each test phase.

Results

We carried out 2 (age group) \times 2 (word pair type) repeated-measures analyses of variance (ANOVAs) on a series of memory measures: hit rate (mean proportion of correct “old” responses to intact pairs); false-alarm rate (mean proportion of incorrect “old” responses to recombined test pairs); an overall associative memory accuracy score (hit rate minus false-alarm rate); and signal detection theory estimates of discriminability (d') and response bias (C). Statistical outcomes were significant at $p < .05$. All measures are set out in Table 1.

The results of the 2 (age group) \times 2 (word pair type) repeated-measures ANOVA on hit rates showed a significantly higher hit rate for younger participants than for older ones, $F(1, 38) = 4.18, p < .05, \eta^2 = .1$, as well as a higher hit rate for CW pairs than for NCW ones, $F(1, 38) = 14.77, p < .001, \eta^2 = .28$. However, the Age group \times Word pair type interaction was not significant, $F(1, 38) = 0.59, p = .45, \eta^2 = .01$. The 2 (age group) \times 2 (word pair type) ANOVA on false-alarm rates showed a main effect of age group, $F(1, 38) = 11.13, p < .01, \eta^2 = .23$, with a higher proportion of false alarms in older participants than in younger ones. There was also a significant main effect of word pair type, $F(1, 38) = 15.24, p < .001, \eta^2 = .29$, with a higher proportion of false alarms for CW versus NCW pairs. The Age group \times Word pair type interaction was not significant, $F(1, 38) = 0.01, p = .96, \eta^2 = .01$. Concerning the overall associative memory accuracy score, analysis revealed higher associative memory accuracy for younger versus older participants, $F(1, 38) = 20.82, p < .001, \eta^2 = .35$. No difference was found in the overall accuracy score between CW and NCW pairs, $F(1, 38) = 0.001, p = .97, \eta^2 = .01$, and the Age group \times Word pair type interaction was not significant, $F(1, 38) = 0.38, p = .54, \eta^2 = .01$. A similar pattern emerged for the analysis of d' scores (see Figure 1). Although younger participants had a significantly higher d' score than the older participants, $F(1, 38) = 21.6, p < .001, \eta^2 = .36$, d' scores did not vary between word pair types, $F(1, 38) = 0.01, p = .93, \eta^2 = .01$, and there was no significant Age group \times Pair type interaction, $F(1, 38) = 1.24, p = .27, \eta^2 = .03$. Finally, concerning C , analysis showed a significant main effect of word pair type, $F(1, 38) = 30.55, p < .001, \eta^2 = .45$, revealing that the response bias was more liberal during CW recognition than during NCW recognition. However, there was no difference between young and older participants, $F(1, 38) = 1.01, p = .32, \eta^2 = .01$, and no Age group \times Word pair type interaction, $F(1, 38) = 0.01, p = .94, \eta^2 = .01$.

Recollection and familiarity estimates

We collected RKG judgments to assess the relative contribution of recollection and familiarity to the recognition of CWs and NCW pairs. These data are provided in Table 2. We separately analyzed each type of response (RKG). Furthermore, as suggested by Yonelinas (2002), we used an independent RK index to compensate for the

Table 1. Associative recognition memory performance as a function of group and condition.

	Exp. 1 – Yes/no recognition paradigm						Exp. 2 – Forced-choice recognition paradigm					
	Young adults (n = 20)			Older adults (n = 20)			Young adults (n = 20)			Older adults (n = 20)		
	CW	NCW		CW	NCW		CW	NCW		CW	NCW	
Hit rate (%)	Mean (SD)	89.09 (11.74)	81.82 (12.86)	85 (11.43)	74.09 (11.14)	83.07 (10.82)	79.2 (13.44)	80.57 (9.13)	75.23 (8.27)			
	Range	[50; 100]	[54.55; 100]	[63.64; 100]	[50; 95.45]	[63.63; 97.73]	[54.55; 100]	[65.91; 97.73]	[61.36; 90.91]			
False-alarm (FA) rate (%)	Mean (SD)	16.14 (13.47)	6.82 (8.01)	26.82 (15.25)	17.73 (12.76)	16.93 (10.82)	20.8 (13.44)	19.43 (9.13)	24.77 (8.27)			
	Range	[0; 45.45]	[0; 22.73]	[4.55; 63.64]	[0; 45.45]	[2.27; 36.36]	[0; 45.45]	[2.27; 34.09]	[9.09; 38.64]			
Hits – FAs	Mean (SD)	72.95 (18.74)	75 (12.81)	58.18 (14.49)	56.36 (14.4)	–	–	–	–			
	Range	[36.36; 95.45]	[45.45; 90.91]	[22.73; 86.36]	[31.82; 77.27]	–	–	–	–			
d'	Mean (SD)	2.48 (0.83)	2.6 (0.54)	1.87 (0.55)	1.73 (0.54)	1.81 (0.83)	1.6 (0.99)	1.61 (0.68)	1.24 (0.47)			
	Range	[1.02; 3.69]	[1.22; 3.34]	[0.6; 3.03]	[0.82; 2.6]	[0.59; 3.41]	[0.19; 3.88]	[0.71; 3.41]	[0.51; 2.28]			
Bias (C)	Mean (SD)	-0.13 (0.33)	0.28 (0.43)	-0.22 (0.47)	0.17 (0.37)	–	–	–	–			
	Range	[-0.94; 0.55]	[-0.63; 0.94]	[-1.17; 0.67]	[-0.79; 0.7]	–	–	–	–			

CW: compound words; NCW: noncompound word pairs.

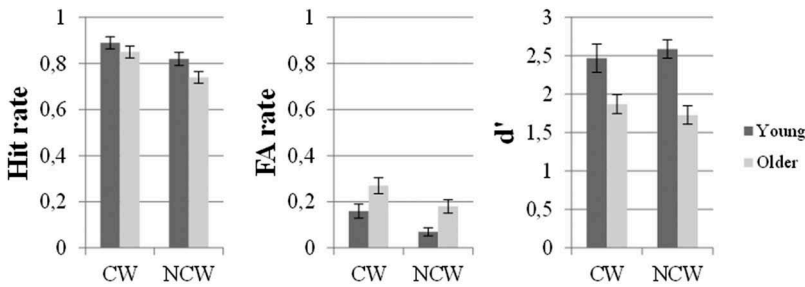


Figure 1. Hit rate (left), false-alarm rate (middle) and d' (right) for young and older adults across the compound (CW) and noncompound word (NCW) conditions.

underestimation of actual familiarity in the proportion of Know responses. In line with this method, the probability of giving a Remember response was used as an index of recollection (“Remember” = R). The index of familiarity, on the other hand, was calculated as the probability of an item receiving a Know response, given that it was not recollected ($F = \text{“Know”}/(1-R)$). We ran 2 (age group) \times 2 (word pair type) repeated-measures ANOVAs on each of these variables for the hit rates, false-alarm rates, and the overall accuracy score (hits – false alarms).

For Remember judgments (see Figure 2), the 2 (age group) \times 2 (word pair type) repeated-measures ANOVA on the hit rate showed no significant difference between either groups, $F(1, 38) = 2.14, p = .15, \eta^2 = .05$, or tasks, $F(1, 38) = 0.01, p = .94, \eta^2 = .01$, and no significant Group \times Word pair type interaction, $F(1, 38) = 0.89, p = .35, \eta^2 = .02$. By contrast, analysis of the false-alarm rate revealed a higher rate for the Remember responses of older adults than for those of younger participants, $F(1, 38) = 10.88, p < .01, \eta^2 = .22$, as well as a higher Remember false-recognition rate for CW than for NCW, $F(1, 38) = 8.19, p < .01, \eta^2 = .18$. However, there was no significant Age group \times Word pair type interaction, $F(1, 38) = 0.51, p = .48, \eta^2 = .01$. Finally, analysis of the overall accuracy score (hit rate – false-alarm rate) for Remember responses showed a higher overall score for younger adults than for older ones, $F(1, 38) = 5.3, p < .05, \eta^2 = .12$, but no effect of word pair type, $F(1, 38) = 1.13, p = .29, \eta^2 = .03$, and no interaction, $F(1, 38) = 1.13, p = .29, \eta^2 = .03$.

For raw Know responses (see Figure 2), analysis of the hit rate failed to reveal any effect of age group, $F(1, 38) = 0.05, p = .82, \eta^2 = .01$, or interaction, $F(1, 38) = 0.13, p = .72, \eta^2 = .01$, but it did show a main effect of word pair type, $F(1, 38) = 25.71, p < .001, \eta^2 = .41$, with CW targets attracting a higher Know response rate than NCW targets. Analysis of the false-alarm rate showed that older participants made more Know false recognitions than younger ones, $F(1, 38) = 7.65, p < .01, \eta^2 = .17$, and CW triggered a higher Know false-recognition rate than NCW, $F(1, 38) = 18.73, p < .001, \eta^2 = .33$. There was no significant interaction, $F(1, 38) = 2.26, p = .14, \eta^2 = .06$. Finally, analysis of the overall accuracy score (hit rate – false-alarm rate for Know responses) showed no significant effect, either of age group, $F(1, 38) = 2.96, p = .09, \eta^2 = .07$, or of word pair type, $F(1, 38) = 3.86, p = .06, \eta^2 = .09$, although the latter nevertheless indicated a marginal advantage for CW. Nor was there any significant Age group \times Word pair type interaction, $F(1, 38) = 1.67, p = .20, \eta^2 = .04$.


Table 2. Remember/Know/Guess judgments during associative recognition memory as a function of group and condition.

