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AN INVESTIGATION OF THE INCREASED RELIANCE ON FAMILIARITY IN

ASSOCIATIVE RECOGNITION OF UNITIZED COMPOUND WORD PAIRS

By

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Abstract

Unitization refers to when two components are integrated or combined into a single unit. So the whole is more familiar than the parts (Graf & Schacter, 1989). Previous researchers have shown unitization of unrelated word pairs can occur by the use of compound definition. As support, they have found unitization to increase reliance on familiarity in associative recognition. The purpose of this PhD dissertation was to examine the effects of unitization of preexperimental associations on associative recognition. The effects of associative recognition of unitized compound word (CW) pairs can serve as a useful benchmark to compare to that of other methods of unitization. In Chapter 2, I present findings from Manuscript 1 consisting of five experiments in which I investigated the effects of unitization of CW pairs on associative recognition. In Experiment 1, I found a CW effect as in higher hit rates and false alarm rates for CW compared to noncompound word (NCW) pairs. In addition, there was no discrimination difference between CW and NCW pairs. In Experiments 2a and 2b, I show from both a non-speeded and speeded forced-choice test that when response bias is minimized, participants show a discrimination advantage for CW pairs. In Experiments 3a and 3b, I show that item recognition is reduced for CW compared to NCW pairs, but when components of the CW and NCW pairs are emphasized at encoding, similar item recognition is shown for both pair types. Lastly, in Experiment 5, I show from receiver operating characteristic (ROC) curves that there is a discrimination advantage for repeated NCW pairs compared to CW and NCW pairs. In Chapter 3, I present findings from Manuscript 2 consisting of three experiments in which I investigated the effects of unitization of CW pairs on associative recognition in older adults. In Experiment 1, older adults showed a discrimination advantage for CW pairs. Moreover, when presentation time was reduced young adults still did not show a discrimination advantage for CW pairs. Finally, in Experiment 3, I found both young and older adults showed a discrimination advantage for CW

pairs in the forced-choice test. Thus, unitization of CW pairs benefited older adults because of ease of encoding and allowing increased use of familiarity during recognition. In addition, test format influences younger adults' use of familiarity. Lastly, in Chapter 4, I present findings from Manuscript 3 consisting of three experiments examining whether processing fluency of unitized CW pairs was associated with the greater use of familiarity. In Experiment 1, minimizing perceptual fluency did not influence the CW effect. In Experiment 2B, I found there was no difference in CW effect between the more conceptual fluent transparent CW than opaque CW pairs. In conclusion, I show there are many effects of unitization of preexperimental associations on associative recognition and there are a number of factors that can determine if there is a benefit of unitization to associative memory. The results provide a set of benchmarks that can be used in the evaluation of different procedures designed to unitize random word pairs.

Authors Contributions for Published/Accepted Manuscripts

I was the main contributor for all three manuscripts. I was responsible for all phases of the studies presented in the manuscripts including the design of the experiments, recruiting participants, testing participants, data analysis and writing of the manuscripts. The co-authors of the manuscripts provided supervision, comments and suggestions on the drafts of the manuscripts and also provided the necessary lab space for me to conduct all the experiments.

I also acknowledge Taylor & Francis Group for allowing me access to publish my two accepted manuscripts ((Ahmad & Hockley (2014); Ahmad et al. (2015)) into my PhD dissertation.

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Chapter 1

General Introduction and Overview

"Such being the phenomenon of memory, or the analysis of its object, can we see how it comes to pass? Can we lay bare its causes? Its complete exercise presupposes two things: 1) The retention of the remembered fact; 2) Its reminiscence, recollection, reproduction, or recall. Now the cause both of retention and of recollection is the law of habit in the nervous system, working as it does in the 'association of ideas.'" –William James, *Principles of Psychology*

The above quote by the renowned psychologist William James (1980, p. 653) suggests memory consists of the retention of information and its recollection. We now know from many research studies that memory is considered a process in which information is encoded, stored and retrieved. Information stored in memory can be represented as items or associations. Item information is represented as individual events such as in words, faces and pictures. In contrast, associative information is represented as relations between items. It is described as the information that binds separate components of information. For example, the context which provides meaning to a word or the name associated with a person's face.

It is critical to understand how associative information is encoded and retrieved, as in our daily lives we engage in the process of learning or acquiring associations between ideas, concepts, words, faces and so forth. For example, we often need to learn to associate a person's name and a profession. According to semantic network theories the process of learning associations enables us to increase our knowledge of a topic by increasing the number of links between concepts and ideas. As a result the amount of factual information stored in our semantic memory is increased because associations are represented in expanding semantic networks (see Johnson-Lairs, Hermann & Chaffin, 1984; McCrae & Jones, 2012 for a review). In the

laboratory, memory of both item and associative information can be tested by recognition of words and unrelated word pairs. Item information is knowledge of whether two words were studied previously, whereas associative information is knowledge of whether two words were studied as a pair together (Gronlund & Ratcliff, 1989).

This Doctoral Dissertation examined the effects of unitization of preexperimental associations on associative and item recognition. The main stimuli I used as unitized associations were compound words presented as compound word pairs (e.g., brain storm). These represent the ideal unitized preexperimental associations, as the two elements of the compound word are always experienced as a single unit. According to researchers in linguistics, compound words are processed as wholes rather than individual units and are formed by a process of compounding (i.e., two individual words are combined or joined together to form a single word). In addition, the whole word meanings of compound words are not predictable from the meanings of their constituents in isolation (Libben & Jarema, 2006).

In this chapter, I will first give a brief overview of how item and associative recognition is tested in the lab. I will then briefly outline the main single and dual process theories of recognition memory and the relevance of the associative recognition paradigm to dual process theories. A brief overview of the early studies on recognition of strong associations and recent emergence of studies using several techniques to examine the effects of unitization on associative recognition will be presented. I will then state the rationale of my dissertation. Finally, a summary of results for each study will be presented.

Testing Item and Associative recognition

In an item recognition task, items are typically shown one at a time to the participant to memorize after which participants are tested on discrimination of studied and new items. In

contrast to item recognition, in an associative recognition task, participants typically study pairs

of items. At test, associative recognition requires participants to discriminate between intact pairs

(i.e., old or studied pairs) and rearranged pairs (i.e., new pairs) (e.g., Humphreys, 1978, Hockley

& Consoli, 1999). A rearranged pair consists of one studied item of one pair and another studied

item of another pair. Associative recognition is successful when intact pairs are endorsed (i.e.,

hits) and rearranged pairs are rejected (i.e., correct rejections). Associative recognition is

unsuccessful when studied pairs are rejected (misses) and rearranged pairs are endorsed (false

alarms). Thus, associative recognition, like item recognition performance improves as hit rates

increase and false alarm rates decreases. Note also that memory for the individual items cannot

assist associative recognition as both intact and rearranged pairs consist of old items.

Discrimination is defined as an increasing function of the probability of classifying an unstudied

item (i.e., hit rate [HR]) and a decreasing function of probability of incorrectly classifying an

unstudied item (i.e., false alarm rate [FAR]). An overall discriminability index can be defined by

a measure that combines the HR and FAR such as d' (the estimated distance between the means

of the old and new distributions in signal detection theory), or corrected recognition scores (HR

minus FAR). Thus, associative recognition provides a relatively pure test of memory for

relational information. As mentioned earlier, performance in item and associative recognition has

been explained by two contrasting theories, single and dual process theories.

Single and Dual Process Theories of Recognition Memory

According to single process models based on signal detection theory (SDT), recognition

is determined by the strength of a quantitative variable called familiarity (e.g., Hintzman, 1984,

Murdock, 1997, Criss & Shiffrin, 2005, Hockley, 1992, Kelley & Wixted, 2001). In general,

according to all single process theories, studied items are recognized accurately due to being

sufficiently familiar. Items are placed on a familiarity continuum with old items on the high end of the continuum and new items on the low end of the continuum. In the SDT model, the familiarity of studied and unstudied items is normally distributed. The normal distribution representing studied items is further to the right than the normal distribution representing un-studied items. A criterion set by the participant bisects this familiarity continuum and determines if the item is accepted as an old (studied) or new (non-studied) item. The criterion (C) can also be considered as defining the strategy of the participant (Abdi, 2007). When the criterion is set at the lower end of continuum (i.e., liberal criterion), both hits and false alarms will increase. However, when the criterion is set at the higher end of continuum (i.e., conservative criterion), both hits and false alarms will decrease. The sensitivity measure $d´$ is the distance in means of these two underlying distributions. No matter where the participant locates the criterion, $d´$ equals the same number (Macmillan & Creelman, 1991). As a result, discrimination as measured by $d´$ according to SDT is unchanged by response bias.

One group of single process models are the global matching models. One version of global matching model assumes that the test item is compared to the contents of the memory of the study list (Murdock, 1982). A familiarity value is obtained by comparing a representation of the test item (i.e., retrieval cue) to the contents of memory (Malmberg, 2008). The familiarity that is associated with the test item is a positive function of similarity between it and traces in memory. Murdock's TODAM model shares similarities with the SAM (Gillund & Shiffrin, 1984), the MINVERA II (Hintzman, 1984) and the Matrix model (Humphreys, Bain & Pike, 1989; Humphreys, Pike, Bain & Tehan, 1989). In general, all these global matching models according to Clark and Gronlund (1996) indicate access to memory is defined by three main

properties. The familiarity of the test items, the familiarity from match of test items to memory at a global level and the activation of memory produced by the test item.

In contrast, according to dual process models, recollection also contributes to item recognition. Similar to signal detection theory, familiarity is conceived as an assessment of "quantitative" memory strength. Recollection is defined as being a threshold or continuous process (Yonelinas, 1994; see Yonelinas, 2002; Malmberg & Xu, 2007; Wixted, 2007). It is described as a specific search for specific information and retrieves episodic or associative details. A process similar to which is present in a recall task. The difference between dual process theories lies in their characterization of familiarity and recollection. Relevant to this dissertation, three dual process theories should be discussed. The first of which is the dual process model proposed by Tulving (1985; Tulving & Markowitsch, 1998). In this model, two separate memory systems are responsible for recognition memory. One is the semantic memory system which contains factual information. The other memory system is the episodic memory system which stores contextual details of past events. According to Tulving, familiarity is associated with the conscious experience of "the feeling of knowing" which arises from semantic memory, whereas recollection is associated with the conscious experience of "remembering" and arises from episodic memory. These two processes are assumed to act independently of each other but in parallel. Support for the Tulving model comes primarily from amnesic patients. Some researchers have shown damage to episodic memory leads to deficits in recollection, whereas damage to surrounding regions of hippocampus leads to deficits in semantic memory (Tulving & Markovitsch, 1998).

However, in the Dual process signal detection (DPSD) model (Yonelinas 1997; Yonelinas, Kroll, Dobbins, & Soltani, 1999) familiarity and recollection do not reflect different

memory systems. Familiarity is based on the quantitative strength, as proposed by signal process

theories (see Figure 1). In contrast, recollection reflects a threshold retrieval process whereby

qualitative information about a previous event is retrieved (Yonelinas, 2002). That is, items for

which participants cannot retrieve qualitative information such as spatial context will fall below

the threshold for recollection. The DPSD model is also called the equal-variance model, because

similar to signal detection theory, targets and lures contain similar memory strength. Memory

strength refers to the amount of evidence for the item having been studied. If the evidence for the

item is higher than criterion, the item is endorsed as being a target. Moreover, the distributions of

the targets and lures are of equal variance and follow a normal distribution.

In contrast, in the dual process version of the signal detection theory called the unequal-

variance signal-detection model (UVSD) proposed by Wixted (2007), single detection theory is

modified to incorporate recollection as a continuous retrieval process. Recollection and

familiarity are viewed as continuous processes that are aggregated into a memory-strength

signal. When a criterion level is exceeded by memory strength, the item is identified as an old or

studied item. Recollection can be similar to familiarity as shown by high degrees of recollection

resulting in high confidence and high accuracy, but low degrees of recollection resulting in low

confidence and low accuracy. Contrary to the DPSD model, targets have memory strength added

to them as a result of their appearance on the study list. As a result, the variance of lures is lower

than of targets.

Interestingly, in the Jacoby model familiarity is not treated as reflecting quantitative

strength but fluency of processing due to extent of prior experience. That is, participants treat

items as more familiar than other items because of being more fluently processed as a result of

past experience with the item (Jacoby & Dallas, 1981; Jacoby & Whitehouse, 1989). Faster

response times or naming times are found for more fluently processed items. Familiarity arises

from both perceptual (enhanced processing of orthographic representation) and conceptual

fluency (enhanced processing of conceptual meaning) (Whittlesea, Jacoby & Girard, 1990). In

contrast, recollection involves retrieval of contextual or relational information. Similar to in

DPSD model, familiarity is considered a fast automatic process, whereas, recollection is

considered a slow controlled analytic process.

Differences between item and associative recognition accounted for by Dual process theories

Dissociations between item and associative recognition have proven problematic for

single process theories. For example, in item recognition, low frequency words are recognized

better than high frequency words. However, in associative recognition, the pattern is reversed

(Clark & Gronlund, 1996). According to most global matching models such as the SAM model,

item and associative information are retrieved together and contribute to a global match to the

stimulus. As a result, the word frequency manipulation should have a similar effect on item and

associative recognition. In addition, single process theories cannot explain why forgetting rates

are faster for item than associative information, because the common assumption is that decay,

interference or both would affect item and associative recognition in a similar manner (Hockley,

1992).

Dual process theories can account for all the dissociations between item and associative

recognition due to the general claim that associative recognition relies more on recollection for

contextual details, in this case the co-occurrence of each item of the pair, whereas item

recognition relies more on familiarity in the absence of retrieval of contextual details (e.g.,

Tulving, 1985; Yonelinas, 1994). Item information reflects the strength or familiarity of an

event, and this information can be directly accessed. Associative information reflects contextual

relations and is retrieved through a recall-like process (Hockley, 1992; Hockley & Cristi, 1996; Hockley & Consoli, 1999).

A number of measurement methods have been used by dual process theorists to dissociate familiarity and recollection (Yonelinas, 2002). For the pattern of results in associative recognition, an increase in hit rates is due to both familiarity and recollection, whereas, an increase in false alarm rates reflects a greater use of familiarity than recollection. Since all items in the pairs of associative recognition tests are familiar, a recall-to reject strategy must be used to correctly reject a rearranged pair. Moreover, response-speed methods have been used to show that familiarity is faster than recollection. For example, in a standard non-speeded item or associative recognition test, recognition performance is assessed for fast and slow recognition responses. Familiarity contributes to fast responses, whereas mostly recollection contributes to slow responses (Hockley, 2008; Yonelinas, 2002).

Finally, process-estimation methods have been used to assess the contribution of familiarity and recollection to associative recognition. One such method is the receiver operating characteristic (ROC) procedure. ROCs are obtained by different ways, but the most common is by collecting confidence ratings for old and new responses (Yonelinas & Parks, 2007). During the recognition test, participants are provided with old and new pairs, they indicate how confident they are in recognizing the item on a scale from 1 (sure new) to 6 (sure old). Another method is to have participants provide an old and new response and then rate the confidence of their response on a scale of 1 to 3. The ROC is constructed by plotting hits against false alarms starting with the most confident to least confident. Based on an analysis of receiver operating characteristic (ROC) curves, Yonelinas (1998) and Rotello and Heit (2000) showed that familiarity contributed more to item recognition of words and recollection contributed more to

associative recognition of word pairs (see Figure 2). Curvilinear ROCs characteristic of greater use of familiarity are produced by item recognition of words and linear ROCs characteristic of greater use of recollection are produced by associative recognition of word pairs (see Yonelinas, Aly & Wang, 2010).

Further support for dual process theory has been provided from measuring associative recognition performance in older adults, amnesic patients and determining electrophysiological and neuropsychological correlates of familiarity and recollection (Yonelinas, 2002). For example, both older adults and amnesic patients show lower hit rates and higher false alarm rates combined with reduced discrimination of unrelated pairs in associative recognition compared to younger adults (Giovanello, Verfaeillie & Keane, 2003; Naveh-Benjamin, 2000).

Another method to dissociate familiarity and recollection is to measure event related potentials (ERPs) obtained by averaging electrophysiological (EEG) recordings from the brain. For both item and associative recognition, during the recognition test, the difference in activity from correctly recognized old and correctly rejected stimuli is obtained to get a measure of the ERP old/new effect. Familiarity is associated with a bilateral frontal old/new effect. That is, correctly recognized items elicit more positive going waveforms than correctly rejected new items between 300-600ms. In contrast recollection is associated with a later onset old/new effect that is maximal over left parietal electrodes (500-800ms) (Rhodes & Donaldson, 2007). Finally, from lesion and functional magnetic resonance imaging (fMRI) studies the hippocampus in the medial temporal lobe (MTL) has been identified as necessary for recollection, whereas regions surrounding the MTL such as the perirhinal cortex (PRc) have been identified as supporting familiarity. To summarize, researchers supporting dual process theory have found a reliance on familiarity for item recognition and a reliance on recollection for associative recognition. They

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have used various techniques to provide evidence for their behavioural results. However, these researchers have also suggested familiarity can primarily contribute to associative recognition when study pairs are unitized (e.g. Yonelinas et al., 1999; Giovanello, Keane & Verfaellie, 2006; Quamme, Yonelinas & Norman, 2007).

The Effects of Unitization on Associative Recognition

Before discussing studies relevant to the examination of the effects of unitization on associative recognition, it is interesting to trace back in history the emergence of the concept of unitization. Researchers examining the effects of encoding strategies on associative memory, suggested the formation of strong associations was due to a 'deeper level of processing' or 'relational organization' (i.e., relational information) which led to an improvement in associative memory. The effects of three encoding strategies on associative memory were examined. These were interactive imagery (i.e., forming a mental image that combined the items of the pair), pair repetition (e.g., Bower, 1970; Begg, 1978; Begg & Sikich, 1984; McGee, 1978) and semantic relatedness (Dosher, 1984; Epstein, Phillips & Johnson, 1975; Hermann & McLaughlin, 1973; Hermann & Harwood, 1980; Roediger & Neely, 1982). Epstein et al., (1975) showed participants had higher cued recall for unrelated word pairs that were semantically processed than those that were processed by orthographic features. McGee (1978, Experiment 3) examined participants' associative recognition of word pairs under three different encoding instructions. Before the study phase, instructions were given to rehearse paired associates, to form separate images of items in the pair, or to form an interactive image of each pair. Participants showed higher discrimination in the interactive compared to separate imagery condition with lowest performance in the rehearsal condition. McGee concluded interactive imagery facilitated encoding of relational information which benefited performance in associative recognition.

A shift from 'levels of processing' or 'relational organization' to 'unitization' came with Graf and Schacter's (1989) study on the effects of unitization on implicit and explicit memory. They proposed associations existed as grouped or unitized representations. Grouping involves forming associations among separate items. In contrast, unitization involves representing separate items as a single unit. In Experiment 3, they examined the idea that encoding of unitized representations was related to the ease or facility with which paired word can be perceived as a single unit. Unrelated concrete and abstract word pairs were presented and participants were to generate and say a meaningful sentence that combined the two items of the pair. The reasoning being connecting word pairs in a meaningful manner would involve interpreting the word pair as a single coherent unit and as a result establish a unitized representation. To test associative memory of these unitized representations word stem completion (for implicit memory) and a cued recall (for explicit memory) tests were included. Graf and Schacter (1989) found both implicit and explicit memory was higher for concrete than abstract word pairs. Moreover, they found a similar result when sentences that related word pairs in a meaningful manner were presented during the study phase. Graf and Schacter concluded both implicit and explicit memory can be improved by unitization and concreteness facilitates unitization.

However, Graf and Schacter (1989) did not state clearly the mechanism of the effects of unitization in their study. For example, there was no mention of how unitization effected encoding and retrieval processes present in cued recall. Secondly, a better test of associative memory would be associative recognition rather than cued recall. Cued recall tests retrieval of both item and associative information. The studied word is presented and the participant recalls the associated word. However, when cued recall fails, it is not clear what type of information cannot be retrieved. With an associative recognition test, a researcher can determine both the

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effects of stimulus manipulation at encoding and retrieval from associative memory. In addition, a variety of behavioural measures can be collected to determine the degree of participants' improvement in associative memory.

Relevant to the experiments presented in this dissertation, recently researchers have shown unitization implemented using a variety of techniques results in a greater reliance on familiarity in associative recognition. Evidence for greater reliance of familiarity in associative recognition of unitized pairs has been provided from behavioural studies involving young, older adults and amnesic patients (e.g., Ahmad & Hockley, 2014; Haskins, Yonelinas, Quamme & Raganath, 2008; Quamme, Yonlinas & Norman, 2007; Kilb & Naveh-Benjamin, 2011; Lloyd, Hartman, Ngo, Ruser, Westerman & Miller, 2015) combined with evidence from electrophysiological (Greve, Rossum & Donaldson, 2007; Kruikova, Bridger & Mecklinger, 2013; Rhodes & Donaldson, 2008) and neuroimaging studies using fMRI (Bader, Opitz, Reith & Mecklinger, 2014; Ford, Verfaeillie & Keane, 2010; Haskins, Yonelinas, Quamme & Raganath, 2008).

The first experimental evidence to show there was a greater reliance on familiarity in associative recognition of unitized pairs was provided by Yonelinas et al. (1999). They presented pairs of faces at study, for which participants were told to try to relate faces together for a later memory test. During the recognition test, intact and rearranged pairs were presented in both upright and inverted position. Participants provided a confidence rating from 1 to 6 on old or new response for the test pair. Yonelinas et al. found ROCs were curvilinear for upright faces, but linear for inverted faces. The researchers suggested familiarity can support associative recognition judgments, if the associated components could be encoded as a coherent whole, as in upright faces.

Since Yonelinas et al.'s (1999) study, a number of researchers have attempted to use various methods or techniques to try to unitize pairs. Support for their behavioural results has been provided by findings using ERP and fMRI. While researchers have shown in a few studies the effects of unitization on associative recognition with preexperimentally established components of compound words presented as compound word pairs (Ahmad & Hockley, 2014; Giovanello et al., 2006; Ford et al., 2010) and experimentally established compound words (Bader et al., 2014; Quamme et al., 2006; Lloyd et al., 2015). Other researchers have suggested other configurations of items comprising coherent representations can be unitized and result in an increased reliance on familiarity in associative recognition. Researchers have suggested a unitized representation can be formed as a result of pair repetition (Kilb & Naveh-Benjamin, 2011; Mickes, Johnson, & Wixted, 2010) and providing interactive imagery instructions to combine the items of the pair into one can also induce unitization (Diana, Yonelinas & Raganath, 2008; Rhodes & Donaldson, 2008). Finally, other researchers have suggested word pairs that represent coherent representations such as in the form of semantically related word pairs (Greve et al., 2007; Kruikova et al., 2013) or within domain associations for which instructions to combine the items of the pair can promote the formation of unitized representations (Bastin, Van der Linden, Schankers, Montaldi & Mayes, 2010).

To make it easier for the reader to understand the similarities and differences between the various techniques designed to promote unitization, I discuss them separately in the subsections below.

Unitization from Pair repetition

Researchers have suggested a unitized association can be formed from the repetition of unrelated pairs. Kilb and Naveh-Benjamin (2011) showed pair repetition of unrelated face pairs

alleviated the age-related associative deficit in older adults. In two experiments participants were repeatedly presented with pairings of items or single items prior to a study list so that the items and pairs were already familiar during the study phase. Kilb and Naveh-Benjamin found pair repetition (the effects of pair repetition after the effects of item recognition are taken into account) increased associative memory for younger and older adults. They suggested pair repetition induces unitization of items in a word pair. That is, in order to unitize a pair, there should be enough repetitions to create and strengthen intra-item organization (Mandler, 1979). Mickes, Johnson and Wixted (2010) also support the idea of pair repetition leading to unitization. They provide evidence in the form of curvilinear ROCs for associative recognition of unrelated word pairs that were repeated during the study phase in an associative recognition test.

Unitization from interactive imagery

Other researchers have suggested associative memory can be improved by unitization as a result of interactive imagery. Diana et al. (2008) examined if interactive imagery that promoted unitization of item and background would lead to greater use of familiarity in a source memory task. In their study, Diana et al tested participants' source memory in two different conditions. In the unitization condition, participants were told to visualize the item as though it were the same color as the background and generate an explanation for why the item was the same color. Color could then be processed as a feature of the item. In the non-unitized condition, participants were told to visualize the item in a situation with green dollar bill if the background was green or with a red stop sign if the background was red. This encouraged the separate encoding of item and background. During the study phase, word was presented on either a background green or red square. At test, studied and non-studied words were presented and participants were asked to give an old/new response on a confidence scale from 1 to 6. Analysis of the results showed no

discrimination difference in source recognition between unitized and non-unitized words. Importantly, more curvilinear ROCs and higher familiarity estimates were found for unitized encoding than for non-unitized encoding condition.

Rhodes and Donaldson (2008) also examined the effect of interactive imagery in promoting unitization but in an associative recognition task involving semantically related word pairs (i.e. categorically related). Word pairs containing an association (e.g., traffic-jam) or an un-associated semantic relationship (e.g. violin-guitar) were studied by participants using either item or interactive imagery. In the interactive imagery condition, participants were instructed to create an image of the two items interacting together. In the item imagery condition, participants were instructed to create a separate image for each item. Participants underwent a practice phase to use these two different encoding instructions. Shortly after the practice phase, the word pairs were presented. At test, participants provided old or new responses for intact and rearranged word pairs. In addition ERP recordings were collected. The researchers found higher discrimination of association and semantically related word pairs encoded with interactive imagery. Importantly, there was an enhanced bilateral frontal old/new effect for semantically related word pairs encoded with interactive imagery, but similar amplitude for left parietal old/new effect compared to semantically related word pairs studied by using item imagery. Rhodes and Donaldson (2008) suggested interactive imagery promotes greater use of familiarity in associative recognition of semantically related word pairs.

Unitization from semantic relatedness

Interestingly, it has also been suggested that semantically related word pairs can be treated as unitized representations. In a study by Greve et al. (2007) associative recognition of semantically related pairs (i.e., categorically related) was compared to that of unrelated word

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pairs. The researchers found discrimination to be higher for semantically related word pairs. Importantly, a process dissociation procedure showed higher familiarity for associative recognition of semantically related than unrelated pairs. ERP results supported the behavioural results with a higher mid-frontal old/new effect for semantically related than unrelated word pairs, although the parietal old/new effect was the same. Greve et al. suggested the enhanced performance and increased familiarity for the semantically coherent stimuli may reflect the benefits of unitization.

However, the degree of familiarity relied on in associative recognition may depend on the thematic relations of semantically related word pairs. Recently, Kruikova et al. (2013) have suggested greater reliance on familiarity in associative recognition can be present due to integration of word pairs as in thematic relations of semantically related word pairs. They examined participants' associative recognition of two types of semantically related word pairs in an associative recognition test. The word pairs were either semantically (i.e., dancer-actor) or thematically related (i.e., dancer-stage). ERP measures were also collected. No encoding instructions were given. Kruikova et al. found discrimination was similar for both pair types, however, there were higher hits and false alarm rates for categorically related than thematically related word pairs. Importantly, an early mid frontal old/new effect was found for both pair types, however a robust left parietal old/new effect was found only for categorically related word pairs indicating a clear contribution of recollection for associative recognition of categorically related word pairs. Kruikova et al. (2013) concluded the degree familiarity is relied on in associative recognition of semantically related word pairs is dependent on the type of semantic relation between paired associates. Moreover in the case of thematically related pairs, familiarity can be sufficiently diagnostic for associative discrimination.

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Furthermore activation of the PRc due to increased use of familiarity in associative

recognition has been found with semantically related pairs. Greve, Evans, Graham and Wilding

(2011) examined whether there was differential activation of perirhinal cortex for semantically

related and unrelated word pairs. Increased activity in PRc at encoding was shown according to

how familiar items are judged to be at retrieval (e.g., Davachi, 2006). Greve et al. used fMRI to

investigate the role of hippocampus and perirhinal cortex in encoding operations leading to

recollection and familiarity. Participants were presented with semantically related and unrelated

word pairs in an associative recognition task. They were tested on associative recognition of

intact and rearranged pairs for both word pair types. Greve et al. (2011) found greater activation

of PRc during encoding, for correct judgments of semantically intact related pairs than unrelated

word pairs.

Unitization from combining within-domain associations

Researchers have suggested within domain associations represent unified representations

and there is a greater reliance on familiarity in associative recognition of within domain (i.e.,

items of the same kind) compared to between domain associations (i.e., items of a different kind

) (Mayes, Montaldi & Migo, 2007; Bastin et al., 2010). According to the domain dichotomy

(DD) hypothesis, provided associative components are directly linked at encoding, within-

domain associative recognition can be largely based on evaluation of the familiarity of the

associations. In contrast, associative familiarity minimally supports between-domain associative

recognition, which depends largely on the recollection that relates the encoding episode to the

target stimuli (Mayes et al., 2007). In contrast, several researchers support the view that

recognition of non-unitized stimuli (within or between associations) depends primarily on the

contribution of recollection (e.g., Hockley& Consoli, 1999; Yonelinas, 1997). Bastin et al.

examined if the DD view would hold for associative recognition of within-domain (face-face) and between domain associations (face-name). At encoding participants were told to judge whether the faces went well together or not. Within and between domain face pairs were presented for the participants to study. There were two associative recognition tests. There was the standard associative recognition test and the familiarity-only recognition test. The familiarity-only recognition test was similar to one used by Quamme et al. (2007) where participants were to base their recognition judgments based on the familiarity of the association rather than recollect the association. They found participants showed higher discrimination for face pairs than face-name pairs. However, in the standard associative recognition test where recollection was the primary contributed to associative recognition, discrimination was higher for face-name than face-face pairs. Bastin et al. (2010) suggested that their results showed that within-domain associative recognition was mainly supported by familiarity, whereas that of between domain associative recognition was supported by recollection.