	Exp. 1 – Yes/no recognition paradigm				Exp. 2 – Forced-choice recognition paradigm				
	Young adults (n = 20)		Older adults (n = 20)		Young adults (n = 20)		Older adults (n = 20)		
	CW	NCW	CW	NCW	CW	NCW	CW	NCW	
Hit rate (%): Remember	Mean (SD)	67.5 (22.23)	70.68 (14.41)	64.09 (14.81)	61.36 (15.15)	51.03 (19.06)	51.59 (21.91)	33.07 (28.37)	28.98 (25.07)
False-alarm (FA) rate (%): Remember	Mean (SD)	5.45 (4.07)	0.91 (1.87)	9.09 (8.85)	6.36 (6.5)	5.34 (4.68)	2.95 (3.31)	2.04 (2.54)	1.48 (1.69)
Hits – FAs: Remember	Mean (SD)	62.04 (24.02)	69.77 (14.47)	55 (19.22)	55 (16.48)	45.68 (19.74)	48.64 (22.29)	31.02 (28.9)	27.5 (24.6)
Hit rate (%): Know	Mean (SD)	20 (15.14)	9.77 (8.11)	20 (11.27)	11.14 (8.66)	23.18 (14.7)	16.59 (10.06)	36.02 (18.38)	31.7 (19.09)
FA rate (%): Know	Mean (SD)	8.41 (9.24)	4.77 (6.16)	16.82 (9.68)	9.32 (8.27)	5.68 (6.36)	7.61 (7.12)	9.32 (8.04)	11.93 (8.66)
Hits – FAs: Know	Mean (SD)	11.59 (15.64)	5 (8.84)	3.18 (14.38)	1.82 (9.37)	17.5 (15.06)	8.98 (8.61)	26.7 (13.91)	19.77 (15.82)
Hit rate (%): IRK	Mean (SD)	56.64 (26.33)	33.39 (24.97)	57.45 (24.95)	26.87 (20.21)	47.31 (22.63)	36.45 (21.03)	49.89 (14.76)	40.78 (17.63)
FA rate (%): IRK	Mean (SD)	9.11 (10.36)	4.83 (6.27)	19.01 (11.78)	10.27 (9.43)	6.13 (6.91)	7.88 (7.3)	9.55 (8.24)	12.07 (8.71)
Hits – FAs: IRK	Mean (SD)	47.52 (28.52)	28.56 (23.06)	38.45 (23.79)	16.6 (17.08)	41.18 (25.15)	28.57 (23.18)	40.34 (13.35)	28.71 (16.02)

CW: compound words; NCW: noncompound word pairs.

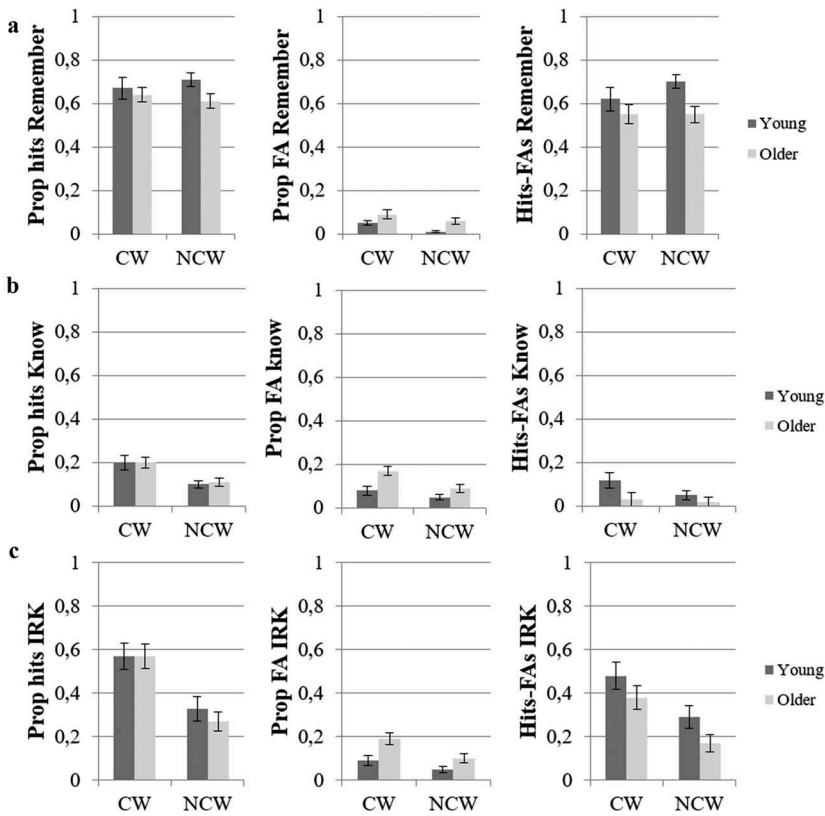


Figure 2. Hit rate (left), false-alarm rate (middle) and hits – false alarms (right) for young and older adults across the compound (CW) and noncompound word (NCW) conditions for (a) Remember responses, (b) Know responses and (c) familiarity estimates calculated using the independent remember/know method (IRK; Yonelinas, 2002).

Analysis of the familiarity estimates yielded by the independent RK (IRK) method (Yonelinas, 2002) (see Figure 2) showed that, like the proportion of hits for Know responses, the hit rate in the IRK measure of familiarity did not differ across age groups, $F(1, 38) = 0.21, p = .65, \eta^2 = .01$, and there was no Age group \times Word pair type interaction, $F(1, 38) = 0.67, p = .42, \eta^2 = .02$. It did, however, reveal a significant main effect of word pair type, $F(1, 38) = 36.06, p < .001, \eta^2 = .49$, with CW targets triggering a higher contribution of familiarity than NCW targets. The false-recognition rate, as calculated with this IRK method, indicated that older participants produced more false alarms on the basis of familiarity than younger participants, $F(1, 38) = 8.51, p < .01, \eta^2 = .18$. It also showed that CW led to a higher false-alarm rate on the basis of familiarity than NCW, $F(1, 38) = 17.29, p < .001, \eta^2 = .31$. However, there was no significant interaction between these two variables, $F(1, 38) = 2.02, p = .16, \eta^2 = .05$. Likewise, analysis of the accuracy score from this index of familiarity did not show any significant difference between the age groups, $F(1, 38) = 3.14; p = .08; \eta^2 = .08$, nor any significant interaction, $F(1, 38) = 0.1; p = .75; \eta^2 = .01$, but showed a higher global accuracy score for CW than NCW pairs, $F(1, 38) = 20.97; p < .001; \eta^2 = .36$.

Lastly, the 2 (age group) \times 2 (word pair type) repeated measures ANOVA on the hit rate for Guess responses did not show any significant effect of age group, $F(1, 38) = 0.06$; $p = .8$; $\eta^2 = .01$, nor word pair type, $F(1, 38) = 0.13$; $p = .72$; $\eta^2 = .01$, nor interaction, $F(1, 38) = 0.52$; $p = .48$; $\eta^2 = .01$. Similarly, the analysis on the false-alarm rate did not show any age group main effect, $F(1, 38) = .06$; $p = .8$; $\eta^2 = .01$, nor word pair type effect, $F(1, 38) = 0.01$; $p = .99$; $\eta^2 = .01$, nor interaction, $F(1, 38) = 1.04$; $p = .32$; $\eta^2 = .01$. Global accuracy score either did not allow to show any main effect, neither of age group, $F(1, 38) = .39$; $p = .54$; $\eta^2 = .01$, nor word pair type, $F(1, 38) = 0.07$; $p = .79$; $\eta^2 = .01$, nor any interaction, $F(1, 38) = 0.07$; $p = .79$; $\eta^2 = .01$.

Reaction times

We computed a 2 (age group) \times 2 (condition) \times 2 (response type: Remember, Know) repeated-measures ANOVA on median reaction times for hits. Reaction times for Guess responses were not included in the analysis, because there were too few data with too high a dispersion in this category. The results showed a significant main effect of condition, with generally faster reaction times in the CW versus NCW condition, $F(1, 28) = 14.33$, $p < .001$, $\eta^2 = .34$, and a main effect of response type, with faster reaction times for Remember than for Know responses, $F(1, 28) = 23.76$, $p < .001$, $\eta^2 = .46$, but no difference between age groups, $F(1, 28) = .02$, $p = .9$, $\eta^2 = .01$. The Condition \times Response type interaction was significant, $F(1, 28) = 8.28$, $p < .01$, $\eta^2 = .23$, showing that while there was no reaction time difference for Remember responses between conditions ($p = .83$), Know responses were significantly faster in the CW versus NCW condition ($p < .001$). Finally, neither the Group \times Condition, $F(1, 28) = .01$, $p = .98$, $\eta^2 = .01$, Group \times Response type, $F(1, 28) = .09$; $p = .76$, $\eta^2 = .01$, nor triple Group \times Condition \times Response type, $F(1, 28) = .01$, $p = .93$, $\eta^2 = .01$, interaction was significant.

Discussion

Using a yes–no associative recognition memory task, Experiment 1 replicated the concordant effect whereby CW pairs attract more “yes” answers than NCW pairs (Ahmad & Hockley, 2014), thus leading to both higher hits and higher false alarms. As predicted, and in line with the idea that unitized associations are mainly recognized using familiarity-based memory processes (Parks & Yonelinas, 2009, 2015; Yonelinas, 1999), familiarity made a greater contribution to associative discrimination for CW pairs than for NCW pairs. This was also supported by response time analyses, which showed slower reaction times for Know than for Remember responses, consistent with previous findings suggesting that familiarity stems from an absence of recollection and from a failure to find contextual details associated with the item (Dewhurst, Holmes, Brandt, & Dean, 2006). With regard to aging, findings confirm that aging specifically affects recollection, and that older adults are poorer at recognizing associations than young adults. However, the use of CW did not result in a reduction in age-related differences. Of note, the current task appeared to rely primarily on recollection, as indicated by the high proportion of responses associated with Remember responses. In Experiment 2, we used a forced-choice recognition memory paradigm in order to allow for more reliable use of familiarity in memory decisions (Bastin & Van der Linden, 2003). If the test procedure

allowed older participants to make full use of their preserved familiarity, we might see a significant attenuation of the age-related differences in associative memory.