Unitization induced by Compound Definition

Another way to examine the effect of unitization on associative recognition is by use of an instructional manipulation that treats unrelated word pairs as compound word pairs. Quamme et al. (2007) used an instructional manipulation in the form of compound definition to induce unitization of unrelated word pairs resulting in the unrelated word pairs being treated as compound word pairs. That is, the researchers reasoned providing a compound definition to encode the unrelated word pairs would be similar to the process of compounding to form compound words. During the study phase, participants in the compound encoding condition were instructed to rate the pair as whole on a scale from one to four according to how the meanings of the words were combined into a single compound by the definition. For example, the word pair,

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cloud-lawn was given the definition a "yard used for sky-gazing". In the sentence encoding condition, participants were to rate how each word fit in the sentence. After the study phase, there was an associative recognition test. The researchers found from ROC analyses that participants in the standard associative task showed similar discrimination for unitized and non-unitized unrelated word pairs. However, in the speeded associative recognition task for which participants were also to base responses on familiarity, a discrimination advantage was shown for unitized pairs. Importantly, amnesic patients known to have intact familiarity but diminished recollection, showed a discrimination advantage for unitized pairs.

Haskins et al. (2008) used the exact same design as Quamme et al. (2007), but tested participants in a functional magnetic resonance imaging (fMRI) study. Similar to Quamme et al., (2007) they found from ROC analyses greater familiarity based recognition judgments for pairs encoded by compound definition than in the sentence encoding condition. In contrast to Quamme et al., they found from ROC analyses that young adults showed a discrimination advantage for unitized than non-unitized pairs. Importantly, during encoding, PRc activation was increased when pairs were unitized by compound definition and this activity predicted subsequent familiarity-based associative memory. Finally, similar to Quamme et al., Lloyd et al. (2015) also found a discrimination advantage for pairs encoded in compound definition compared to unrelated word pairs in a speeded associative recognition task. However, they also found the increase in familiarity-based judgments was not associated with the higher processing fluency of unitized than non-unitized pairs.

Unitization of Compound Word Pairs

Finally, the effects of unitization on associative recognition have been examined by use of preexperimental associations in the form of compound words. As mentioned earlier,

Giovanello et al. (2006) examined participants' associative recognition of unitized

preexperimental associations as in compound and unrelated word pairs. During the study phase,

the experimenter read out loud sentences incorporating compound words or unrelated word pairs.

Participants provided rating of likelihood of occurrence of the information conveyed in the

sentence. At test, participants discriminated between compound word pairs (e.g., brain storm)

and unrelated word pairs. Giovanello et al. found controls showed no discrimination difference

between unitized and non-unitized pairs. They found a concordant compound word effect, as in

higher hit rates and false alarm rates for compound word pairs. Moreover, amnesic patients

showed a discrimination advantage for CW pairs.

In a related study, Ford, Verfaellie and Keane (2010) used fMRI to examine the

familiarity effect induced from associative recognition of unitized CW pairs. During the study

phase, participants said a sentence out loud when the compound word or unrelated word pair was

presented. Unlike Giovanello et al. they found similar hit rate and false alarm rate for compound

and unrelated word pairs. Similar to Giovanallo et al., there was no discrimination difference

between compound and unrelated word pair. Importantly, Ford et al. (2010) found for retrieval,

higher activation of PRc (associated with greater use of familiarity) for discrimination of unitized

than non-unitized pairs. Thus, the above studies showed that participants rely more on familiarity

for unitized compared to non-unitized pairs in an associative recognition task which normally

requires recollection for discrimination.

Rationale for Dissertation

In summary, researchers have argued unitization can occur in different ways ranging

from a compound definition instruction to semantically related word pairs. How could

unitization from these various methods improve performance as reflected in a discrimination

advantage for unitized pairs in an associative recognition test? When unrelated word pairs are

unitized to form a single item, the unified pair is more familiar than its components. As a result,

an intact pair can be distinguished from a rearranged pair because of the higher familiarity of the

intact pair. However, this benefit holds only for those with impaired recollection (amnesic

patients) and when younger adults are encouraged to use familiarity more than recollection

(Quamme et al., 2007; Giovanello et al., 2006).

The effects of unitization on associative recognition seem to vary by the type of

manipulation. In some cases, having items in a strongly associated pair may produce greater

reliance on familiarity in associative recognition. This could be the case with unitization of

unrelated word pairs by use of a compound definition or with other types of associations that are

suggested to represent unitized associations.

For example, one could argue that the effects of unitization of unrelated pairs using a

compound definition on associative recognition were not due to unitization but rather due to

presence of strong associations. Quamme et al. (2007) did not provide a test in their study to

show that the unrelated pairs were actually unitized. Furthermore, there is inconsistency in the

results of ROC analysis of pairs that are unitized by compound definition. Quamme et al. (2007)

showed from their ROC analysis that there was no discrimination difference between unitized

and non-unitized pairs. However, they found based on ROC analysis that familiarity-based

judgments were higher for unitized than non-unitized pairs. Similarly, Haskins et al. (2008) also

found that participants showed greater familiarity- based judgments for unitized than non-

unitized pairs. In contrast to Quamme et al. (2007), Haskins et al. found a discrimination

advantage for unitized than non-unitized pairs.

Findings from neuroimaging studies also suggest that encoding unrelated word pairs by a compound definition may not promote unitization. Instead the unrelated word pairs would be strongly associated due to an instructional manipulation. Both Haskins et al. (2008) and Ford et al. (2010) found greater activation of PRc for unitized pairs. However, Haskins examined activation of PRc for unitized pairs only at encoding, whereas Ford et al. (2010) examined de-activation of PRc at retrieval. Finally, Bader, Opitz, Reith and Mecklinger (2014) investigated activation of brain regions associated with retrieval of pairs unitized by a compound definition compared to pairs encoded in a sentence. They found unitization at encoding by compound definition reduced involvement of recollection network, but engaged regions within the familiarity network at retrieval. However, the researchers did not find activation of PRc during retrieval of unitized pairs.

The difference in some of the results between studies using different methods to promote unitization as shown above brings up the question of whether unitization is a continuous variable or a dichotomous variable. Yonelinas et al. (2010) suggest two important points regarding the effects of unitization. Firstly, unitization is a continuous variable, meaning it should be referred to as a 'levels of unitization' manipulation. That is, researchers can manipulate the conditions so that they are more likely to promote or lead to unitization, but researchers cannot know for sure whether or not subjects, or all subjects, did unitize the pair. Secondly, Yonelinas et al. suggest factors other than unitization could be contributing to greater use of familiarity in recognition.

I agree with Yonelinas et al. (2010) that we can manipulate conditions so that there is more or less ambiguity as to whether or not unitization is likely to occur. However, I would argue that the use of CW pairs, which will be presented in all experiments in my dissertation, represent a condition where unitization is most likely to occur (i.e., CW pairs represent a less

ambiguous or a true unitization condition than new compound definitions or repeated unrelated

word pairs). Finally, even though we cannot know for certain if a subject unitized a pair, we can

do more than create likely conditions for unitization to occur. We can also try to measure

unitization directly. My test of item recognition for CW and NCW pairs in the first paper is one

example of an empirical test of unitization. It would be expected item recognition for a unitized

word pair would be lower than that of a non-unitized word pair, because the encoding of CW

pairs emphasizes the unitized whole. As Bastin et al. (2010) state, when the well-integrated

whole becomes more familiar than its parts, pairs of items are considered unitized. That is, the

two concepts are unified or fused such that they lose their individual identities. In contrast, there

should not be an encoding trade-off for non-unitized word pairs, because as shown by Hockley

and Cristi (1996) when participants emphasized the encoding of associative information, the

encoding of individual words of unrelated word pairs was not diminished. None of the research

studies briefly presented above has tested their manipulation of unitization using item

recognition. Furthermore, another way to test if more familiarity based judgments are present

with a manipulation of unitization is to test participants' associative recognition in a forced-

choice test (i.e., an associative recognition test in which recognition can be primarily based on

familiarity). Indeed in the first study of my dissertation I found younger adults showed a

discrimination advantage for CW pairs in a forced-choice test.

Therefore, the principal aim of my dissertation was to examine the effects of unitization

on associative recognition. Such results would provide a benchmark for comparison to other

methods of unitization. There is no ambiguity that compound word pairs are preexperimental

unitized associations. However, the increased reliance on familiarity brought about by other

types of associations as by an instructional manipulation, pair repetition or semantic relatedness

could be due to the formation of strong associations rather than by unitization. Researchers have

not used direct ways to measure unitization. They also have not agreed upon a measure for

unitization. Even though, ROCs, electrophysiological and neuroimaging measures from ERP and

fMRI have been obtained, there have been differences in these measures between studies

investigating the effects of different procedures to promote unitization on associative

recognition. Three research studies were conducted with different aims or research questions. For

the experiments presented in chapter 2, I sought to examine the effects of unitization on

associative recognition of CW pairs. For the experiments presented in chapter 3, I examined if

unitization of CW pairs could alleviate the age-related associative deficit. Finally, for the

experiments presented in chapter 4, I examined if the CW effect was present due to familiarity

arising from the processing fluency of unitized CW pairs.

Chapter 2: The Effects of Unitization on Associative Recognition of CW pairs

Chapter 2 of this dissertation consisted of a set of experiments to examine the effects of

unitization of CW pairs on associative recognition. One of the aims of the study was to examine

young adults' associative recognition of unitized compound word (CW) pairs. The experimental

design was similar to Giovanello et al. (2006) with some important differences. Firstly,

participants were young adults, not middle aged adults. In addition, participants were not

presented with sentences read aloud by the experimenter to fill in with a CW or NCW pair.

Instead, similar to a standard associative recognition task, CW and NCW pairs were presented

sequentially in a randomized order for which participants were to memorize the word pairs for a

later memory test. We found a similar pattern of results as Giovanello et al. (2006). There was an

increase in hit rates and false alarm rates for CW pairs, but no difference in discrimination. We

called this pattern of results the CW pair effect.

A second aim of the study was to show that increased familiarity-based recognition judgments were due to unitization and not response bias. Instead of relying more on familiarity for unitized pairs, participants may have simply been biased to provide more old responses to CW than NCW pairs in the yes-no test. To test this alternative interpretation, participants were tested in a two-alternative forced-choice test in which response bias is minimized. In addition, some researchers have suggested the forced-choice test encourages greater use of familiarity. In the forced-choice test, response bias is eliminated when performance is compared between unitized and non-unitized pairs in the pure pair test conditions, because the target and lure are of the same pair type in these conditions. As a result, any difference in recognition performance between pure pair test conditions must be due to differences in familiarity. We found participants showed a discrimination advantage for CW pairs in both the pure pair test and mixed pair test conditions. The discrimination advantage for CW pairs was also present when familiarity-based judgments were emphasized in a speeded forced-choice test.

A third question addressed in Chapter 2 was to determine if item recognition could be a valid test of unitization. We hypothesized if unitization led to encoding of pairs as a single unit, then item recognition would be reduced for CW compared to NCW pairs. Our results matched our prediction. Moreover, when instructions were provided to participants to encode items in the unitized pair as individual items similar to non-unitized pairs, the CW effect was eliminated. A fourth aim of the study presented in Chapter 2 was to determine whether pair repetition was sufficient for unitization as some researchers had suggested. Ratings of confidence were included with old and new judgements to plot ROC curves. The ROC curves showed discrimination to be higher for repeated NCW pairs compared to non-unitized NCW pairs. In addition, there was no discrimination difference between CW and non-repeated NCW pairs. These findings indicated

contrary to some researchers' suggestions, pair repetition does not lead to unitization but rather to strong associations.

Chapter 3: The Effects of Unitization on the Age-related Associative deficit

As mentioned early, not only has the effects of unitization in an associative recognition task been investigated in young adults, but also in individuals who rely on familiarity for recognition based decisions due to diminished recollection. Such individuals are older adults and amnesic patients. The latter represent an extreme case. As mentioned before, Quamme et al. (2007) showed from ROC curves that amnesic patients benefited in associative recognition performance for pairs unitized by compound definition. They concluded amnesic patients benefited in associative memory for unitized pairs, because of greater reliance on familiarity and inherent impaired use of recollection. Bastin, Diana, Simon, Collette, Yonelinas and Salmon (2013) also examined associative memory for unitized pairs in participants who relied on familiarity due to impaired use of recollection. However these participants were older adults and recall of background color was tested in a source memory task. The study consisted of two conditions. In the item detail condition designed to promote unitization, participants had to imagine the item was in the same color as the background. In the context detail condition, participants had to imagine the item interacted with another colored object. The researchers found only in the item detail condition, there was an alleviation of age-related associative deficit in source memory performance.

Therefore, the aim of the study presented in Chapter 3 was to determine if unitization of CW pairs could improve older adults' performance in yes-no associative recognition. A number of researchers have shown older adults possess an associative deficit. That is, they are unable to bind together items in unrelated pairs efficiently in order to store them in long term memory

(Naveh-Benjamin, 2000). Providing instructions to encode word pairs in sentences minimally alleviates the age-related associative deficit. However, if older adults study word pairs that rely on their semantic memory, such as semantically related word pairs, they show an improvement in associative memory. The main question addressed in the study presented in Chapter 3 was whether encoding CW pairs would alleviate the age-related associative deficit due to ease of encoding and greater use of familiarity in associative recognition of unitized CW pairs. A secondary question addressed was the effect of type of test (i.e., yes-no, forced-choice test) on young adults' use of familiarity in associative recognition.

Similar to Experiment 1 presented in Chapter 2, young adults showed a CW effect and no discrimination difference between CW and NCW pairs. Similarly, older adults showed a CW effect. However, older adults also showed a discrimination advantage for CW pairs, indicating they benefited from the ease of encoding of CW pairs and greater use of familiarity for associative recognition of CW pairs. In addition, we found that the type of associative recognition test had an influence on young adults' familiarity-based judgments for unitized pairs.

Chapter 4: The Increase in Familiarity from Unitization of Compound Word Pairs is not based on Processing Fluency

One favouring a fluency processing account of familiarity (see the Jacoby model discussed earlier) might argue the enhanced familiarity from CW pairs was not from unitization but from the processing fluency of unitized pairs. Ahmad and Hockley (2014) suggested preexperimental familiarity and study-induced familiarity from unitization of CW pairs was the source of the CW effect. However, unitized CW pairs are definitely processed more fluently than NCW pairs and as a result more old responses would be provided for unitized CW than NCW pairs. A study by Lloyd et al. (2015) examined if the increased reliance on familiarity in

associative recognition for unrelated pairs unitized by compound definition was due to processing fluency rather than unitization of the unrelated word pairs. A priming procedure was implemented during the associative recognition test, intact and rearranged pairs of unitized and non-unitized pairs were primed with a match or mismatch. Lloyd et al. found no difference in associative recognition of unitized pairs primed by a match compared to non-unitized pairs primed by a match. They concluded increased reliance on familiarity was from unitization brought about by compound definition rather than processing fluency of the unitized pairs.

Thus, the aim of the study presented in Chapter 4 was to test the assumption that the CW effect was simply due to the higher processing fluency of unitized CW compared to NCW pairs. Three experiments were conducted. In Experiment 1, we found when perceptual fluency of CW pairs was reduced by presenting individual words of the CW pair on separate screens, a CW effect was still found. In Experiment 2A, we confirmed from a lexical decision task, that a list of CW pairs classified as transparent CW pairs was more conceptually fluent or semantically transparent than opaque CW pairs. However, in Experiment 2B a similar CW effect was shown for CW pairs of different conceptual fluency in associative recognition. Therefore, similar to Lloyd et al. (2015) we found no evidence that processing fluency led to the CW effect. Rather it was due to preexperimental and experimental familiarity from unitization of CW pairs.

In summary, the main aim of this dissertation was to examine the effects of preexperimental unitization on associative recognition. The results of my research studies would serve as a bench mark to compare with other methods of unitization such as instructional manipulation.

Chapter 5: General Discussion

The final chapter will provide a discussion of all the findings of the three chapters and address the question of what characterizes unitization in associative recognition. In addition implications of the present results for single and dual process theories of recognition memory and for future research will be discussed.

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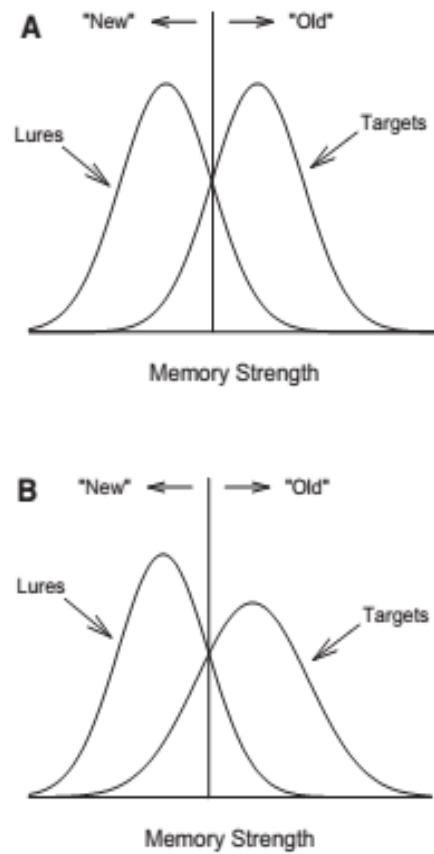
Figure 1. The equal-variance signal detection model (Panel A) representing familiarity in the

dual-process signal-detection (DPSD) model of recognition memory, and the unequal-variance

signal-detection (UVSD) model (panel B), representing both recollection and familiarity in the

UVSD model of recognition memory. Modified from Wixted (2007).
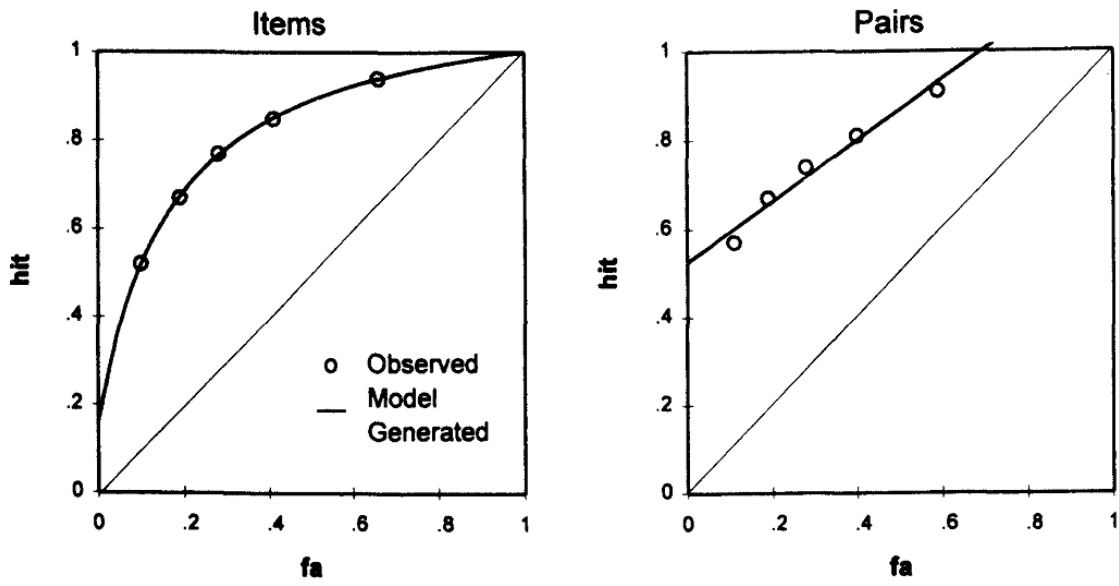
Figure 2. ROCs obtained from Experiment 2 for item and associative recognition plotted along

with the functions generated by the dual-process model. Modified from Yonelinas (1997).

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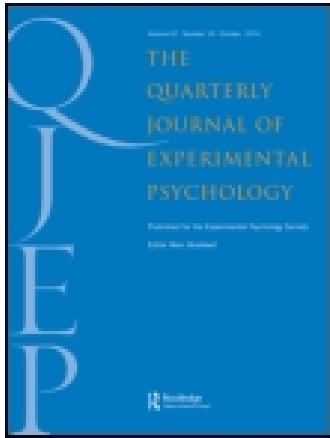
The role of familiarity in associative recognition of unitized compound word pairs

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The role of familiarity in associative recognition of unitized compound word pairs

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This study examined the effect of unitization and contribution of familiarity in the recognition of word pairs. Compound words were presented as word pairs and were contrasted with noncompound word pairs in an associative recognition task. In Experiments 1 and 2, yes–no recognition hit and false-alarm rates were significantly higher for compound than for noncompound word pairs, with no difference in discrimination in both within- and between-subject comparisons. Experiment 2 also showed that item recognition was reduced for words from compound compared to noncompound word pairs, providing evidence of the unitization of the compound pairs. A two-alternative forced-choice test used in Experiments 3A and 3B provided evidence that the concordant effect for compound word pairs was largely due to familiarity. A discrimination advantage for compound word pairs was also seen in these experiments. Experiment 4A showed that a different pattern of results is seen when repeated noncompound word pairs are compared to compound word pairs. Experiment 4B showed that memory for the individual items of compound word pairs was impaired relative to items in repeated and nonrepeated noncompound word pairs, and Experiment 5 demonstrated that this effect is eliminated when the elements of compound word pairs are not unitized. The concordant pattern seen in yes–no recognition and the discrimination advantage in forced-choice recognition for compound relative to noncompound word pairs is due to greater reliance on familiarity at test when pairs are unitized.

Keywords: Associative recognition; Compound word pairs; Unitization; Concordant effect; Familiarity; Familiarity-only procedure

In item recognition, participants are presented with items at study and are then subsequently assessed on their ability to discriminate between individual old and new items at test. In contrast, in associative recognition, random pairs of items are typically presented at study, and participants are instructed to form a relation between them. At test, participants discriminate between intact pairs (i.e., old or studied pairs) and rearranged pairs (i.e., new pairs constructed from old items from different study pairs; e.g., Hockley & Consoli, 1999; Humphreys, 1978). Associative recognition is successful when intact pairs are endorsed (i.e., hits), and rearranged pairs are rejected (correct rejections). Memory for the individual items cannot assist associative recognition as both intact and

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rearranged pairs consist of old items. Thus, successful associative recognition depends only on retrieval of relational information.

Dual-process theory, in its broadest terms, is a generally accepted account of item and associative recognition. This theory holds that recognition decisions are based on two processes: familiarity and recollection (e.g., Jacoby, 1991; see Yonelinas, 2002, for a review). Recollection is a relatively slow process, described as a search for specific details associated with prior presentation of an item. It is a process similar to that involved in a recall task. Familiarity is a relatively fast process and allows a recognition decision to be made even though no specific details of a prior presentation of an item have been retrieved (Wixted, 2007). Thus, participants' greater use of familiarity in a recognition decision can be ascertained by fast response times, whereas use of recollection has been associated with slower response times (e.g., Yonelinas, 2002; see Hockley, 2008, for a review). Moreover, the pattern of hit and false-alarm rates provide additional evidence for greater use of familiarity than recollection, according to dual-process theory. An increase in hit rate could be due to familiarity or recollection or both, whereas an increase in false-alarm rate reflects a greater use of familiarity than recollection. This interpretation is supported by a study by Greene (1999). In the study, half of the study and test items were familiarized by presenting them in an earlier study phase. Both hit and false-alarm rates were greater for the familiarized items than for the nonfamiliarized items. Greene attributed this concordant pattern of results to the higher familiarity of the previously presented items.

It has been argued that associative recognition relies more on recollection for contextual details, in this case the co-occurrence of each item of the pair, whereas item recognition relies more on familiarity in the absence of retrieval of contextual details (e.g., Tulving, 1985; Yonelinas & Jacoby, 1994). Based on an analysis of receiver operating characteristic (ROC) curves, Yonelinas, Kroll, Dobbins, Lazzara, and Knight (1998) and Rotello and Heit (2000) showed that familiarity contributed more to item recognition of words, and recollection contributed more to associative recognition of word pairs. Curvilinear ROCs were produced by recognition tests of single words, and linear ROCs were produced by associative recognition of word pairs. In addition, using a remember/know procedure, Hockley and Consoli (1999) found that associative recognition judgements were associated with more remember responses and fewer know responses than item recognition judgements. Remember judgements indicate use of recollection at retrieval, whereas know judgements reflect the use of familiarity. Moreover, Hockley and Consoli (1999) found that discrimination between intact and rearranged pairs was at chance for recognition decisions classified as know judgements.

Recently, however, researchers have found that familiarity can support associative recognition when the pairs of items presented at study are unitized (Bastin, Linden, Schankers, Montaldi, & Mayes, 2010; Ford, Verfaellie, & Giovanello, 2010; Giovanello, Keane, & Verfaellie, 2006; Rhodes & Donaldson, 2007; Quamme, Yonelinas, & Norman, 2007; Yonelinas, Kroll, Dobbins, & Solatani, 1999; see Murray & Kensinger, 2013, for a review). Items are considered unitized when the components of the association have been encoded as a coherent whole, so that the well-integrated whole becomes more familiar than its constituents and should then be more familiar than a new recombined association (Bastin et al., 2010; Graf & Schacter, 1989). Thus, unitization would promote similar use of familiarity in associative recognition as in an item recognition task. Unitization has been achieved by instructional manipulation at encoding and by the use of stimuli with preexperimental associations or relations.

Quamme et al. (2007) used an instructional manipulation involving a compound definition to induce unitization at encoding in an associative recognition test. They had young adults study unrelated word pairs using a compound definition. For example, given the unrelated word pair CLOUD–LAWN, participants were to rate the pair on how well the definition "A yard used for sky-gazing" combined the two words into a sensible compound. In the nonunitized condition,

participants studied unrelated word pairs presented in a sentence. For example, given the unrelated word pair WATCH–LECTURE, participants were to rate how well the words fit into a sentence "He glanced at the __ as the __ began". The sentence condition encouraged relational encoding of the pairs. At test, participants were randomly assigned to a standard or a familiarity-only test instruction group. In the familiarity-only procedure, devised by Mayes, Montalidi, and Migo (2007), participants are instructed to respond quickly and base responses only on familiarity. Quamme et al. found from ROC analyses that participants in the standard recognition test instruction group showed no difference between recognition of unitized and nonunitized pairs. However, participants in the familiarity-only test instruction group showed a discrimination advantage for unitized pairs. A discrimination advantage for unitized pairs was also shown by amnesics with lesions restricted to the hippocampus in Quamme et al.'s first experiment, in which only standard test instructions were provided. Quamme et al. concluded that recognition of unitized word pairs relied on familiarity to a greater extent, whereas associative recognition for nonunitized word pairs was based more on recollection.

Another way to examine the effects of unitization on associative recognition is by presenting pairs of items that have preexperimental associations. Greve, van Rossum, and Donaldson (2007) showed there was greater use of familiarity in associative recognition of semantically related than in that of unrelated pairs. The semantically related word pairs were words of the same category (e.g., rabbit–mouse). They found a concordant effect, with an increase in hit rate and false-alarm rate for semantically related compared to unrelated pairs, indicating greater use of familiarity for semantic than unrelated pairs. Discrimination was also higher for semantically related than for unrelated pairs. Further support for greater use of familiarity for recognition of semantically related pairs was shown by a more positive N400 old/new effect for semantically related than for unrelated pairs.

In an event-related potential (ERP) study, Rhodes and Donaldson (2007) examined whether word pairs with a meaningful relationship and considered to be unitized at encoding elicited ERP components typically associated with familiarity-based responding. In the behavioural task, participants were asked to remember word pairs sharing an association (traffic–jam) or a semantic relationship (cereal–bread) in an associative recognition task. The reported examples of the associated pairs suggest that they were largely compound words[1] (e.g., glow–worm, grave–digger, spark–plug). A pretest showed that subjective ratings of unitization were greater for the associated pairs than for the semantic pairs. On the associative recognition test, the hit rate was also greater for the associated pairs than for semantically related pairs. There was no difference in false-alarm rates, but it was not clear whether or not the rearranged pairs maintained any association or semantic relation. Only the associated pairs elicited an early bilateral frontal old/new ERP effect during retrieval that is typically associated with familiarity. Rhodes and Donaldson concluded that unitization leads to an enhancement of familiarity-based associative recognition.