Experiment 2

Methods

Participants

Twenty young adults (age range = 18–27 years, $M = 23.4$, $SD = 1.73$; 11 women) and 20 healthy older adults (age range = 62–83 years, $M = 72.15$, $SD = 6.86$, 12 women) took part in this experiment. None of them had participated in Experiment 1. All participants were recruited from the local community. They were all fluent French speakers and reported having normal or corrected-to-normal vision. None of them reported any neurological or psychiatric disorder that might interfere with their cognitive functioning. The mean number of years of education was 14.8 ($SD = 1.7$) for younger participants and 14.4 ($SD = 1.5$) for older ones. The two age groups did not differ on their number of years of education, $t(38) = 0.79$, $p = .44$. The Mattis Dementia Rating Scale was administered to the older adults. None of them displayed any signs of cognitive or neurological impairment (score range: 139–144 out of 144). The groups were matched on vocabulary abilities, as assessed with the Mill Hill Vocabulary test (Part B; Deltour, 1993; young adults: $M = 21.55$ (/33), $SD = 3.85$; older adults: $M = 23.55$, $SD = 5.48$, $t(38) = -1.34$, $p = .19$). Written informed consent was obtained from all participants, as required by the Ethics Committee of the Psychology Faculty of the University of Liège.

Materials

The same materials were used as in Experiment 1.

Procedure

As in Experiment 1, participants performed the test in two conditions: CW and NCW. In each condition, the study list contained 88 word pairs. Contrary to Experiment 1, where the study was self-paced, the presentation time was set at 8 s,¹ during which each stimulus remained on the screen. Furthermore, participants were simply asked to memorize the associations and were informed that they could use the sentence as an aid to create a link between the words. After a 10-min interval filled with an arithmetic task, the recognition phase was completed with a two-alternative forced-choice recognition paradigm. For each of the 44 test trials, participants had to identify the studied pair among two alternatives (the target and its corresponding recombined lure pair, that is, the third pair from the triplet). A RKG judgment was collected for each response.

Results

A series of 2 (age group) \times 2 (word pair type) repeated-measures ANOVAs were performed on the proportion of correct responses (hit rate) and the d' scores adapted to two-alternative forced-choice paradigms (Macmillan & Creelman, 1991). The .05 level of significance was used to evaluate all significant statistical outcomes. These measures are presented in Table 1 and Figure 3.

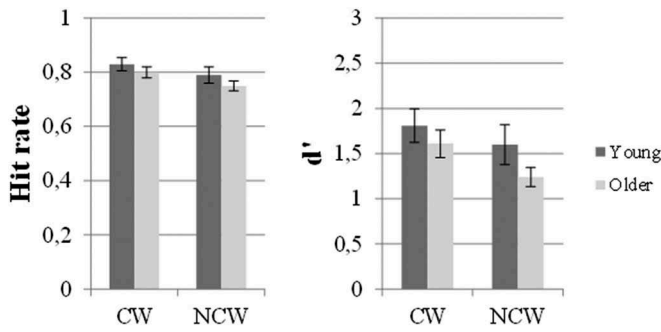


Figure 3. Hit rate (left) and d' (right) for young and older adults across the compound (CW) and noncompound word (NCW) conditions.

The 2 (age group) \times 2 (word pair type) repeated-measures ANOVA on the proportion of correct responses showed a higher hit rate for CW compared with NCW, $F(1, 38) = 11.08$, $p < .01$, $\eta^2 = .23$. Neither the effect of age group, $F(1, 38) = 1.12$, $p = .29$, $\eta^2 = .03$, nor the Age group \times Word pair type interaction, $F(1, 38) = 0.28$, $p = .6$, $\eta^2 = .01$, was significant. A significantly higher d' score for CW versus NCW estimates was highlighted, $F(1, 38) = 9.19$, $p < .01$, $\eta^2 = .19$, but neither the effect of age group, $F(1, 38) = 1.63$, $p = .21$, $\eta^2 = .04$, nor the interaction, $F(1, 38) = 0.71$, $p = .4$, $\eta^2 = .02$, was significant.

Recollection and familiarity estimates

We then analyzed responses acquired using the RKG paradigm (see Table 2). Regarding Remember responses (see Figure 4), there was a higher hit rate for younger versus older participants, $F(1, 38) = 7.77$, $p < .01$, $\eta^2 = .17$. However, there was no effect of word pair type, $F(1, 38) = 0.78$, $p = .38$, $\eta^2 = .02$, and no Age group \times Word pair type interaction, $F(1, 38) = 1.37$, $p = .25$, $\eta^2 = .03$. Analysis false Remember recognition rate revealed a higher false-alarm rate for Remember responses among older versus younger participants, $F(1, 38) = 9.03$, $p < .01$, $\eta^2 = .19$, as well as a higher false-alarm rate for CW versus NCW pairs, $F(1, 38) = 5.15$, $p < .05$, $\eta^2 = .12$. However, there was no significant interaction between these two variables, $F(1, 38) = 1.95$, $p = .17$, $\eta^2 = .05$. Finally, the ANOVA on the overall accuracy score (hit rate – false-alarm rate) for Remember responses showed a higher overall accuracy score for younger versus older participants, $F(1, 38) = 5.98$, $p < .05$, $\eta^2 = .14$, but there was no effect of word pair type, $F(1, 38) = .02$, $p = .89$, $\eta^2 = .01$, and no Age group \times Word pair type interaction, $F(1, 38) = 2.26$, $p = .14$, $\eta^2 = .06$.

For raw Know responses, the ANOVA on hit rates revealed a main effect of age group, $F(1, 38) = 8.73$, $p < .01$, $\eta^2 = .19$, as well as a main effect of word pair type, $F(1, 38) = 9.52$, $p < .01$, $\eta^2 = .2$, with a higher hit rate for Know responses among versus younger adults, and for CW versus NCW pairs. There was, however, no significant interaction between the variables, $F(1, 38) = 0.41$, $p = .52$, $\eta^2 = .01$. Analysis of the Know false-recognition rate showed a higher false-alarm rate accompanied by Know responses for NCW than for CW, $F(1, 38) = 4.33$, $p < .05$, $\eta^2 = .1$, but no effect of age group, $F(1, 38) = 3.46$, $p = .07$, $\eta^2 = .08$, although it came close to significance. There was no significant interaction, $F(1, 38) = 0.01$, $p = .76$, $\eta^2 = .01$. Finally, the ANOVA on the overall accuracy score for Know

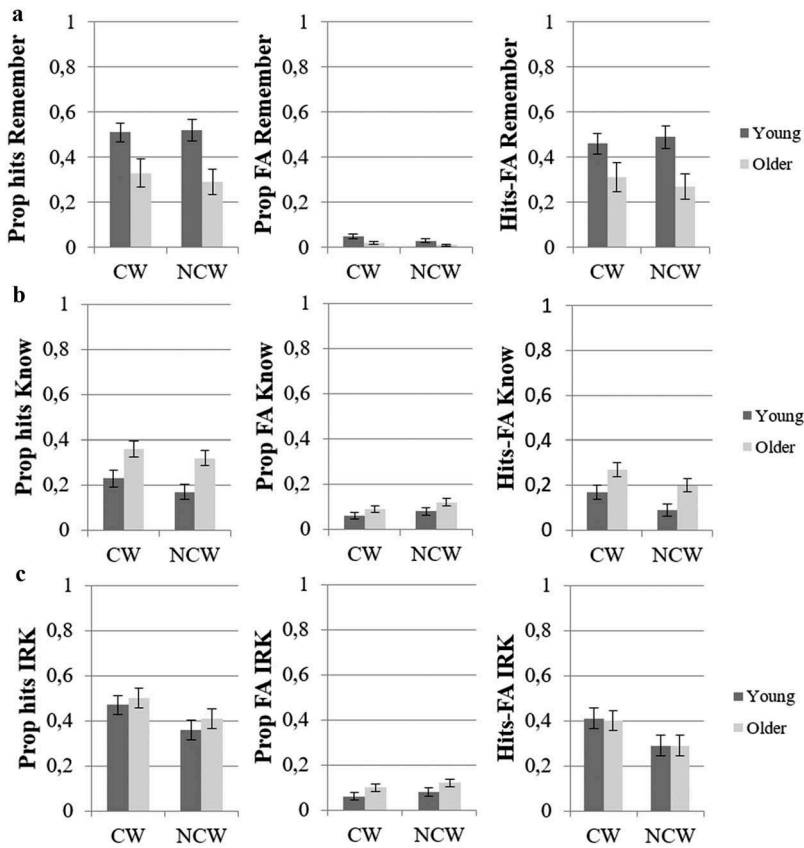


Figure 4. Hit rate (left), false-alarm rate (middle) and hits – false alarms (right) for young and older adults across the compound (CW) and noncompound word (NCW) conditions for (a) Remember responses, (b) Know responses, and (c) familiarity estimates calculated using the independent remember/know method (IRK; Yonelinas, 2002).

responses revealed better discrimination among older versus younger adults, $F(1, 38) = 7.21, p < .05, \eta^2 = .16$, and for CW versus NCW pairs, $F(1, 38) = 12.56, p < .01, \eta^2 = 0.25$. There was no significant interaction, $F(1, 38) = 0.13, p = .72, \eta^2 = .01$.

We then computed 2 (age group) \times 2 (word pair type) repeated-measures ANOVAs on the index of familiarity, corrected using the IRK method (Yonelinas, 2002). The IRK index indicated that there was no effect of age group on hits triggered by familiarity, $F(1, 38) = 0.41, p = .53, \eta^2 = .01$. It did, however, reveal an effect of word pair type, $F(1, 38) = 12.85, p < .001, \eta^2 = .25$, with a higher hit rate on the basis of familiarity for CW than for NCW pairs. There was no significant Age group \times Word pair type interaction, $F(1, 38) = 0.1, p = .75, \eta^2 = .01$. Moreover, there was no significant difference in the false-recognition rate based on familiarity between either the CW and NCW pairs, $F(1, 38) = 2.99, p = .09, \eta^2 = .07$, or the two age groups, $F(1, 38) = 3.56, p = .07, \eta^2 = .09$, although both effects were close to significance. There was no interaction, $F(1, 38) = 0.12, p = .73, \eta^2 = .01$. We failed to find a difference in the overall accuracy score calculated for familiarity-based responses between the two age groups, $F(1, 38) = 0.01, p = .95, \eta^2 = .01$. The discrimination score for familiarity responses was

higher for CW than for NCW pairs, $F(1, 38) = 14.06, p < .001, \eta^2 = .27$. There was no significant interaction, $F(1, 38) = 0.02, p = .88, \eta^2 = .01$.

Finally, compared with CW pairs, NCW pairs elicited a higher hit rate, $F(1, 38) = 6.18, p < .05, \eta^2 = .14$, as well as a higher false-alarm rate, $F(1, 38) = 12.82, p < .001, \eta^2 = .25$, accompanied by Guess responses in both age groups, as there was no significant difference between the groups on either hit rate, $F(1, 38) = 2.22, p = .14, \eta^2 = .06$, or false-alarm rate, $F(1, 38) = 0.74, p = .4, \eta^2 = .02$, in Guess responses, and no interaction (hit rate: $F(1, 38) = 0.19, p = .67, \eta^2 = .01$; false-alarm rate: $F(1, 38) = 0.23, p = .63, \eta^2 = .01$). There was no significant difference in the overall accuracy score calculated for Guess responses between either the age groups, $F(1, 38) = 0.62, p = .43, \eta^2 = .02$, or word pair types, $F(1, 38) = 1.17, p = .29, \eta^2 = .03$, and no interaction, $F(1, 38) = 0.77, p = .39, \eta^2 = .02$.

Reaction times

A 2 (age group) \times 2 (condition) \times 2 (response type: Remember, Know) repeated-measures ANOVA was computed on median reaction times for hits. Reaction times for Guess responses were excluded from this analysis because there were too few data in this category. Moreover, a technical incident damaged the RT data of nine older adults, preventing them from being included in this analysis. The results showed a main effect of condition, with faster reaction times in the CW versus NCW condition, $F(1, 25) = 14.26, p < .001, \eta^2 = .36$, as well as a main effect of response type, with faster response times for Remember versus Know responses, $F(1, 25) = 7.91, p < .01, \eta^2 = .24$. There was no difference between the age groups, $F(1, 25) = 1.18, p = .29, \eta^2 = .04$. The Condition \times Response type interaction was significant, $F(1, 25) = 7.28, p < .05, \eta^2 = .23$, showing that reaction times increased in the NCW versus CW condition for both Remember ($p < .05$) and Know ($p < .001$) responses, although this increase was greater for Know responses.

Discussion

Experiment 2 was consistent with Experiment 1, as well as with previous findings, in showing that memory for CW was more often associated with familiarity-based processes than memory for NCW. The relative proportions of Remember and Know responses recorded here pointed to a greater reliance on familiarity, compared with the proportions in Experiment 1 that indicated predominantly recollection-based decisions, consistent with the idea that a forced-choice recognition memory test facilitates the use of familiarity during memory judgments. Reaction time analyses were also consistent with results from Experiment 1 and from previous studies (Dewhurst et al., 2006), showing slower response times for Know than for Remember responses, probably reflecting familiarity judgments made after searches in memory for contextual details. Interestingly, the forced-choice procedure eliminated age-related associative memory differences. Moreover, both groups showed better memory discrimination for CWs than for NCWs.

Discussion

The aim of this study was to test the hypothesis that unitization helps to improve older adults' associative memory performances by increasing their reliance on

familiarity-based discrimination. To do so, we asked young and older adults to perform a yes–no recognition memory test for unitized (CWs known prior to the experiment) versus nonunitized (unrelated word pairs) associations in Experiment 1, and a two-alternative forced-choice recognition test on the same materials in Experiment 2. Underlying recognition memory processes were assessed with the RKG procedure in both experiments. Overall, even though familiarity-based discrimination was promoted by the use of CWs in both age groups, Experiment 1 did not highlight the expected disproportionate enhancement of associative memory performances in older adults for CW versus NCW pairs. Rather, the older adults displayed a clear associative decline, with fewer hits and more false alarms than young adults in both conditions. By contrast, Experiment 2, which featured a forced-choice paradigm thought to enhance the contribution of familiarity processes to recognition, highlighted similar performances for both age groups, and for both compound and NCWs. The associative decline was therefore not evidenced in this experiment. Overall, it is interesting to note that in spite of some changes made to the experimental procedure (described below), most of the hypotheses formulated on the basis of Ahmad et al.'s (2015) study were confirmed, except for the absence of an age-related benefit of unitization in the yes–no recognition memory task, which could be accounted for by differences in the methods we used. This suggests that the finding of increased reliance on associative familiarity for unitized associations can be generalized even among older adults, and despite procedural differences. However, concerning the age-related benefit of unitized associations, methodological constraints are to be taken into account in order to evidence such an effect.

Effect of test format on recognition memory processes

As in Ahmad and Hockley (2014) and Ahmad et al. (2015), the two experiments described in this study differed on the paradigm used to assess recognition memory: yes/no versus forced-choice. In Experiment 1, featuring a yes/no recognition paradigm, we expected to reproduce Ahmad and Hockley's (2014) and Ahmad et al.'s (2015) findings: (1) a concordant effect, with the enhancement of both hit and false-alarm rates for CW compared with NCW in both age groups, generally attributable to greater use of familiarity, as well as to the partial contribution of a more liberal response bias in the CW condition; (2) no overall difference in the young adults' overall discrimination scores between the two conditions; and (3) a discrimination advantage for CW in older adults. A concordant effect was indeed observed in Experiment 1, with higher hit and false-alarm rates, as well as a more liberal response bias for CW recognition in both young and older adults (Ahmad et al., 2015). In line with Ahmad and Hockley (2014) hypothesis, the concordant effect was mainly due to more familiarity-based hits and false alarms for CW than for NCW. However, in our study, the concordant effect was also accompanied by a higher false recollection rate for CW in both groups. Moreover, as predicted, in the young adults, this concordant effect did not result in a discrimination advantage for CWs. This may have been due to the fact that yes/no associative recognition encourages the use of recollection to a greater extent than a forced-choice paradigm (Ahmad et al., 2015). Finally, the results for older adults did not fit with our predictions, as their performances did not improve in the CW condition. In other

words, even if the use of CW enhanced familiarity-based associative discrimination, it did not bring about a disproportionate advantage for older participants. We return to this finding later in the Discussion.

In Experiment 2, featuring a forced-choice recognition paradigm, we expected to observe (1) a discrimination advantage – due to better familiarity-based recognition memory – for both young and older adults for CW, (2) no age-related benefit of preexisting unitized associations, and (3) an increased use of familiarity in both CW and NCW conditions relative to the yes–no paradigm (Ahmad et al., 2015). First, overall performance was shown to be higher for CW than for NCW in both age groups, confirming our hypothesis. Moreover, we did indeed observe greater use of familiarity, but this effect was particularly shown across the two conditions in older adults compared to young ones. Overall, therefore, the older adults seemed able to compensate for their recollection deficit by increasing their reliance on familiarity in forced-choice situations, and this appeared to be efficient, as their associative memory performance was comparable to that of young adults. Familiarity therefore seems to represent an efficient basis for recognizing items in two-alternative forced-choice situations, even for arbitrary associations (Bastin & Van der Linden, 2003).

Effect of age on recognition memory processes

This study reproduced the classic age-related recollection deficit, with relatively preserved familiarity (Koen & Yonelinas, 2014; Light, 2012; Yonelinas, 2002). Moreover, it confirmed that the age-related associative memory decline is mainly due to a decrease in recollection (Cohn et al., 2008). Across the two experiments, RKG data systematically highlighted a weaker overall accuracy score based on recollection in the older adults, either due mainly to a high false recollection rate (Exp. 1), or because of a high false-recognition rate combined with a low hit rate on the basis of recollection (Exp. 2). Moreover, the high false-alarm rates for CW pairs indicated impaired use of a recall-to-reject strategy during associative memory, as previously shown (Cohn et al., 2008), but preserved familiarity for individual items.

By contrast, the overall accuracy score based on familiarity showed either no difference between young and older adults in their use of familiarity (Exp. 1), or an even greater use of familiarity in older versus younger adults (Exp. 2, but only apparent in raw Know responses). Nevertheless, although this did not influence the overall accuracy of familiarity-based judgments, it should be noted that older adults also showed an increase in familiarity-based false alarms, especially in the yes/no paradigm, suggesting that they are more prone to mistakenly using familiarity than younger adults are. This issue is discussed further in the next section.

Effect of unitization on recognition memory processes during associative memory

Across the two experiments, we confirmed previous findings (e.g., Giovanello et al., 2006), by showing a greater use of familiarity in recognition memory for CW versus NCW, and a lack of effect of condition on recollection estimates, with the exception of false recollections, which were also shown to be greater for CW than for NCW (although numerically scarce: fewer than 10% of the responses to lures). This finding is notable

because it suggests that this result can be generalized, even for older adults and despite some changes in the procedure we implemented.

It is important to consider by which mechanisms familiarity may contribute to the recognition of CWs. It is thought that the processing of a CW involves two mechanisms (Gagné & Spalding, 2009; Libben, 1998). One is the breakdown of the CW into its constituent morphemes (e.g., *snow* and *ball* in *snowball*). The other is access to the meaning that is unique to the CW. The meaning of the compound as a whole is sometimes supported by the relational nature between the constituents (e.g., a snowball is a ball made of snow) in the case of endocentric (i.e., semantically transparent) compounds, but is independent of the meaning of the constituents and specific to the whole unit in the case of exocentric (i.e., semantically opaque) compounds (Libben, 1998). Participants may thus experience increased familiarity for the constituent morphemes (Jones, Brown, & Atchley, 2007), as well as for the whole unit after studying the compounds (Giovanello et al., 2006). In the current data, their significantly greater ability to endorse intact compounds with familiarity compared with familiarity-based false recognition of recombined lures (made of two studied morphemes that were part of two distinct compounds) reflects associative familiarity for the specific compound as a whole. Nevertheless, a portion of the familiarity judgments for compound items, and especially recombined lures, may arise from sources other than familiarity for the unitized entity.