Giovanello et al. (2006) provide converging evidence for the role of familiarity in the recognition of unitized pairs. They compared associative

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[1]Compound words have been distinguished in terms of the relationship between the two lexemes. For example, the modifier (the first word) can define a subclass of the general category denoted by the second word or head noun (e.g., darkroom). The two elements together can also denote a particular kind of unexpressed semantic head (e.g., skinhead or paleface, where the semantic head is "person"). A compound word can also express the "sum" or totality of what the two elements denote (e.g., bittersweet). Compound words are also distinguished as to whether the contribution of the meaning of each lexeme to the compound word is based on its original meaning (transparent) or a shifted meaning (opaque). Both members of a compound can be transparent (e.g., blueberry), the head member can be transparent and the other member opaque (e.g., strawberry), the head member can be can be opaque and the other member transparent (e.g., jailbird), and both members can be opaque (e.g., buttercup). The available evidence indicates that the encoding of familiar unspaced compound words is based on the components, but the meaning of a compound word is not constructed from its separate parts (Frisson, Niswander-Klement, & Pollatsek, 2008).

recognition for the two elements of compound words and unrelated word pairs in a group of amnesic patients and a matched group of middle-aged adults. During the study phase, the experimenter read a sentence aloud that incorporated either the two words of the unrelated pairs or the compound words. For each sentence, participants provided a rating of the likelihood of occurrence of the information conveyed in the sentence. After a 10-minute delay, the test phase began. At test, participants discriminated between studied unrelated word pairs and compound word pairs (e.g., landscape, blackmail, jailbird) and rearranged unrelated word pairs and rearranged compound word pairs (e.g., blackbird). Giovanello et al. found that both hit and false-alarm rates were significantly higher for compound words than for unrelated word pairs for both the control and the amnesic groups. However, only in the amnesic group did discrimination increase for compound words relative to unrelated word pairs; discrimination did not differ for the control group. Giovanello et al. concluded that enhanced familiarity induced by studying compound word pairs led the amnesic group to discriminate more effectively between studied and recombined compounds than between studied and recombined random word pairs. Giovanello et al. also found in a separate experiment that normal participants were more likely to base their associative recognition decisions for compound word pairs on the basis of familiarity as measured by the remember–know response procedure.

In a subsequent study based on Giovanello et al.'s (2006) associative recognition procedure, Ford et al. (2010) used blood-oxygen-level-dependent (BOLD) functional magnetic resonance imaging (fMRI) to identify neural activity during retrieval of unitized and nonunitized pairs. Unlike in Giovanello et al.'s study, participants created a simple sentence including the compound words or the words in the unrelated pair. After completion of the study phase, participants were placed in scanner to provide yes–no judgements to studied and nonstudied word pairs. Ford et al. found that recognition of previously presented compound words was associated with left perirhinal activity

(indicating use of familiarity), whereas recognition of unrelated word pairs was associated with activity in left hippocampus (indicating use of recollection). In terms of the behavioural results, however, Ford et al. did not find a significant difference in the hit and false-alarm rates or overall discrimination between compound and unrelated word pairs, although there was a trend toward higher hit and false-alarm rates for compound word pairs. One notable difference between the procedures of Ford et al. and Giovanello et al. (2006) was that participants were young adults (20–25 years) rather than older adults ($M = 59$ years).

The above studies examining associative recognition for meaningfully related word pairs provide evidence for unitization and the role of familiarity in these decisions. These studies, however, have not provided a consistent pattern of results. Whereas amnesics showed a discrimination advantage for compound word pairs over unrelated word pairs (Giovanello et al., 2006), normal adults typically did not show a difference (Ford et al., 2010; Giovanello et al., 2006; Rhodes & Donaldson, 2007). In contrast, Greve et al. (2007) did find a discrimination advantage for semantically related word pairs. Normal adults demonstrated a concordant increase in both hit and false-alarm rates for compound pairs (Giovanello et al., 2006), only an increase in hit rate (Rhodes & Donaldson, 2007), or no differences (Ford et al., 2010).

It is not clear why findings from previous studies have been inconsistent because differences in procedures make it difficult to isolate the reasons for the various results.

Associative recognition of compound word pairs bears a strong resemblance to the conjunction effect in item recognition. Both tasks involve discriminating between intact and rearranged compound words. In the associative task, the emphasis has been on contrasting recognition for compound versus noncompound word pairs. In the item recognition task, the focus has been on the false-alarm rates for the rearranged lures. In studies examining item recognition of compound words in the conjunction memory paradigm, significantly higher false-alarm rates are found for conjunction lures than for new words. For example, at study

the compound words *brainwash, hailstorm,* and *watchtower* are presented. During the recognition test, participants would see *brainwash* (a studied target), *brainstorm* (a conjunction lure), *watchmaker* (a feature lure), or *stockyard* (a new compound word). The proportion of old responses is higher for targets, next highest for conjunction lures, followed by feature lures, and then new stimuli (i.e., old > conjunction > feature > new; Jones & Jacoby, 2001; Reinitz, Lammers, & Cochran, 1992; Reinitz, Verfaellie, & Milberg, 1996). The increase in the false-alarm rate for conjunction lures is referred to as the conjunction effect. Jones and Jacoby (2001) argued that the higher false-alarm rate for conjunction lures than for new words occurs due to the greater familiarity of conjunction lures. It follows that rearranged compound word pairs in an associative recognition test should also be experienced as more familiar.

The purpose of the current study was to examine the contribution of familiarity in the associative recognition of unitized pairs based on preexperimental associations by comparing performance for compound (CW) and noncompound (NCW) or unrelated word pairs. Both types of word pairs were constructed in a counterbalanced manner to equate the familiarity of the individual words in each pair. Based on the findings of Giovanello et al. (2006) and the conjunction effect in item recognition, we predicted that both the false-alarm and the hit rate would be higher for CW than for NCW pairs in yes–no associative recognition (i.e., a concordant effect). The greater false-alarm rate would reflect the preexperimental familiarity of CW pairs. The increased hit rate would reflect familiarity and recollection arising from encoding during the study phase in addition to preexperimental familiarity. Thus, the increase in hit rate should be greater than the increase in false-alarm rate, resulting in a discrimination advantage for CW pairs over NCW pairs.

Seven experiments are reported. Yes–no associative recognition performance for CW and NCW pairs was compared in Experiments 1, 2, and 4A. The basis of the concordant effect found in Experiments 1 and 2 was examined using a two-alternative forced-choice procedure in Experiments 3A and 3B. In Experiment 4A, associative recognition of CW pairs was compared with NCW pairs that were repeated four times at study. Experiment 2 and Experiment 4B were also conducted to demonstrate that item recognition for the individual components is impaired for compound word pairs relative to unrelated word pairs, providing evidence of the unitization of the CW pairs. Finally, Experiment 5 was designed to see whether the difference in item recognition observed in Experiments 2 and 4B could be eliminated when the encoding task emphasized item information rather than associative information.

EXPERIMENT 1

The purpose of Experiment 1 was to compare associative recognition for CW and NCW pairs in a yes–no associative recognition task. A modified version of Giovanello et al.'s (2006) procedure was used for this purpose. The principal changes were as follows. First, the CW and NCW pairs were compared within rather than between lists. Secondly, the individual words of the pairs were counterbalanced in order to equate item information for the two types of pairs (see Table 1 for examples). Thirdly, pairs were presented with six spaces rather than one between each component (e.g., "land   scape" rather than "land scape") in order to emphasize the individual components of each pair and to better equate, procedurally, the presentation of CW and NCW pairs.

It was predicted that since words within CW pairs (e.g., air stream) are more easily unitized than words in NCW pairs (e.g., passion vine) due to prior learning, familiarity would be used to a greater extent in the recognition of CW pairs. This would be shown in a concordant pattern, where both hit and false-alarm rates would be significantly higher for CW than for NCW pairs. As the encoding of associative information should be much easier for CW pairs, the increase in hit rate should exceed the increase in false-alarm rate, giving rise to a discrimination advantage for CW pairs as well.

Table 1. *Examples of the counterbalanced compound and noncompound sets of word pairs used in each associative recognition experiment*

Set	Study		Test	
	CW	*NCW*	*CW*	*NCW*
A			**Intact**	**Intact**
	air stream	*death thing*	*air stream*	*death thing*
	home sick	*play wish*	*home sick*	*play wish*
	arm pit	*door pepper*	*arm pit*	*door pepper*
	lady like	*step mint*	*lady like*	*step mint*
	candle wax	*bar foot*	**Rearranged**	**Rearranged**
	slap stick	*passion vine*	*candle stick*	*bar vine*
	check list	*grape stool*	*check point*	*grape rest*
	needle point	*fruit rest*		
B			**Intact**	**Intact**
	death wish	*air home*	*death wish*	*air home*
	play thing	*stream sick*	*play thing*	*stream sick*
	door step	*arm lady*	*door step*	*arm lady*
	pepper mint	*pit like*	*pepper mint*	*pit like*
	foot rest	*candle list*	**Rearranged**	**Rearranged**
	bar stool	*slap check*	*foot stool*	*candle check*
	grape vine	*needle wax*	*grape fruit*	*needle stick*
	passion fruit	*point stick*		

Note: CW = compound word; NCW = noncompound word.

Method

Participants
All participants in each experiment were undergraduate students enrolled in a psychology course at Wilfrid Laurier University who participated for course credit. A total of 31 students participated in Experiment 1. One participant's data file was not included in the data analyses because of chance performance in the NCW condition (i.e., their hit rate was less than their false-alarm rate).

Materials and apparatus
The experiment was run on PC compatible laboratory computers equipped with 17″ LCD monitors and SuperLab 2.0 software (Cedrus Corp.) was used to control stimulus presentation and response recording. From a list of 160 compound words provided by Jones (2005), 48 CW pairs and 48 NCW pairs were constructed. To create the NCW pairs, the left word from one CW pair was paired with the right word from another CW pair. This was done to equate the individual words of the compound and NCW pairs. To create a rearranged

CW pair, the first member of the parent CW pair was paired with the second member of another CW pair. For example, the rearranged CW pair *check–point* was made from the parent CW pairs, *check–list* and *needle–point*. Two sets (A and B) were constructed to counterbalance the components of the CW and NCW pairs across participants. Examples of the intact and rearranged CW and NCW pairs in Sets A and B are shown in Table 1.

Procedure
At the beginning of the study phase, participants were told they would be presented with a list of word pairs presented one at a time on the screen. They were asked to try to form a relation between the words in each pair by forming either an image or a sentence combining the two words in the pair as this would help them remember the word pair at test. The critical portion of the study list consisted of 48 CW and 48 NCW pairs. In addition, there were two buffer pairs, one CW pair and one NCW pair, at the beginning and end of each study list to minimize

primacy and recency effects. The order of the study pairs (excluding buffers) was random, with a different random order for each subject. The two members of the CW and NCW pairs were separated by six blank spaces (e.g., heart   beat, death   clap). Each word pair appeared in the centre of the screen for 4 s with no interval between successive pairs. After the study phase was completed, for approximately 1 min duration, the experimenter presented the test instructions to the participants. They were informed of the difference between old (intact) and new (rearranged) test pairs and were instructed to press the "/" and "z" keys for old and new judgements, respectively. They were also asked to respond as accurately as possible. Response time was not mentioned. In addition, they were instructed to provide a confidence judgement for old and new responses. That is, after participants entered their old or new response, they made a confidence judgement by pressing 1 for "not sure", 2 for "sure", or 3 for "very sure".

During the test phase, each trial began with a test pair displayed in the centre of the screen in the same format as the study pairs. Test pairs remained on the screen until the participant responded, and response time was measured from the onset of presentation until the response was made. There were 16 intact and 16 rearranged CW pairs and 16 intact and 16 rearranged NCW pairs presented in a different random order for each participant.

Results and discussion

Initial analyses showed that there were no differences in the pattern of results between Pair Sets A and B, and the reported results are collapsed over this stimulus variable. The mean proportions of hits (correct old responses to intact pairs) and false alarms (incorrect old responses to rearranged test pairs) for CW and NCW pairs are presented in Table 2. The .05 level of significance was used to evaluate all statistical outcomes in all experiments.

A 2 (word pair type) × 2 (probe type) repeated measures analysis of variance (ANOVA) was conducted on the proportions of old responses. There was a significant main effect of test probe [$F(1, 29) = 133.3$, $MSE = .049$, $p < .001$, $\eta^2 = .821$]. The hit rate was significantly higher than the false-alarm rate showing that overall discrimination performance was above chance. There was also a significant main effect of word pair type [$F(1, 29) = 56.8$, $MSE = .010$, $p < .001$, $\eta^2 = .662$]; the hit and false-alarm rates were both greater for the CW than the NCW pairs, reflecting a concordant effect. The interaction between word pair type and test probe was not significant [$F(1, 29) = 0.314$, $MSE = .015$, $p = .579$, $\eta^2 = .011$]. Similar analyses of confidence judgements and response times showed that these measures were consistent with the concordant effect observed for hit and false-alarm rates.[2]

To further examine performance between conditions, corrected recognition scores (hit rate minus false-alarm rate) and signal detection theory estimates of discriminability (d') and response bias (C) were calculated. Analyses of corrected recognition scores and d' showed the same statistical patterns of results, and only the analyses of d' are reported. Mean estimates of d' and C are also shown in Table 2. A 2 (pair type) within-factor ANOVA revealed that there was no significant difference in d' estimates between CW and NCW pairs [$F(1, 29) = 1.13$, $MSE = 0.569$, $p = .297$, $\eta^2 = .038$]. The same analysis of estimates of C revealed that there was a significant difference in criterion placement between CW and NCW pairs [$F(1, 29) = 40.1$, $MSE = .121$, $p < .001$, $\eta^2 = .580$]. Participants adopted a more liberal decision criterion for CW than for NCW pairs.

As several researchers (e.g., Wixted, 2007; Yonelinas, 2002; Yonelinas & Parks, 2007) have

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[2]Statistical analysis showed that mean confidence for hits was higher for CW ($M = 2.82$, $SD = 0.16$) than for NCW pairs ($M = 2.71$, $SD = 0.20$), and mean confidence for correct rejections was lower for CW ($M = 1.98$, $SD = 0.40$) pairs than for NCW ($M = 2.09$, $SD = 0.41$) pairs. Response time for hits was faster for CW ($M = 1490$ ms, $SD = 653$) than for NCW pairs ($M = 1769$ ms, $SD = 503$), whereas response time for correct rejections did not differ for CW ($M = 1987$ ms, $SD = 659$) and NCW pairs ($M = 979$ ms, $SD = 506$).