More specifically, one should consider here the nature of the familiarity assessed by the RKG paradigm. When reporting a Know judgment, participants may actually experience two kinds of phenomenological experience (Conway, Gardiner, Perfect, Anderson, & Cohen, 1997): knowing as an absolute feeling of familiarity (e.g., “I know this word very well”); and a feeling of relative familiarity regarding the study episode (e.g., “This word is more familiar than the other and I think it was on the study list”). This distinction between sources of familiarity was made as early as 1980 by Mandler, who differentiated between baseline and incremental familiarity. According to this distinction, *baseline*, or *absolute*, familiarity refers to the strength of a given memory representation, whereas *incremental familiarity* is defined as an increase in the familiarity signal relative to the preexperimental baseline. Support for the existence of this distinction has come from electrophysiological findings showing a greater mid-frontal old/new effect for infrequent versus frequent names (Stenberg, Hellman, Johansson, & Rosén, 2009), thought to reflect an interaction between experimental and preexperimental familiarity. The same ERP distinction was made by Bader et al. (2010) and Wiegand, Bader, and Mecklinger (2010), when studying memory for unitized versus nonunitized word pairs, as well as Tibon et al. (2014), when studying memory for unitized pairs of semantically related objects. Moreover, when Coane, Balota, Dolan, and Jacoby (2011) investigated the word frequency effect, they suggested that two distinct familiarity mechanisms contribute to the influence of word frequency on recognition memory performances. In addition to baseline familiarity and recollection, they proposed the existence of a distinct, fast-acting process involving the assessment and computation of a relative change in familiarity that influences both hits and errors when source discrimination is required but not available. Given that relative familiarity represents an incremental increase in the strength of familiarity, we can assume that this mechanism induces greater familiarity for low-frequency versus high-frequency words, which are already at asymptotic levels

of familiarity (Coane et al., 2011). This model is further supported by the results of an ERP study of the word frequency effect (Bridger, Bader, & Mecklinger, 2014), which identified two topographically distinct familiarity signals with an overlapping time window that was modulated by the frequency of the presented words.

The notion of familiarity is also closely linked to that of fluency, and several authors support the idea that the detection of a mismatch between perceived and expected processing fluency could be used as a signal for *oldness* and trigger a feeling of familiarity (Jacoby & Dallas, 1981; Whittlesea, 2002; Whittlesea & Williams, 2001). For instance, Jacoby and Whitehouse (1989) showed that increasing the processing speed for recognition test items via priming can lead to increased false-alarm and hit rates. Interestingly, Bader et al. (2010) and Wiegand et al. (2010), suggested that the familiarity assessment could be driven by ease of integration into preexisting semantic knowledge, as reflected by conceptual fluency. According to this conceptual fluency account, a feasible or fluent integration within preexisting knowledge – as reflected by conceptual fluency – signals that the stimulus has previously been encountered, and therefore implies absolute, conceptually driven familiarity. In the case of preexperimentally novel stimuli that have close-to-zero expected fluency, such as experimentally unitized CWs, the unexpected perceived fluency may trigger conceptually driven absolute familiarity, signaling a previous encounter at study. However, in the case of materials using preexperimental, conceptually fluent knowledge, absolute familiarity is not sufficient to help discriminate recent (study phase) occurrences from general ones, and a more subtle discrimination between the two sources of familiarity is thus needed.

In other words, an assessment of absolute familiarity can only diagnose prior occurrence in recognition tasks in which there is no preexperimental familiarity. By contrast, in tasks such as ours, using preexperimentally familiar materials, only sensitivity to relative changes in familiarity can diagnose prior occurrence (e.g., old words in a recognition task are relatively more familiar than new ones, even if all of them are familiar in absolute terms) since all test items have a strong baseline familiarity (MacKenzie & Donaldson, 2007). However, any incremental increase in the relative familiarity of preexperimental knowledge can only be subtle, as familiarity levels are already high. Along these lines, testing associative recognition memory using preexperimental knowledge with CWs – as opposed to newly created CWs, or unrelated objects unitized using mental imagery, for example – brings with it a risk of false alarms, because of the ease of integration into conceptual-semantic knowledge, leading to conceptual fluency and conceptually driven absolute familiarity, of the recombined CW pairs, added to the relative familiarity triggered by the constituent morphemes of the recombined pair.

In Experiment 1, we argue that the concordant effect and liberal response bias for CW arose at least partly from strong absolute familiarity due to preexperimental knowledge of all CW pairs. The use of a yes/no recognition paradigm must have led to cases where the absolute familiarity of an unstudied item was stronger than the relative familiarity of a studied one (Migo, Montaldi, Norman, Quamme, & Mayes, 2009; Norman & O'Reilly, 2003). This could explain why, despite enhanced familiarity-based judgments for CW compared with NCW, discrimination performances remained similar across the two conditions. By contrast, in Experiment 2, the familiarity-based hit rate for CW increased, compared with that of NCW, while false-alarm rates were similar in both conditions. Therefore, the influence of absolute familiarity may have been weaker in Experiment 2.

This could be explained by the fact that the forced-choice paradigm requires the participant to discriminate between two items of similar absolute familiarity. In all probability, therefore, relative familiarity mostly influenced the better recognition of unitized CW than of NCW pairs. This would support the idea that unitized entities are more likely to trigger familiarity responses than NCW. Moreover, even if some false alarms were produced in the CW condition, probably owing to strong absolute familiarity, most of the mistakes were produced for the NCW and accompanied by weak memory (Guess responses). Again, this shows how the forced-choice paradigm allows for a reliable use of familiarity, contrary to the yes/no paradigm, in which there is no possible comparison to block the effect of absolute familiarity.

The question of how older adults process these different sources of familiarity, and whether the distinction between the two is as readily available to them as it is to young adults, has still to be explored. One tentative interpretation of the current findings (i.e., no attenuation of age-related differences during yes/no associative memory of CWs), in terms of difficulty distinguishing between absolute and relative familiarity in aging, nonetheless seems worth considering.

Effect of unitization on the age-related associative decline

The main hypothesis of our study was that when the yes–no recognition paradigm is administered, older adults demonstrate a discrimination advantage for CW versus NCW pairs that may not be present in young adults. We expected this to manifest itself as an interaction between age group and condition for the overall accuracy score. We also expected this effect to be accompanied by older adults' greater use of familiarity. Contrary to our predictions, however, we observed no such interaction. Moreover, in the forced-choice memory task, we expected to replicate Ahmad et al.'s (2015) findings of an increase in performance for CWs across both age groups, and the absence of an age-related benefit for preexisting unitized associations. This we did, although unlike Ahmad et al., we did not find any age-related associative decline. In other words, when we used this procedure, unitization did not provide any age-related associative benefit.

In Experiment 1, both young and older adults exhibited similar associative memory performances in the CW and NCW conditions. Even if the older adults had intact familiarity, this did not give them any advantage for recognizing CW. As suggested below, even if CW pairs do indeed induce strong absolute familiarity, the latter does not provide any discrimination advantage when it comes to distinguishing between intact and recombined pairs. In this type of task, recollection is needed to distinguish between studied pairs and recombined pairs characterized by strong absolute familiarity. However, recollection did not contribute more to CW associative recognition performance than to NCW associative recognition. In fact, CW pairs even induced more false recollections than NCW pairs. The reasons why participants made more false recollections of CW are unclear. One possibility is that thoughts associated with the encoding of some CW were actually also reactivated by the corresponding recombined lures, because of overlapping semantic meanings between the intact and recombined CW. In about half the CW triplets, there was a semantic link between the CWs (e.g., *beau-père*, *petit-fils*, *beau-fils* [stepfather, grandson, stepson]). A high conceptual overlap may indeed trigger illusory recollection of shared gist-related information, as shown with

the Deese–Roediger–Macdermott paradigm (Gallo & Roediger, 2003). The self-paced nature of the task may also have promoted the use of recollection processes. Moreover, the discrepancy between our findings and those of Ahmad et al. (2015) study may be explained, at least in part, by methodological differences. In particular, the use of framing sentences accompanying the word pairs, following Giovanello et al. (2006), probably induced greater use of recollection than of associative familiarity. Additionally, the separation of the word pairs' syllables on the screen was different in Ahmad et al.'s (2015) study, where four spaces were left between the words, in order to force participants to unitize the word pair syllables. Here, the pairs were separated by a single space. Moreover, owing to language rules, in the framing sentences that accompanied the word pairs, NCW pairs were often separated by elements of the sentence, unlike CW pairs (e.g., NCW: *actrice maison*, "Cette *actrice* habite une *maison* magnifique" vs. CW: *bateau mouche*, "Une promenade en *bateau-mouche*, c'est agréable"). Moreover, both the encoding and retrieval phases were self-paced in Experiment 1, and the encoding phase was limited to 8 s for each pair presentation in Experiment 2, as opposed to a pair presentation of 4 s in Ahmad et al. (2015). Finally, CW versus NCW pairs were presented in separate conditions, and the material could not be counter-balanced across conditions because the French language does not provide enough CWs to allow us to do so. Taken together, those methodological differences contributed to our failure to observe an age-related benefit of preexisting unitized associations, unlike Ahmad et al. (2015), by modifying the relative reliance on associative familiarity versus recollection as a function of the procedure.

By contrast, in Experiment 2, the advantage afforded by the forced-choice paradigm led to similar performances by young and older participants. There was therefore no age-related associative decline to be attenuated by unitization. This was a surprising result, as the age-related associative decline had previously been highlighted even in forced-choice recognition paradigms (see Naveh-Benjamin, Guez, & Shulman, 2004, for example) as well as in Ahmad et al.'s (2015) study, which used a very similar task. One possible explanation for this absence of an associative decline is that the forced-choice paradigm allowed older adults to reliably base their recognition on familiarity to the same extent in the NCW condition as in the CW condition. However, the recognition of unrelated word pairs typically relies predominantly on recollection, and should not benefit from the use of familiarity (Hockley & Consoli, 1999; Yonelinas, 1997). There are, however, two exceptions where familiarity can support memory for novel associations. First, Mayes, Montaldi, and Migo's (2007) Domain Dichotomy theory holds that two items of the same kind can converge in the perirhinal cortex in such a way that they are represented as a single mnemonic representation, and are subsequently recognized on the basis of familiarity only. However, this suggests that it is only possible when the two similar items are directly linked to one another, without any mediator. In the current study, a sentence accompanied each word pair and could clearly play a mediating role, as participants were told that they could use the sentence to help them remember the association. According to the Domain Dichotomy theory, in this circumstance, the associations are mainly recognized through recollection of the mediator. Even so, participants did not have to use the sentence during encoding, and some NCW pairs may have been directly associated, allowing for familiarity-based associative memory. The second exception suggests that

new associations can be recognized on the basis of familiarity, if they were unitized at encoding (Quamme et al., 2007; Yonelinas, 2002; Yonelinas, Aly, Wang, & Koen, 2010). In our study, however, the NCW pairs could not be as unitized as CWs that had been known for years, and familiarity-based recognition should still have been weaker for NCW than for CW pairs. Moreover, there is no certainty that encoding using the descriptive sentences in which the two words were embedded was liable to induce unitization. According to Quamme et al. (2007), placing words within sentence frames is not sufficient to induce familiarity. Similarly, Giovanello et al. (2006) showed that using the words separately in a sentence does not induce familiarity-based recognition. In this study, the sentence frames may have provided more schematic support for unrelated word pairs than for preexisting CW, thereby providing more encoding benefit to older adults. Nevertheless, this should only have been true for plausible sentences. Another way of creating a unitized representation is through mental imagery. For example, Rhodes and Donaldson (2008) showed that two arbitrarily associated (but semantically related) words placed in a sentence encouraging interactive imagery can subsequently be recognized based on familiarity (see also Pilgrim, Murray, & Donaldson, 2012). However, after considering the sentences provided at encoding in this study (concrete vs. abstract ones, assuming that concrete sentences induce mental imagery more easily), we concluded that only 44 of our 88 sentences could have induced mental imagery of concrete situations. This would not have been sufficient to induce the unitization required to suppress the effect of age.

The current findings could also be interpreted with reference to studies testing the effect of the use of prior knowledge during episodic memory tasks and how this influences age-related differences in episodic memory performance. It has been argued that anchoring study items within preexisting knowledge or schemata may improve older adults' memory performance by providing support for deep encoding (Levels of Processing account, Craik & Lockhart, 1972), allowing older adults to capitalize on overlapping neural representations (Mackay & Burke, 1990), and acting as a cue for retrieval (for a review, see Umanath & Marsh, 2014). More generally, the presence of prior knowledge could help older adults initiate encoding and retrieval strategies. Moreover, prior knowledge within associations to be remembered, such as items from the same semantic category or sharing a thematic relationship, has been shown to enhance the contribution of familiarity to recognition memory (Greve, van Rossum, & Donaldson, 2007; Kriukova, Bridger, & Mecklinger, 2013). The idea that older adults may benefit from preexisting knowledge to a greater extent than young adults was put forward by Naveh-Benjamin et al. (2003), who highlighted improved associative memory performances in older adults for semantically related versus unrelated word pairs. This benefit was further evidenced using not just word pairs (Badham, Estes, & Maylor, 2012; Patterson, Light, Van Ocker, & Olfman, 2009) but also face-famous name associations when the face was congruent with the famous name (Badham & Maylor, 2015), and memory for consistent versus inconsistent grocery prices (Castel, 2005). Badham et al. (2012) further suggested that semantic relationships enhance older adults' memory in a similar extent to *integrative* relationships (e.g., *travel book, lemon cake, beach house*), which appear to be very close to our preexperimentally unitized pairs. However, a boundary condition to the benefits of prior knowledge for older adults' associative memory was recently highlighted. It is thought that preexperimental knowledge only

reduces age-related differences when it allows for the unambiguous endorsement of old items and the rejection of lures (Badham, Hay, Foxon, Kaur, & Maylor, 2016; Mohanty, Naveh-Benjamin, & Ratneshwar, 2016). For instance, when they compared cued recall performances for pairs of semantically related words that belonged either to two different main categories (*shared relations* condition) or each pair to one specific category (*unique relations* condition), Badham et al. (2016) demonstrated that prior knowledge only benefits older adults' associative memory when it operates as an additional cue in a memory task, providing additional information to strategically access appropriate episodic memories. Along the same lines, Mohanty et al. (2016) showed that there is no attenuation of age-related differences in associative memory during a recognition memory task where intact pairs of related words are mixed with recombined lure pairs featuring related words belonging to the same studied category. Our use of recombined CW pairs can be likened to this last example, and probably represents an instance of this boundary condition. The results of the present study therefore suggest that the use of preexisting knowledge belonging to the general category of CWs is not sufficiently specific to guide and cue older adults' memory in a yes/no associative recognition memory task.

Limitations

Previous research showing that memory for CWs enhances reliance on familiarity, as evidenced by more Know judgments (Giovanello et al., 2006) or by increased amplitude of the familiarity-related old/new frontal ERP effect (Zheng, Li, Xiao, Broster, Jiang, et al., 2015), was conducted with either English or Chinese CWs. Moreover, studies that enhanced familiarity for word pairs by asking participants to encode them as new CWs (Bader et al., 2010; Quamme et al., 2007) were conducted in either English or in German. CWs are very common in English, German, and Chinese, and recombining the same set of words to create new compounds is a flexible way of generating a wide variety of meanings. By contrast, CWs are less frequently used in French, and their component morphemes only appear in a very small number of other CWs. In French, CWs are considered to be set phrases (Gross, 1996). Thus, the current experiments may have examined CWs that were less flexible than in other studies. One consequence is that intact and recombined CWs may have been closer in meaning than they would have been in other languages. As suggested previously, this could have induced more false recollections, when the recollected information was associated with the general meaning of the CW, rather than being idiosyncratic to the word. This could also contribute to the greater difficulty of discriminating between intact and recombined CWs owing to their high level of absolute familiarity. Although many of the effects observed in the current study are similar to those described in previous reports (e.g., Ahmad et al., 2015; Ahmad & Hockley, 2014; Giovanello et al., 2006), the generalizability of the findings to other languages needs to be tested.

Conclusions

The current study corroborates previous findings showing that unitized associations can be recognized on the basis of associative familiarity. Moreover, this was demonstrated even in older adults, and in spite of several methodological variations. Nevertheless, the yes–no

recognition memory paradigm used in Experiment 1 failed to highlight a disproportionate benefit of unitization for older adults' associative memory performance for preexisting associations as CWs. We suggest that this may have been due to the lures' high absolute familiarity, as well as to methodological characteristics that should be further explored as potential modifiers of the age-related beneficial effect of unitization. One possibility that needs to be investigated is that older adults have difficulty distinguishing between competing sources of familiarity, such as relative versus absolute familiarity. In Experiment 2, using a forced-choice recognition paradigm, older adults' performances were equivalent to those of young adults across the two conditions, and no associative memory decline was evidenced. Moreover, both groups showed better memory discrimination for CW than for NCW pairs. This finding is consistent with previous findings, and with the idea that the forced-choice recognition memory procedure facilitates the use of familiarity during memory judgments. Taken together, our findings suggest that older adults can only take advantage of preexisting unitization to improve their associative memory performances to the level of young adults under certain circumstances. These circumstances must allow for the reliable use of relative familiarity to retrieve studied information and reject new pairings, and should avoid high absolute preexisting familiarity of recombined unitized associations, as this requires a fine-grained distinction to be made between sources of familiarity, as well as the support of recollection.

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Notes

1. This encoding time appeared sufficient for both groups, as median response times during the encoding phase of Experiment 1 showed that, on average, participants needed less than 8 s to process the pairs (young adults: CW condition: 5350 ± 1418 ms; NCW condition: 6692 ± 2545 ms; older adults: CW condition: 5353 ± 1686 ; NCW condition: 6231 ± 2185).

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References

Ahmad, F. N., Fernandes, M., & Hockley, W. E. (2015). Improving associative memory in older adults with unitization. *Aging, Neuropsychology, and Cognition*, 22(4), 452–472. doi:10.1080/13825585.2014.980216