Table 2. *Experiment 1: Mean hit and false-alarm rates, estimates of discrimination, and criterion placement for compound and noncompound word pairs*

	Accuracy			
Test pair	HR	FAR	d'	C
CW	0.84 (0.11)	0.36 (0.23)	1.67 (1.24)	−.37 (0.47)
NCW	0.69 (0.14)	0.24 (0.17)	1.47 (1.03)	0.19 (0.39)

Note: HR = hit rate; FAR = false-alarm rate; d' = estimate of discrimination; C = criterion placement; CW = compound word pairs; NCW = noncompound word pairs. Standard deviations of the means are given in parentheses.

suggested that analysis of ROC curves provides a more sensitive measure of recognition discrimination than d' or corrected recognition scores, ROC curves for CW and NCW pairs were derived from the associative recognition confidence judgements in the manner described by Yonelinas and Parks (2007). That is, ROCs were constructed by plotting hit and false-alarm pairs beginning with the most confidently recognized items [e.g., hits = P(6|old); false alarms = P(6|new)] then repeatedly recalculating the values by including the next most confidently recognized items [e.g., hits = P(6|old) + P(5|old); false alarms = P(6|new) + P(5|new); etc.]. The ROC curves presented in Figure 1 show no difference in discrimination

between CW and NCW pairs. In fact, a similar area under the curve was shown for associative recognition of both pair types.

The results of Experiment 1 showed a concordant pattern for hit and false-alarm rates. Hit and false-alarm rates were significantly higher for CW than for NCW pairs without a significant difference in overall discrimination. Although Giovanello et al. (2006) did not find such an effect in their first experiment, they did find a concordant effect for both amnesic and nonamnesic participants in their second experiment. Amnesic patients also showed a discrimination advantage for CW pairs whereas the control participants did not. The results of Experiment 1, therefore, provide a replication of Giovanello et al.'s Experiment 2 results for their nonamnesic participants. Moreover, our ROC analysis follows with Quamme et al.'s (2007) finding of no difference between associative recognition of unitized and nonunitized pairs in the control group.

The concordant effect can be explained by familiarity boosting the proportion of old responses for CW pairs, leading to increased hit rates and decreased correct rejection rates for CW pairs in contrast to NCW pairs. The pattern of confidence judgements and response times were also largely consistent with such a familiarity-based account. Mean confidence was higher for hits and lower
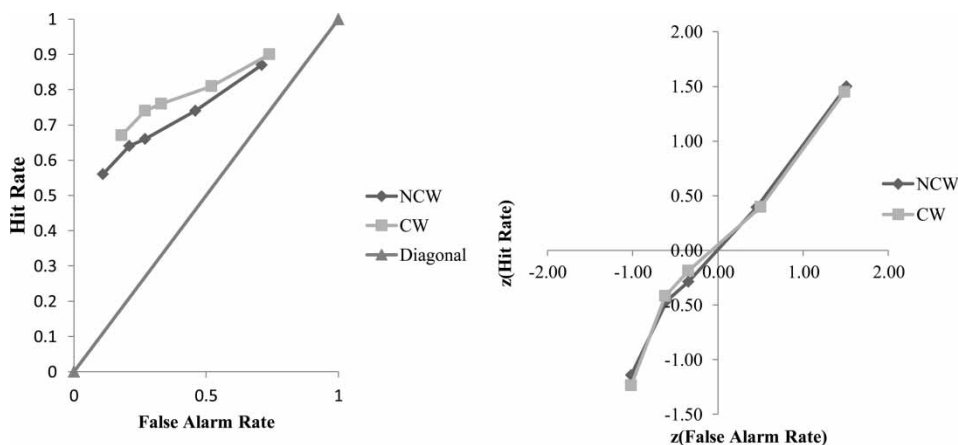

Figure 1. *Receiver-operating characteristic (ROC) analysis of averaged performance of all participants in associative recognition of noncompound word (NCW) pairs and compound word (CW) pairs in Experiment 1.*

for correct rejections for CW than for NCW pairs. Mean response times for hits were faster for CW than for NCW pairs, although there was no difference in response time for correct rejections.

Although the predicted concordant effect was found, there was no difference in the level of accuracy or discrimination between CW and NCW pairs. The absence of a discrimination advantage for CW pairs is somewhat surprising given that the encoding of relational information would be expected to be much easier for CW than for NCW pairs. Any such benefit for hit rate was nullified by the increase in the false-alarm rate. Experiment 2 was designed to replicate this pattern of results in a between-participants comparison of associative recognition for CW and NCW word pairs. A second purpose of Experiment 2 was to provide evidence for the unitization of CW pairs by comparing item recognition for the components of CW and NCW pairs.

EXPERIMENT 2

In Experiment 2, participants studied either CW or NCW pairs. They were then tested on both single item and associative yes–no recognition. Pairs of items are considered unitized when the well-integrated whole becomes more familiar than its constituents (Bastin et al., 2010). If the encoding of CW pairs emphasizes the unitized whole, then it follows that the encoding of the individual words of CW pairs would be diminished. In contrast, Hockley and Cristi (1996) showed that the encoding of the individual words of unrelated word pairs is not diminished when participants emphasized the encoding of associative information. It was predicted that single item recognition would be less accurate for the individual words from CW pairs than for words from NCW pairs. That is, there would be an encoding trade-off between the encoding of item and associative information for CW pairs but not for NCW pairs. Such a result would support the view that the CW pairs were encoded as unitized associations.

A second goal of Experiment 2 was to replicate the concordant effect seen for CW pairs in

Experiment 1 in a between-subject comparison. Experiment 2 also provided an additional test of whether or not there is a discrimination difference between CW and NCW pairs in yes–no associative recognition. To further test associative recognition discrimination, distractor pairs consisting of one old and one new item (half-old pairs) were included in addition to rearranged test pairs. Half-old pairs are equivalent to feature lures in the conjunction effect for item recognition. Based on the conjunction effect, it was expected that participants would make fewer false alarms to half-old pairs than to rearranged old pairs because half-old pairs would not be as familiar as rearranged old pairs (cf. Humphreys, 1978).

Method

Participants
A total of 46 students were tested; 22 participants were randomly assigned to the NCW pair condition, and 24 to the CW pair condition. Two participant data files in the NCW and four participant data files in the CW condition were not included in the data analyses because they showed chance performance for item discrimination. Note that excluding more participants from the CW than the NCW condition for chance performance works against the prediction that item recognition will be diminished in the CW condition.

Materials and apparatus
The materials and apparatus were the same as those in Experiment 1; however, an additional 32 compound words were taken from Jones's (2005) list of compound words.

Procedure
The study list consisted of 60 CW or 60 NCW pairs with two buffer pairs at the beginning and end of the list. Study instructions were the same as those in Experiment 1. In the test list, there were 10 intact and 10 rearranged word pairs and 10 studied and 10 new single items. For item recognition, the item was the second member of a word pair. In addition, there were 20 pairs composed of a studied item paired with a new item

that was not presented in the study list. The new item was always on the right of the pair. The order of test was random. Each test presentation began with an item or test pair displayed in the centre of the screen and remained on the screen until the participant responded. Associative recognition test instructions were the same as those in Experiment 1; however, for the single words, participants were instructed to press the "/" if the word had been shown at study and to press the "z" otherwise. Participants were also told that if they remembered seeing the word at study, to press the "/" key even if they did not remember the word that was presented with it at study.

Results and discussion

The mean proportions of hits and false alarms and estimates of d' and C for the associative and item recognition tests of CW and NCW pairs are presented in Table 3. Associative recognition (intact versus rearranged test pairs), pair recognition (intact versus half-old test pairs), and single item recognition tests were analysed separately.

Associative recognition
A 2 (probe: intact vs. rearranged) × 2 (pair type: CW vs. NCW) ANOVA was conducted on the proportions of old responses. There was a significant main effect of probe [$F(1, 38) = 248$, $MSE = .015$, $p < .001$, $\eta^2 = .867$]; hits were significantly higher than false alarms. Pair type was also significant [$F(1, 38) = 7.27$, $MSE = .032$, $p < .05$, $\eta^2 = .161$]; participants made more old responses to CW than to NCW pairs. The interaction between probe

and pair types was not significant [$F(1, 38) < 1$]. The increase in the proportion of old responses for CW compared to NCW pairs was comparable for both hits and false alarms.

A one-way ANOVA for pair type based on d' confirmed there was no difference in discrimination between CW and NCW pairs [$F(1, 38) < 1$]. The same comparison of criterion placement indicated that participants adopted a more liberal decision criterion for CW pairs and a more conservative criterion for NCW pairs [$F(1, 38) = 7.63$, $MSE = .302$, $p = .009$].

The results for association recognition replicated the findings of Experiment 1 in a between-participants comparison. Hit rates and false alarms were both higher for CW than NCW pairs, with no difference in overall discrimination.

Pair recognition
To examine recognition performance between intact and half-old test pairs, a 2 (old vs. new tests) × 2 (CW vs. NCW pairs) mixed ANOVA was conducted on the proportions of old responses. There was a significant main effect of probe [$F(1, 38) = 705$, $MSE = .014$, $p < .001$, $\eta^2 = .949$]; hits were higher than false alarms. Pair type was not significant [$F(1, 38) = 0.591$, $MSE = .009$, $p = .447$, $\eta^2 = .015$], but there was a significant interaction between probe and pair type [$F(1, 38) = 4.69$, $MSE = .068$, $p < .05$, $\eta^2 = .110$]. Hit rates were significantly higher for CW than for NCW pairs [$t(38) = 0.379$, $p = .373$; $t(38) = 2.276$, $p < .05$, respectively] whereas false alarms were similar for CW and NCW pairs.

Table 3. *Experiment 2: Mean hit and false-alarm rates for intact, rearranged, and half-old pairs and estimates of discrimination and criterion placement for item recognition and associative recognition of compound and noncompound pairs*

Test pair	Associative recognition							Item recognition			
	Intact HR	Rearranged FAR	Half-old FAR	d' (R)	C (R)	d' (H-O)	C (H-O)	Old HR	New FAR	d'	C
CW	0.92 (0.08)	0.38 (0.22)	0.14 (0.14)	2.10 (1.0)	−.64 (0.59)	2.96 (0.98)	−.21 (0.55)	0.60 (0.21)	0.20 (0.18)	1.54 (0.81)	0.36 (0.78)
NCW	0.84 (0.13)	0.24 (0.20)	0.18 (0.13)	2.12 (1.2)	−.16 (0.51)	2.25 (0.98)	−.09 (0.49)	0.74 (0.21)	0.17 (0.18)	2.34 (1.2)	0.25 (0.80)

Note: HR = hit rate; FAR = false-alarm rate; d' = estimate of discrimination; C = criterion placement; CW = compound word pairs; NCW = noncompound word pairs. Standard deviations of the means are given in parentheses.

A between-factor ANOVA comparing d' for intact and old–new pairs showed that discrimination was greater for CW than for NCW pairs [$F(1, 38) = 5.28$, $MSE = .959$, $p < .05$]. A one-way ANOVA was also conducted for estimates of criterion and showed no significant difference in criterion placement [$F(1, 38) = 0.549$, $MSE = .246$, $p = .463$].

Interestingly, when comparing associative recognition performance based on the discrimination of intact from half-old pairs, a different pattern of results emerged than was seen for discrimination of intact from rearranged papers. As expected, the hit rate was higher for CW than for NCW pairs, but the false-alarm rate was similar for the two types of rearranged pairs, producing a discrimination advantage for CW pairs. The half-old pairs are similar to feature lures in the conjunction effect for item recognition. The familiarity of the half-old pairs is sufficiently reduced to reverse the concordant effect seen for rearranged pairs. Thus, the compound word effect in associative recognition is very similar to the conjunction effect seen in item recognition in that the proportion of old responses is greatest for intact pairs and old compound words, next greatest for rearranged pairs and conjunctions lures, and lowest for new–old pairs and feature lures.

Item recognition

A 2 (old vs. new probe) × 2 (CW vs. NCW pair type) ANOVA was conducted on the proportion of old responses. Hits were significantly greater than false alarms [$F(1, 38) = 221$, $MSE = .022$, $p < .001$, $\eta^2 = .853$)]. There was no main effect of pair type [$F(1, 38) = 1.06$, $MSE = .056$, $p = .309$, $\eta^2 = .027$], but the interaction between probe and pair type was significant [$F(1, 38) = 6.75$, $MSE = .022$, $p < .05$, $\eta^2 = .151$]. The hit rate was higher, and the false-alarm rate was lower in the NCW condition than in the CW pair condition. A one-way ANOVA based on estimates of d' confirmed that item discrimination was higher in the NCW than in the CW condition [$F(1, 38) = 6.05$, $MSE = 1.07$, $p < .05$]. There was no significant difference in the estimates of criterion placement, $F(1, 38) < 1$.

The results of Experiment 2 showed, as predicted, that recognition accuracy is greater for single items studied in NCW pairs than for those in CW pairs. The hit rate was higher and the false-alarm rate lower for words studied in NCW than for those in CW pairs. Moreover, discrimination as estimated by d' was greater for items studied in unrelated word pairs. These results indicate that CW pairs were largely encoded as whole words instead of individual items and support the view that CW pairs are unitized at encoding. In contrast, recognition for the items in NCW pairs is more accurate because the encoding of associative information does not reduce the encoding of item information for unrelated word pairs (cf. Hockley & Cristi, 1996). In other words, there is an encoding trade-off between item and associative information for CW pairs, but not for NCW pairs.

A robust concordant effect was seen in the within- and between-subject comparisons of associative recognition for CW and NCW pairs. Within the framework of signal detection theory, this pattern of results can be explained by assuming that the underlying familiarity distributions representing old and new CW pairs are greater than the distributions representing NCW pairs due to the greater familiarity of the CW pairs. A concordant pattern without a change in discrimination can also occur, however, if participants adopted a more liberal decision criterion for CW pairs and a more conservative criterion for NCW pairs. This would also increase the hit and false-alarm rates for CW pairs without changing discrimination. A two-alternative forced-choice recognition test procedure was used in Experiments 3A and 3B to evaluate the role of response bias in associative recognition for CW and NCW pairs.

EXPERIMENTS 3A AND 3B

The goal of Experiments 3A and 3B was to determine whether response bias contributed to the higher hit and false-alarm rates observed for CW pairs in Experiment 1 using a two-alternative forced-choice recognition task. Major and Hockley (2007) successfully used forced-choice

recognition to distinguish between familiarity and response bias accounts of the different forms of the revelation effect. In Experiments 3A and 3B, two types of forced-choice test trials were compared. In the pure pair test conditions, intact CW pairs were tested with rearranged CW pairs, and intact NCW pairs were tested with rearranged NCW pairs. Response bias favouring one pair type cannot play a role in the pure test conditions as both test alternatives are the same type of pair. Therefore, any differences in recognition performance between these two types of tests must be due to differences in familiarity. Response bias, however, could play a role in the mixed pair test conditions where intact pairs of one pair type were tested with rearranged pairs of the other type. In these tests, a response bias to choose the CW test pair would increase the proportion of correct responses when CW pairs were the correct alternative and would decrease performance when NCW pairs were the correct choice. Thus, a comparison of accuracy in the pure and mixed test conditions in Experiment 3A would provide a measure of response bias in associative recognition of CW and NCW pairs.