- Ahmad, F. N., & Hockley, W. E. (2014). The role of familiarity in associative recognition of unitized compound word pairs. *The Quarterly Journal of Experimental Psychology*, 67(12), 2301–2324. doi:10.1080/17470218.2014.923007
- Bader, R., Mecklinger, A., Hoppstädter, M., & Meyer, P. (2010). Recognition memory for one-trial-unitized word pairs: Evidence from event-related potentials. *NeuroImage*, 50(2), 772–781. doi:10.1016/j.neuroimage.2009.12.100
- Bader, R., Opitz, B., Reith, W., & Mecklinger, A. (2014). Is a novel conceptual unit more than the sum of its parts?: fMRI evidence from an associative recognition memory study. *Neuropsychologia*, 61, 123–134. doi:10.1016/j.neuropsychologia.2014.06.006
- Badham, S. P., Estes, Z., & Maylor, E. A. (2012). Integrative and semantic relations equally alleviate age-related associative memory deficits. *Psychology and Aging*, 27(1), 141–152. doi:10.1037/a0023924
- Badham, S. P., Hay, M., Foxon, N., Kaur, K., & Maylor, E. A. (2016). When does prior knowledge disproportionately benefit older adults' memory? *Aging, Neuropsychology, and Cognition*, 1–28. doi:10.1080/13825585.2015.1099607
- Badham, S. P., & Maylor, E. A. (2015). What you know can influence what you are going to know (especially for older adults). *Psychonomic Bulletin & Review*, 22(1), 141–146. doi:10.3758/s13423-014-0672-8
- Bastin, C., Diana, R. A., Simon, J., Collette, F., Yonelinas, A. P., & Salmon, E. (2013). Associative memory in aging: The effect of unitization on source memory. *Psychology and Aging*, 28(1), 275–283. doi:10.1037/a0031566
- Bastin, C., & Van der Linden, M. (2003). The contribution of recollection and familiarity to recognition memory: A study of the effects of test format and aging. *Neuropsychology*, 17(1), 14–24. doi:10.1037/0894-4105.17.1.14
- Bender, A. R., Naveh-Benjamin, M., & Raz, N. (2010). Associative deficit in recognition memory in a lifespan sample of healthy adults. *Psychology and Aging*, 25(4), 940–948. doi: 10.1037/a0020595
- Bridger, E. K., Bader, R., & Mecklinger, A. (2014). More ways than one: ERPs reveal multiple familiarity signals in the word frequency mirror effect. *Neuropsychologia*, 57, 179–190. doi:10.1016/j.neuropsychologia.2014.03.007
- Brubaker, M. S., & Naveh-Benjamin, M. (2014). The effects of presentation rate and retention interval on memory for items and associations in younger adults: a simulation of older adults' associative memory deficit. *Aging, Neuropsychology, And Cognition*, 21(1), 1–26. doi: 10.1080/13825585.2013.772558
- Castel, A. D. (2005). Memory for grocery prices in younger and older adults: The role of schematic support. *Psychology and Aging*, 20(4), 718–721. doi:10.1037/0882-7974.20.4.718
- Coane, J. H., Balota, D. A., Dolan, P. O., & Jacoby, L. L. (2011). Not all sources of familiarity are created equal: The case of word frequency and repetition in episodic recognition. *Memory & Cognition*, 39(5), 791–805. doi:10.3758/s13421-010-0069-5
- Cohn, M., Emrich, S. M., & Moscovitch, M. (2008). Age-related deficits in associative memory: The influence of impaired strategic retrieval. *Psychology and Aging*, 23(1), 93–103. doi:10.1037/0882-7974.23.1.93
- Content, A., Mousty, P., & Radeau, M. (1990). Brulex. Une base de données lexicales informatisée pour le français écrit et parlé. *L'Année Psychologique*, 90(4), 551–566. doi:10.3406/psy.1990.29428
- Conway, M. A., Gardiner, J. M., Perfect, T. J., Anderson, S. J., & Cohen, G. M. (1997). Changes in memory awareness during learning: The acquisition of knowledge by psychology undergraduates. *Journal of Experimental Psychology: General*, 126(4), 393–413. doi:10.1037/0096-3445.126.4.393
- Craik, F. I., & Lockhart, R. S. (1972). Levels of Processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior*, 11, 671–684. doi:10.1016/S0022-5371(72)80001-X
- Daselaar, S. M., Fleck, M. S., & Cabeza, R. (2006). Triple dissociation in the medial temporal lobes: Recollection, familiarity, and novelty. *Journal of Neurophysiology*, 96(4), 1902–1911. doi:10.1152/jn.01029.2005

- Davidson, P. S., & Glisky, E. L. (2002). Neuropsychological correlates of recollection and familiarity in normal aging. *Cognitive, Affective, & Behavioral Neuroscience*, 2(2), 174–186. doi:10.3758/CABN.2.2.174
- Deltour, J. (1993). *Echelle de vocabulaire de Mill Hill de J.C. Raven. Adaptation française et normes comparées du Mill Hill et du Standard Progressive Matrices (PM 38). Manuel*. Braine-le-Château: Editions l'Application des Techniques Modernes.
- Dewhurst, S. A., Holmes, S. J., Brandt, K. R., & Dean, G. M. (2006). Measuring the speed of the conscious components of recognition memory: Remembering is faster than knowing. *Consciousness and Cognition*, 15(1), 147–162. doi:10.1016/j.concog.2005.05.002
- Diana, R. A., Van den Boom, W., Yonelinas, A. P., & Ranganath, C. (2011). ERP correlates of source memory: Unitized source information increases familiarity-based retrieval. *Brain Research*, 1367, 278–286. doi:10.1016/j.brainres.2010.10.030
- Diana, R. A., Yonelinas, A. P., & Ranganath, C. (2008). The effects of unitization on familiarity-based source memory: Testing a behavioral prediction derived from neuroimaging data. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 34(4), 730–740. doi:10.1037/0278-7393.34.4.730
- Ford, J. H., Verfaellie, M., & Giovanello, K. S. (2010). Neural correlates of familiarity-based associative retrieval. *Neuropsychologia*, 48(10), 3019–3025. doi:10.1016/j.neuropsychologia.2010.06.010
- Gagné, C. L., & Spalding, T. L. (2009). Constituent integration during the processing of compound words: Does it involve the use of relational structures? *Journal of Memory and Language*, 60(1), 20–35. doi:10.1016/j.jml.2008.07.003
- Gallo, D. A., & Roediger, H. L. (2003). The effects of associations and aging on illusory recollection. *Memory & Cognition*, 31(7), 1036–1044. doi:10.3758/BF03196124
- Gardiner, J. M., & Java, R. I. (1990). Recollective experience in word and nonword recognition. *Memory & Cognition*, 18(1), 23–30. doi:10.3758/BF03202642
- Giovanello, K. S., Keane, M. M., & Verfaellie, M. (2006). The contribution of familiarity to associative memory in amnesia. *Neuropsychologia*, 44(10), 1859–1865. doi:10.1016/j.neuropsychologia.2006.03.004
- Graf, P., & Schacter, D. L. (1989). Unitization and grouping mediate dissociations in memory for new associations. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 15(5), 930. doi:10.1037/0278-7393.15.5.930
- Greve, A., van Rossum, M. C. W., & Donaldson, D. I. (2007). Investigating the functional interaction between semantic and episodic memory: Convergent behavioral and electrophysiological evidence for the role of familiarity. *NeuroImage*, 34(2), 801–814. doi:10.1016/j.neuroimage.2006.07.043
- Gross, G. (1996). *Les expressions figées en français: Mots composés et autres locutions*. Paris: Ophrys.
- Guillaume, F., & Etienne, Y. (2015). Target-context unitization effect on the familiarity-related FN400: A face recognition exclusion task. *International Journal of Psychophysiology*, 95(3), 345–354. doi:10.1016/j.ijpsycho.2015.01.004
- Haskins, A. L., Yonelinas, A. P., Quamme, J. R., & Ranganath, C. (2008). Perirhinal cortex supports encoding and familiarity-based recognition of novel associations. *Neuron*, 59(4), 554–560. doi:10.1016/j.neuron.2008.07.035
- Healy, M. R., Light, L. L., & Chung, C. (2005). Dual-process models of associative recognition in young and older adults: Evidence from receiver operating characteristics. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 31(4), 768–788. doi:10.1037/0278-7393.31.4.768
- Hockley, W. E., & Consoli, A. (1999). Familiarity and recollection in item and associative recognition. *Memory & Cognition*, 27(4), 657–664. doi:10.3758/BF03211559
- Jacoby, L. L., & Dallas, M. (1981). On the relationship between autobiographical memory and perceptual learning. *Journal of Experimental Psychology: General*, 110(3), 306–340. doi:10.1037/0096-3445.110.3.306
- Jacoby, L. L., & Whitehouse, K. (1989). An illusion of memory: False recognition influenced by unconscious perception. *Journal of Experimental Psychology: General*, 118(2), 126–135. doi:10.1037/0096-3445.118.2.126

- Jäger, T., & Mecklinger, A. (2009). Familiarity supports associative recognition memory for face stimuli that can be unitised: Evidence from receiver operating characteristics. *European Journal of Cognitive Psychology*, 21(1), 35–60. doi:10.1080/09541440802003140
- Jäger, T., Mecklinger, A., & Kipp, K. H. (2006). Intra- and inter-item associations doubly dissociate the electrophysiological correlates of familiarity and recollection. *Neuron*, 52(3), 535–545. doi:10.1016/j.neuron.2006.09.013
- Jäger, T., Mecklinger, A., & Kliegel, M. (2010). Associative recognition memory for faces: More pronounced age-related impairments in binding intra- than inter-item associations. *Experimental Aging Research*, 36(2), 123–139. doi:10.1080/03610731003613391
- Jones, T. C., Brown, A. S., & Atchley, P. (2007). Feature and conjunction effects in recognition memory: Toward specifying familiarity for compound words. *Memory & Cognition*, 35(5), 984–998. doi:10.3758/BF03193471
- Koen, J. D., & Yonelinas, A. P. (2014). Recollection, not familiarity, decreases in healthy ageing: Converging evidence from four estimation methods. *Memory*, 1–14. doi:10.1080/09658211.2014.985590
- Kriukova, O., Bridger, E., & Mecklinger, A. (2013). Semantic relations differentially impact associative recognition memory: Electrophysiological evidence. *Brain and Cognition*, 83(1), 93–103. doi:10.1016/j.bandc.2013.07.006
- Libben, G. (1998). Semantic transparency in the processing of compounds: Consequences for representation, processing, and impairment. *Brain and Language*, 61(1), 30–44. doi:10.1006/brln.1997.1876
- Light, L. L. (2012). Dual-process theories of memory in old age: An update. In M. Naveh-Benjamin & N. Ohta (Eds.), *Memory and Aging: Current and future directions* (pp. pp. 97–124). New York: Psychology Press.
- Mackay, D. G., & Burke, D. M. (1990). Cognition and aging: A theory of new learning and the use of old connections. *Aging and Cognition: Knowledge Organization and Utilization*, 71, 213.
- MacKenzie, G., & Donaldson, D. I. (2007). Dissociating recollection from familiarity: Electrophysiological evidence that familiarity for faces is associated with a posterior old/new effect. *NeuroImage*, 36(2), 454–463. doi:10.1016/j.neuroimage.2006.12.005
- Macmillan, N. A., & Creelman, C. D. (1991). *Detection theory: A user's guide*. Cambridge: Cambridge University Press.
- Mayes, A., Montaldi, D., & Migo, E. (2007). Associative memory and the medial temporal lobes. *Trends in Cognitive Sciences*, 11(3), 126–135. doi:10.1016/j.tics.2006.12.003
- Migo, E., Montaldi, D., Norman, K. A., Quamme, J., & Mayes, A. (2009). The contribution of familiarity to recognition memory is a function of test format when using similar foils. *The Quarterly Journal of Experimental Psychology*, 62(6), 1198–1215. doi:10.1080/17470210802391599
- Mohanty, P., Naveh-Benjamin, M., & Ratneshwar, S. (2016). Beneficial effects of semantic memory support on older adults' episodic memory: Differential patterns of support of item and associative information. *Psychology and Aging*, 31(1), 25–36. doi:10.1037/pag0000059
- Naveh-Benjamin, M., Brav, T. K., & Levy, O. (2007). The associative memory deficit of older adults: the role of strategy utilization. *Psychology And Aging*, 22(1), 202–208. doi: 10.1037/0882-7974.22.1.202
- Naveh-Benjamin, M., Guez, J., & Shulman, S. (2004). Older adults' associative deficit in episodic memory: Assessing the role of decline in attentional resources. *Psychonomic Bulletin & Review*, 11(6), 1067–1073. doi:10.3758/BF03196738
- Naveh-Benjamin, M., Hussain, Z., Guez, J., & Bar-On, M. (2003). Adult age differences in episodic memory: further support for an associative-deficit hypothesis. *Journal Of Experimental Psychology: Learning, Memory, And Cognition*, 29(5), 826–837. doi: 10.1037/0278-7393.29.5.826
- Naveh-Benjamin, M., & Kilb, A. (2012). How the measurement of memory processes can affect memory performance: The case of remember/know judgments. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 38(1), 194–203. doi:10.1037/a0025256
- Norman, K. A., & O'Reilly, R. C. (2003). Modeling hippocampal and neocortical contributions to recognition memory: A complementary-learning-systems approach. *Psychological Review*, 110(4), 611–646. doi:10.1037/0033-295X.110.4.611

- Old, S. R., & Naveh-Benjamin, M. (2008). Differential effects of age on item and associative measures of memory: a meta-analysis. *Psychology And Aging, 23*(1), 104–118. doi: [10.1037/0882-7974.23.1.104](https://doi.org/10.1037/0882-7974.23.1.104)
- Parks, C. M., & Yonelinas, A. P. (2009). Evidence for a memory threshold in second-choice recognition memory responses. *Proceedings of the National Academy of Sciences, 106*(28), 11515–11519. doi:[10.1073/pnas.0905505106](https://doi.org/10.1073/pnas.0905505106)
- Parks, C. M., & Yonelinas, A. P. (2015). The importance of unitization for familiarity-based learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 41*(3), 881–903. doi:[10.1037/xlm0000068](https://doi.org/10.1037/xlm0000068)
- Patterson, M. M., Light, L. L., Van Ocker, J. C., & Olfman, D. (2009). Discriminating semantic from episodic relatedness in young and older adults. *Aging, Neuropsychology, and Cognition, 16*(5), 535–562. doi:[10.1080/13825580902866638](https://doi.org/10.1080/13825580902866638)
- Pedraza, O., Lucas, J. A., Smith, G. E., Petersen, R. C., Graff-Radford, N. R., & Ivnik, R. J. (2010). Robust and expanded norms for the Dementia Rating Scale. *Archives of Clinical Neuropsychology, 25*(5), 347–358. doi:[10.1093/arclin/acq030](https://doi.org/10.1093/arclin/acq030)
- Pilgrim, L. K., Murray, J. G., & Donaldson, D. I. (2012). Characterizing episodic memory retrieval: Electrophysiological evidence for diminished familiarity following unitization. *Journal of Cognitive Neuroscience, 24*(8), 1671–1681. doi:[10.1162/jocn_a_00186](https://doi.org/10.1162/jocn_a_00186)
- Quamme, J. R., Yonelinas, A. P., & Norman, K. A. (2007). Effect of unitization on associative recognition in amnesia. *Hippocampus, 17*(3), 192–200. doi:[10.1002/hipo.20257](https://doi.org/10.1002/hipo.20257)
- Rhodes, S. M., & Donaldson, D. I. (2007). Electrophysiological evidence for the influence of unitization on the processes engaged during episodic retrieval: Enhancing familiarity based remembering. *Neuropsychologia, 45*(2), 412–424. doi:[10.1016/j.neuropsychologia.2006.06.022](https://doi.org/10.1016/j.neuropsychologia.2006.06.022)
- Rhodes, S. M., & Donaldson, D. I. (2008). Electrophysiological evidence for the effect of interactive imagery on episodic memory: Encouraging familiarity for non-unitized stimuli during associative recognition. *NeuroImage, 39*(2), 873–884. doi:[10.1016/j.neuroimage.2007.08.041](https://doi.org/10.1016/j.neuroimage.2007.08.041)
- Stenberg, G., Hellman, J., Johansson, M., & Rosén, I. (2009). Familiarity or conceptual priming: Event-related potentials in name recognition. *Journal of Cognitive Neuroscience, 21*(3), 447–460. doi:[10.1162/jocn.2009.21045](https://doi.org/10.1162/jocn.2009.21045)
- Tibon, R., Gronau, N., Scheuplein, A.-L., Mecklinger, A., & Levy, D. A. (2014). Associative recognition processes are modulated by the semantic unitizability of memoranda. *Brain and Cognition, 92*, 19–31. doi:[10.1016/j.bandc.2014.09.009](https://doi.org/10.1016/j.bandc.2014.09.009)
- Umanath, S., & Marsh, E. J. (2014). Understanding how prior knowledge influences memory in older adults. *Perspectives on Psychological Science, 9*(4), 408–426. doi:[10.1177/1745691614535933](https://doi.org/10.1177/1745691614535933)
- Whittlesea, B. W., & Williams, L. D. (2001). The discrepancy-attribution hypothesis: I. The heuristic basis of feelings and familiarity. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 27*(1), 3. doi:[10.1037/0278-7393.27.1.3](https://doi.org/10.1037/0278-7393.27.1.3)
- Whittlesea, B. W. A. (2002). False memory and the discrepancy-attribution hypothesis: The prototype-familiarity illusion. *Journal of Experimental Psychology: General, 131*(1), 96–115. doi:[10.1037//0096-3445.131.1.96](https://doi.org/10.1037//0096-3445.131.1.96)
- Wiegand, I., Bader, R., & Mecklinger, A. (2010). Multiple ways to the prior occurrence of an event: An electrophysiological dissociation of experimental and conceptually driven familiarity in recognition memory. *Brain Research, 1360*, 106–118. doi:[10.1016/j.brainres.2010.08.089](https://doi.org/10.1016/j.brainres.2010.08.089)
- Yonelinas, A. P. (1997). Recognition memory ROCs for item and associative information: The contribution of recollection and familiarity. *Memory & Cognition, 25*(6), 747–763. doi:[10.3758/BF03211318](https://doi.org/10.3758/BF03211318)
- Yonelinas, A. P. (1999). The contribution of recollection and familiarity to recognition and source-memory judgments: A formal dual-process model and an analysis of receiver operating characteristics. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 25*(6), 1415. doi:[10.1037/0278-7393.25.6.1415](https://doi.org/10.1037/0278-7393.25.6.1415)
- Yonelinas, A. P. (2002). The nature of recollection and familiarity: A review of 30 years of research. *Journal of Memory and Language, 46*(3), 441–517. doi:[10.1006/jmla.2002.2864](https://doi.org/10.1006/jmla.2002.2864)

- Yonelinas, A. P., Aly, M., Wang, W.-C., & Koen, J. D. (2010). Recollection and familiarity: Examining controversial assumptions and new directions. *Hippocampus*, 20(11), 1178–1194. doi:10.1002/hipo.20864
- Zheng, Z, Li, J, Xiao, F, Broster, L. S, & Jiang, Y. (2015). Electrophysiological evidence for the effects of unitization on associative recognition memory in older adults. *Neurobiology Of Learning And Memory*, 121, 59–71. doi: 10.1016/j.nlm.2015.03.006
- Zheng, Z, Li, J, Xiao, F, Broster, L. S, Jiang, Y, & Xi, M. (2015). The effects of unitization on the contribution of familiarity and recollection processes to associative recognition memory. *Evidence From Event-related Potentials. International Journal Of Psychophysiology*, 95, 355–362. doi: 10.1016/j.ijpsycho.2015.01.003

Appendix

Table A1. Examples of intact and recombined CW and NCW pairs.

<i>Intact CW pairs</i>	<i>Encoding sentence</i>	<i>Recombined CW pairs</i>
serre tête	Le serre-tête est redevenu à la mode	casse tête
casse cou	Un casse-cou est une personne plutôt prudente	
essuie main	Il ne faut pas posséder une fortune pour acheter un essuie-main	essuie tout
risque tout	Cet homme est audacieux, c'est un risque-tout	
soutien gorge	Son soutien-gorge était posé sur la commode	rouge gorge
peau rouge	Le sheriff a combattu un peau-rouge	
<i>Intact NCW pairs</i>	<i>Encoding sentence</i>	<i>Recombined NCW pairs</i>
herbe idée	Piétiner l' herbe n'est pas une bonne idée .	chêne idée
chêne don	Le chêne a le don de soigner les gens.	
star folie	Cette star a fait une folie en dépensant des fortunes	métal folie
métal société	Le métal est fabriqué dans cette société	
parc deux	Le chemin du parc forme un " deux ".	
anorak sourire	Mon anorak lui rendit son sourire .	anorak deux