In order to further evaluate a familiarity-based account of the concordant effect for CW pairs in the forced-choice procedure, a familiarity-only procedure developed by Quamme et al. (2007) and adapted by Bastin et al. (2010) to the forced-choice test procedure was implemented in Experiment 3B. The familiarity-only procedure facilitates greater use of familiarity than recollection. Quamme et al. found that performance in their unitized pair definition condition was significantly better than that in the nonunitized condition under familiarity-only instructions. In this procedure participants are instructed to make their recognition decisions as quickly as possible based only on degree of familiarity of the association and not the familiarity of the individual words. As Quamme et al. note, the familiarity-only procedure is not expected to eliminate the use of recollection, but reduce the amount of recollection used for each recognition decision. A second purpose of Experiment 3B was to replicate the results of Experiment 3A.

Method

Participants
A total of 28 students participated in Experiment 3A. Two participants' data files were not included in the data analyses because of chance performance in the NCW pair condition. A total of 31 students participated in Experiment 3B. One participant's data were not included in the analyses because of chance performance for NCW pairs.

Materials and apparatus
For both Experiments 3A and 3B, the apparatus and stimuli were the same as those in Experiment 1 with the exception that Super Lab 4.0 software (Cedrus Corp.) was used to control stimulus presentation and response recording.

Procedure
For Experiment 3A, the study phase was exactly the same as that in Experiment 1. The test pairs were also the same as those in Experiment 1. However, during the test phase two word pairs were presented, and participants were to select which pair had been presented at study. There were four discrimination conditions represented at test in the two-alternative forced choice task. Studied CW pairs were paired with rearranged CW pairs in one condition and with rearranged NCW pairs in another. Similarly, intact NCW pairs were paired with rearranged NCW pairs and with rearranged CW pairs in separate test conditions. For each test presentation, one pair was presented in the top half of the screen and one in the bottom half. A random half of the intact pairs were presented in the top portion of the screen and half in the bottom portion. The order of test presentation was random with a different random order for each participant. Participants pressed the "1" key to choose the top pair and the "2" key for the bottom pair. The test phase was subject paced.

For Experiment 3B, the study and test procedures were identical to those in Experiment 3A, except that participants were instructed to select the test alternative based on the degree of familiarity. Participants were told to press "1" if the top

word pair was more familiar or press "2" if the bottom word pair was more familiar. Participants were told to ignore the familiarity of the individual words, but to focus on the association, judging which pair was more familiar. Participants were not told about the difference between intact and rearranged pairs, but were informed about the difference between familiarity and recollection. Familiarity was described as retrieval of gist information compared to recollection as retrieval of specific details. They were asked to respond as soon as they got a feeling of familiarity for a pair without trying to recollect anything about it. To further increase familiarity-based responding, participants were also told to respond as quickly as possible.

Results and discussion

The results of Experiments 3A and 3B are analysed separately.

Experiment 3A

The mean proportion of correct responses, estimates of d', and mean response times for each test condition, are shown in Table 4. The d' values for the forced-choice task were computed from the proportion of correct responses corrected for this procedure (Macmillan & Creelman, 1991).[3] A 2 (CW vs. NCW target) × 2 (CW vs. NCW distractor) within-factor ANOVA was conducted on the proportion of correct responses, revealing a significant main effect of type of target [$F(1, 25) = 16.1$, $MSE = .184$, $p < .001$, $\eta^2 = .393$]. The proportion of correct responses was greater when CW rather than NCW pairs were the targets. There was also a significant main effect of type of distractor [$F(1, 25) = 4.99$, $MSE = .034$, $p < .05$, $\eta^2 = .166$]. Proportion correct was lower when CW rather than NCW pairs were distractors. The main effects were qualified by a significant interaction between target and distractor [$F(1, 25) = 7.91$,

$MSE = .034$, $p < .05$, $\eta^2 = .240$]. Discrimination of intact CW pairs was not affected by the nature of the distractor, whereas discrimination of intact NCW pairs was greater when tested with a rearranged NCW pair and worse with a rearranged CW pair. Paired t-test showed that proportion correct was higher for CW pairs than for NCW pairs in the pure test condition, $t(25) = 2.4$, $p < .05$, and in the mixed test condition, $t(25) = 3.8$, $p = .001$.

A 2 (target type) × 2 (distractor type) within-factor ANOVA was conducted on d' estimates, revealing a significant main effect of target [$F(1, 25) = 16.1$, $MSE = 0.722$, $p < .001$, $\eta^2 = .392$]. Discrimination was greater for CW than for NCW pairs. There was no significant main effect of distractor [$F(1, 25) = 2.01$, $MSE = 0.484$, $p = .168$, $\eta^2 = .075$], but the interaction between target and distractor was significant [$F(1, 25) = 5.21$, $MSE = 0.418$, $p < .05$, $\eta^2 = .172$]. The discrimination advantage for CW pairs was largely unaffected by the nature of the rearranged test pair whereas discrimination of NCW pairs was worse when tested with a CW rearranged pair. Paired t-test showed that discrimination was higher for CW pairs than for NCW pairs in the pure, $t(25) = 2.5$, $p < .05$, and the mixed, $t(25) = 3.7$, $p = .001$, test conditions.

The results of Experiment 3A demonstrate that the compound word effect in forced-choice recognition is seen as a discrimination advantage favouring the unitized pairs. Proportion correct was significantly greater for CW than for NCW pairs in the pure test conditions where response bias could not play a role. Response bias was seen in the mixed test condition, however, as accuracy was reduced for NCW intact pairs when tested with a rearranged CW pair compared to a NCW lure. Mean response time was also faster for CW than for NCW targets. Thus, it is likely that response bias contributed to the concordant effect seen in Experiment 1, but familiarity was the principal factor.

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[3]According to signal detection theory, the two-alternative forced-choice procedure produces a performance advantage over the yes–no procedure of approximately $\sqrt{2}$. Thus, it has been proposed to divide the forced-choice d' score by $\sqrt{2}$ to compensate for this advantage (Hacker & Ratcliff, 1979; Macmillan & Creelman, 1991).

Table 4. *Experiments 3A and 3B: Mean proportions of correct responses, mean correct response time, and mean d′ estimates for the different combinations of intact and rearranged compound and noncompound test pair alternatives*

Two-alternative forced-choice condition	Proportion correct		Response time		d′	
	Exp. 3A	Exp. 3B	Exp. 3A	Exp. 3B	Exp. 3A	Exp. 3B
Intact CW vs. rearranged CW	0.92 (0.08)	0.81 (0.15)	2243 (759)	1981 (402)	2.31 (0.98)	1.46 (0.908)
Intact CW vs. rearranged NCW	0.92 (0.06)	0.84 (0.11)	2260 (746)	1912 (439)	2.22 (0.86)	1.69 (1.01)
Intact NCW vs. rearranged CW	0.80 (0.16)	0.70 (0.20)	2679 (1030)	2101 (476)	1.36 (0.87)	0.91 (0.94)
Intact NCW vs. rearranged NCW	0.87 (0.11)	0.75 (0.15)	2774 (1602)	2237 (566)	1.84 (0.89)	1.10 (0.83)

Note: Response time in ms. CW = compound word pairs; NCW = noncompound word pairs; Exp. = Experiment. Standard deviations of the means are given in parentheses.

Experiment 3B

The mean proportion of correct responses, estimates of $d′$, and mean responses times for each test condition are shown in Table 5. The same ANOVA analysis was conducted for Experiment 3B, revealing a significant main effect of target [$F(1, 29) = 16.3$, $MSE = .018$, $p < .001$, $\eta^2 = .361$]. Proportion correct was higher for CW than for NCW pairs. There was no significant effect of type of distractor [$F(1, 29) = 2.03$, $MSE = .019$, $p = .165$, $\eta^2 = .066$], and the interaction between target and distractor was not significant, $F(1, 29) < 1$. Paired t-tests showed that proportion correct was higher for CW pairs than for NCW pairs in both the pure, $t(30) = 2.47$, $p < .05$, and the mixed test conditions, $t(30) = 3.21$, $p = .003$.

The same ANOVA conducted on estimates of $d′$ also revealed that discrimination was higher for CW than for NCW pairs [$F(1, 29) = 16$, $MSE = 0.619$,

Table 5. *Experiment 4A: Mean hit and false-alarm rates, estimates of discrimination, and criterion placement for compound, noncompound, and repeated NCW word pairs*

Test pair	HR	FAR	d′	C
CW	0.80 (0.11)	0.40 (0.23)	1.37 (1.24)	−.38 (0.53)
NCW	0.58 (0.14)	0.18 (0.17)	1.39 (1.0)	0.48 (0.45)
R-NCW	0.96 (0.05)	0.32 (0.17)	2.6 (0.91)	−.77 (0.34)

Note: HR = hit rate; FAR = false-alarm rate; $d′$ = estimate of discrimination; C = criterion placement; CW = compound word pairs; NCW = noncompound word pairs; R-NCW = repeated noncompound word pairs. Standard deviations of the means are given in parentheses.

$p < .001$, $\eta^2 = .36$]. There was also no significant main effect of distractor [$F(1, 29) = 1.97$, $MSE = 0.660$, $p = .17$, $\eta^2 = .063$] and no significant interaction [$F(1, 29) = .019$, $MSE = 0.010$, $p = .892$, $\eta^2 = .001$]. Paired t-tests again showed that discrimination was higher for CW pairs than for NCW pairs for pure test, $t(30) = 3.6$, $p < .001$, and mixed test, $t(30) = 2.97$, $p = .006$, comparisons.

Participants in Experiment 3B were instructed to respond as quickly as possible based on their feelings of familiarity. Therefore, if participants were able to follow these instructions, mean response times should be faster in Experiment 3B than in Experiment 3A where participants did not receive such instructions. A 2 (Experiment 2 vs. Experiment 3) × 2 (CW vs. NCW target) × 2 (CW vs. NCW distractor) mixed-factor analysis was conducted to compare the correct response times in Experiments 3A and 3B. There was a significant main effect of experiment [$F(1, 54) = 5.21$, $MSE = 1,986,151$, $p < .001$, $\eta^2 = .088$]. Overall correct response time was faster in Experiment 3B ($M = 2058$ ms) than in Experiment 3A ($M = 2489$ ms). This comparison indicates that participants followed instructions introduced in Experiment 3B to respond as quickly as possible. There was also a significant main effect of target [$F(1, 54) = 15.7$, $MSE = 431,553.61$, $p < .001$, $\eta^2 = .226$]. For both Experiments 3A and 3B, mean response time was faster for CW than for NCW targets. There was no significant main effect of distractor [$F(1, 54) = 1.02$, $MSE = 104,642.6$, $p = .315$, $\eta^2 = .019$]. The interaction

between target and distractor [$F(1, 54) = 1.70$, $MSE = 165,029$, $p = .198$, $\eta^2 = .030$] and the interaction between target, distractor, and experiment [$F(1, 54) = 0.336$, $MSE = 165,029$, $p = .564$, $\eta^2 = .006$] were not significant.

The results of Experiment 3B replicated the forced-choice discrimination advantage for CW pairs seen in Experiment 3A. The finding of a discrimination advantage for CW compared to NCW pairs in Experiments 3A and 3B contrasts with the finding of no difference in discrimination seen in Experiments 1 and 2. Some researchers have suggested that differences in sensitivity between yes/no and forced choice could arise because of differences in the length of the test list and resulting differences in study–test lag (e.g., Bayley, Wixted, Squire, & Hopkins, 2008). An analysis of shorter versus longer study–test intervals in the test lists of Experiment 1 did not show a decline in discrimination.[4] This unexpected difference in discrimination with test format is considered further in the General Discussion.

The results of Experiment 3B are consistent with the view that the recognition advantage for CW pairs was largely due to their increased familiarity. The CW pair advantage is similar in this respect to the advantage of word pairs unitized by compound definitions (Quamme et al., 2007) and the recognition advantage for within-domain associations due to their easier unitization (Bastin et al., 2010). Experiments 4A and 4B were designed to compare yes–no recognition for once-presented CW and NCW pairs with that for familiarized NCW pairs that were repeated four times at study.

EXPERIMENTS 4A AND 4B

The purpose of Experiments 4A and 4B was to compare the effects of the preexperimental familiarity of unitized associations to study-induced familiarity of repeated NCW pairs. Repeating NCW pairs during the study phase may induce a similar unitization effect to that for CW pairs. Kilb and Naveh-Benjamin (2011) argued that repeating unrelated face–scene pairs prior to the study phase increased their subsequent pair familiarity due to unitization. In their study, they examined whether the associative deficit in older adults would be reduced when they relied more on familiarity in associative recognition.

The age-related associative deficit in older adults is shown by reduced accuracy in yes/no associative recognition for unrelated items in a pair compared to that for young adults. One reason for the age-related associative deficit is older adults' reduced use of recollection when retrieving associations. As numerous researchers using different methodologies have suggested, there is a reduced use of recollection as people age (e.g., Jennings & Jacoby, 1997; Light, Patterson, Chung, & Healey, 2004). Kilb and Naveh-Benjamin (2011) repeated individual items and item pairs prior to face–scene pairs being presented at study. Older adults showed higher yes–no recognition discrimination for repeated pairs than for pairs consisting of repeated items and concluded that pair familiarity brought about by repeating pairs reduced older adults' associative memory deficit. Importantly, when comparing the pattern of hits and false alarms for repeated pairs compared to pairs presented once, they found that both young and older showed higher hits but lower false alarms for repeated pairs than for pairs consisting of repeated items.

Experiment 4A was designed to compare yes–no associative recognition performance for once-presented CW and NCW pairs with that for NCW pairs that were shown four times in the study list (repeated noncompound word,

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[4]We thought a more direct approach to examine whether test interference due to study and test delay was responsible for the absence of discrimination in yes–no associative recognition test would be to compare discrimination of CW and NCW pairs in the first half to that in the second half of the test lists of Experiment 1. This analysis, however, showed no difference in the mean estimates of d'. The main effect of test list half was not significant [$F(1, 29) = 3.58$, $MSE = 6.67$, $p = .069$, $\eta^2 = .110$], but there was a trend for overall discrimination to increase from the first half (1.38) to the second half (1.86) of the test list. There was no significant main effect of pair type [$F(1, 29) = 2.50$, $MSE = 2.46$, $p = .125$, $\eta^2 = .079$]. Moreover, the interaction between test list half and pair type did not approach significance [$F(1, 29) = 0.073$, $MSE = 0.088$, $p = .789$, $\eta^2 = .078$].

R-NCW, pairs). Would associative recognition of R-NCW pairs show a concordant pattern similar to CW pairs or a discrimination advantage as found by Kilb and Naveh-Benjamin (2011)? In Experiment 4B, the study phase was the same as that in Experiment 4A but item recognition for words studied in CW, NCW, and R-NCW pairs was examined. The purpose of Experiment 4B was to replicate the decrease in item recognition for words from CW pairs seen in Experiment 2 and to determine whether item recognition for words from R-NCW pairs shows a similar or opposite pattern of results.

Method

Participants
A total of 32 students participated in Experiment 4A. Two participant data files were not included in the data analyses because of chance performance in the NCW condition. In Experiment 4B, a total of 26 students were tested.

Materials and apparatus
For Experiment 4A, the materials and apparatus were the same as those in previous experiments. However, an additional 96 compound words were taken from the Jones (2005) list and added into the 160 CW list used in previous experiments, in order to create the 36 repeated NCW pairs. Similar to Experiment 1, to create the NCW pairs, a left member from one CW pair was paired with the right member from another CW pair. Two sets (A and B) were constructed to counterbalance the components of the CW and NCW pairs. For Experiment 4B, the materials and apparatus were the same as those in Experiment 4A; however, an additional 72 new single words were taken from components of compound words in Jones's (2005) list.

Procedure
For Experiment 4A, the procedure was the same as that in Experiment 1; however, during the study phase the 36 R-NCW pairs were presented four times in four different study blocks. For each block, 9 CW pairs, 9 NCW pairs, and 36

R-NCW pairs were presented in a random order. The 36 R-NCW pairs were repeated in each block. During the test phase, 12 intact and 12 rearranged pairs of each pair type were presented in a different random order for each participant. For Experiment 4B, the study phase was exactly the same as that in Experiment 4A; however, during the test phase participants made only item recognition judgements. Thirty-six words from each pair type, CW, NCW, and R-NCW, were presented. For half the studied pairs, the item was the first item of the pair, whereas for the other half of the studied pairs, the item was the second item of the pair. In addition, 72 new words were presented. The test list was shown in random order and was subject based.

Results and discussion

For Experiment 4A, the mean proportion of hits and false alarms for CW, NCW, and R-NCW pairs are presented in Table 5. A 3 (word pair type) × 2 (probe type) repeated measures ANOVA was conducted on the proportion of old responses. There was a significant main effect of test probe [$F(1, 29) = 311$, $MSE = .033$, $p < .001$, $\eta^2 = .915$]. The hit rate was significantly higher than the false-alarm rate, showing that overall discrimination was above chance. There was also a significant main effect of word pair type [$F(2, 58) = 74.9$, $MSE = .016$, $p < .001$, $\eta^2 = .721$]. Overall old responses were highest for repeated NCW pairs, followed by CW pairs, and then lowest for nonrepeated NCW pairs. There was also a significant interaction between probe and word pair type [$F(2, 58) = 18.0$, $MSE = .016$, $p < .001$, $\eta^2 = .384$]. Both hits and false alarms were higher for CW and R-NCW pairs than for NCW pairs [$t(29) = 6.02$, $p < .001$; $t(29) = 4.567$, $p < .001$; $t(29) = 6.28$, $p < .001$; $t(29) = 11.69$, $p < .001$]. However, hits and false alarms were lowest for nonrepeated NCW pairs.

A 3 (word pair type) one-way ANOVA was conducted on d' scores. There was a significant main effect of word pair type [$F(2, 58) = 26.7$, $MSE = 0.560$, $p < .001$, $\eta^2 = .480$]. Paired t-tests

showed that discrimination was higher for R-NCW pairs than for NCW and CW pairs [$t(29) = 5.52$, $p < .001$; $t(29) = -6.31$, $p = .001$, respectively]. As in Experiment 1, discrimination was similar for CW and NCW pairs, $t(29) = -0.096$, $p = .924$. The same analysis revealed a significant effect of criterion placement [$F(2, 58) = 86.6$, $MSE = 0.144$, $p < .001$, $\eta^2 = .749$]. Participants showed the most liberal criterion for R-NCW pairs and the most conservative criterion for NCW pairs. Criterion placement was more liberal for R-NCW than for CW and NCW pairs [$t(29) = -4.3$, $p < .001$; $t(29) = -16$, $p < .001$, respectively] and more liberal for CW than for NCW pairs, $t(29) = -7.3$, $p < .001$.

The ROC curves presented in Figure 2 show no difference in discrimination between CW and NCW pairs. A similar area under the curve was shown for associative recognition of both pair types. Discrimination was higher for R-NCW pairs than for CW and NCW pairs, as supported by a higher area under the curve for R-NCW pairs than for CW and NCW pairs.

The results of Experiment 4A showed a different pattern of results for R-NCW pairs than for once-presented CW pairs. The hit rate was higher, and the false-alarm rate was lower for R-NCW pairs than for CW pairs (i.e., a mirror pattern; cf. Glanzer & Adams, 1985). Importantly, although a

discrimination advantage was seen for R-NCW pairs, there was no difference in discrimination between CW and nonrepeated NCW pairs, replicating the results of Experiments 1 and 2. The discrimination advantage for R-NCW pairs does not appear to be due to unitization. Contrary to Kilb and Naveh-Benjamin's (2011) suggestion that repeating unrelated pairs leads to unitization, the findings of the current experiment do not support such a suggestion. It is more likely that repeated presentation led to a stronger association rather than unitization. Thus, in the framework of dual-process theory, repetition of NCW pairs led to both an increase in recollection and study-induced familiarity. Hits were higher due to the increased contributions of both recollection and familiarity. In contrast, false alarms were lower than CW pairs but higher than nonrepeated NCW pairs, because the increase in recollection could partially offset the increase in study-induced familiarity (i.e., recall-to-reject; Rotello & Heit, 2000).

Experiment 4B

Mean hit rates showed item recognition to be highest for R-NCW pairs ($M = 0.88$, $SD = 0.09$), next highest for NCW pairs ($M = .64$, $SD = .12$), and lowest for CW pairs ($M = .59$, $SD = .13$). The mean false-alarm rate was .24 ($SD = .07$). A one-way ANOVA based on hit rates showed a
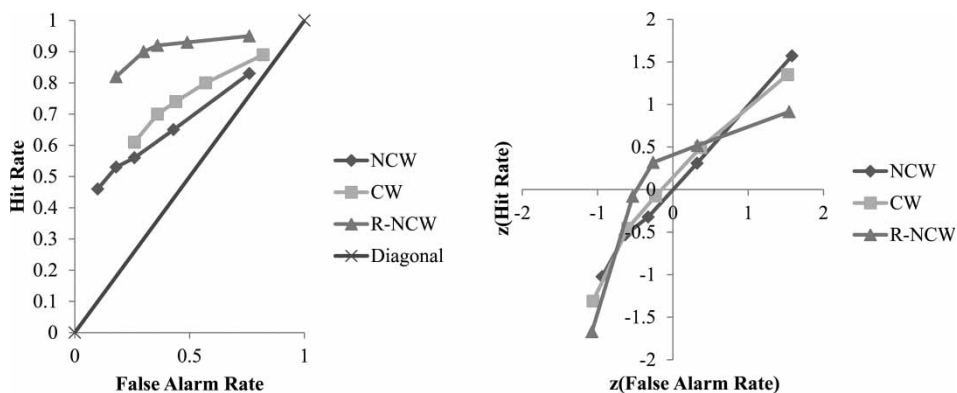

Figure 2. Receiver-operating characteristic (ROC) analysis of averaged performance of all participants in associative recognition of noncompound word (NCW) pairs, repeated noncompound word (R-NCW) pairs, and compound word (CW) pairs in Experiment 4.

significant main effect of type of word pair [$F_{(2, 75)} = 46.1$, MSE = .645, $p < .001$, $\eta^2 = .552$]. Two-tailed paired-sample t-tests showed item recognition for R-NCW to be higher than that for NCW and CW pairs [$t(25) = -12.9$, $p < .001$; $t(25) = -12.8$, $p < .001$, respectively] and item recognition for CW pairs to be lower than that for NCW pairs, $t(25) = -3.74$, $p = .001$.

The results of Experiment 4B replicated the item recognition disadvantage for words studied in CW compared to NCW word pairs seen in Experiment 2. In contrast, item recognition was greater for items studied in R-NCW pairs, indicating that repetition of NCW pairs benefited both associative recognition and item recognition of the individual components of NCW pairs. Thus, the results of Experiment 4B provide further evidence that CW pairs are unitized whereas R-NCW pairs are not.

If the encoding of the individual components of CW pairs is diminished due to unitization when associative information is emphasized, it follows that the encoding of item information should improve when item information is emphasized at encoding. Experiment 5 was designed to test this possibility.

EXPERIMENT 5

If unitization of CW pairs at encoding is responsible for reduced item recognition of the components of CW compared to NCW pairs seen in Experiments 2 and 4B, then item recognition should not be reduced if the unitization of CW pairs is minimized at encoding. To reduce the unitization of CW pairs in Experiment 5, participants were instructed to encode the items of each word pair as individual items. This was done using Tulving and Osler's (1968) and Winograd, Karchmer, and Russell (1971) cued recognition procedure where the target item is presented in capital letters and the cue word in lower case. Participants in both the CW and NCW pair conditions were told they would be tested on their recognition of the second member of the pair, the capitalized word. Moreover, they were told that

their recognition accuracy would be improved if they also studied the first member of the pair.

It was hypothesized that item recognition would be similar for CW and NCW pairs, since the study instructions emphasized the encoding of the individual items rather than the associations. By encoding CW pairs as individual items, participants would be prevented from encoding CW pairs as whole units as they did in the previous experiments, and, as a consequence, item recognition should not suffer. Pair type was manipulated between participants.

Method

Participants
Twenty-two participants studied NCW pairs, and 22 participants studied CW pairs. Two participant data files from each pairs condition were not included in the data analyses because they showed chance performance for item discrimination.

Materials and apparatus
The materials and apparatus were exactly the same as those in Experiment 4A.

Procedure
Participants were randomly assigned to either the CW or the NCW condition. During the study phase, participants were presented with a list of 60 word pairs presented one at a time on the screen. Each word pair appeared in the centre of the screen for 4 s with no interval between pairs. As in the previous experiments, there were six spaces between the words of each pair. The left member of the pair was the cue word in lower case, and the right member of the pair was the target word in upper case. For example, participants in the CW pair condition would see the word pair "night MARE", whereas those in NCW pair condition would see the word pair "door PEPPER".

The instructions were adapted from Tulving and Osler (1968). Participants were told:

Your job in this session is to remember as many of the capitalized words as you can. Although you are responsible for remembering the capitalized words, you should also pay close attention to the words with which the capitalized words are paired, because

making associations between the two words on each slide may help you to better remember the capitalized words. (p. 596)

The order of the study pairs (excluding buffers) was random, with a different random order for each subject.

After the study phase was completed, for approximately 1 min duration, the experimenter presented the test instructions to the participants. Participants were informed they would be presented with the capitalized words either with a cue word or as a single item. They were instructed to press the "z" if they had not seen the capitalized word at study or press the "/" if they had seen the capitalized word at study. Participants were also told that if they saw the capitalized word with another word, to use the first word in lower-case letters as a cue to help in deciding whether the capitalized word was old or new. They were also instructed to respond as accurately as possible. Response time was not mentioned.

The test list consisted of 10 old items with the same old cue, 10 old items with a different old cue, 20 new items with an old cue, 10 old single items, and 10 new single items. Cues were presented on the right in lower-case letters, and recognition test probes were presented in capital letters to the right of a cue or in the centre of the screen. The order of the tests was random, and the test presentation was subject paced.

Results and discussion

Mean hit and false-alarm rates and estimates of d' and C for single and cued item recognition are shown in Table 6. Single item and cued item recognition were analysed separately.

Single item recognition

A 2 (old vs. new probe) × 2 (CW vs. NCW pair type) ANOVA was conducted on the proportion of old responses. Hits were significantly higher than false alarms [$F(1, 38) = 361.6$, $MSE = 5.56$, $p < .05$, $\eta^2 = .905$]. The main effect of pair type [$F(1, 38) = 0.083$, $MSE = .003$, $p = .775$, $\eta^2 = .002$] and the interaction between probe and pair type [$F(1, 38) = 1.857$, $MSE = .029$, $p = .181$, $\eta^2 = .047$] were not significant. A one-way ANOVA based on d' estimates confirmed that discrimination of words from CW and NCW pairs did not differ reliably [$F(1, 38) = 0.559$, $MSE = .441$, $p = .459$]. There was also no significant difference in criterion placement [$F(1, 38) = 0.207$, $MSE = .095$, $p = .652$].

Cued item recognition

A 2 (cue: same cue vs. different cue) × 2 (pair type: CW vs. NCW) ANOVA conducted on hit rates revealed a significant main effect of cue [$F(1, 38) = 22.6$, $MSE = .028$, $p < .01$, $\eta^2 = .373$]. Hits were higher in the same cue (.82) than in the different cue condition (.67). The hit rate was also significantly greater for NCW (.78) than for CW (.71) items [$F(1, 38) = 4.38$, $MSE = .120$, $p = .043$, $\eta^2 = .103$]. The interaction between cue and pair type was not significant [$F(1, 38) = 1.37$, $MSE = .028$, $p = .250$, $\eta^2 = .035$]. The false-alarm rate was also greater for NCW (.32) than for CW (.29) pairs, but this difference was not reliable, $t(38) = -0.646$, $p = .522$.

Table 6. *Experiment 5: Mean hit and false-alarm rates and estimates of d' and C for cued item recognition for same and different cues and single item recognition for words in the compound and noncompound pair conditions*

Test pair	Old–same HR	Old–different HR	Half-old FAR	Cued item recognition				Single item recognition			
				d' (S)	C (S)	d'(D)	C (D)	Old HR	New FAR	d'	C
CW	0.80 (0.18)	0.61 (0.17)	0.29 (0.14)	1.7 (0.93)	−.20 (0.56)	1.02 (0.68)	0.15 (0.54)	0.69 (0.19)	0.20 (0.16)	1.8 (0.88)	0.30 (0.72)
NCW	0.84 (0.10)	0.73 (0.16)	0.32 (0.15)	1.8 (0.88)	−.33 (0.51)	1.27 (0.79)	−.08 (0.47)	0.74 (0.15)	0.18 (0.17)	2.0 (0.90)	0.20 (0.63)

Note: HR = hit rate; FAR = false-alarm rate; C = criterion placement; S = same cues; D = different cues; CW = compound word pairs; NCW = noncompound word pairs. Standard deviations of the means are given in parentheses.

A 2 (cue) × 2 (pair type) ANOVA based on d' estimates showed that discrimination was greater in the same cue (1.74) than in the different cue (1.14) condition [$F(1, 38) = 15.6$, $MSE = 0.461$, $p < .001$, $\eta^2 = .291$]. The main effect of pair type, $F(1, 38) < 1$, and the interaction between cue and pair type, $F(1, 38) < 1$, did not approach significance. The same analysis for estimates of criterion showed that criterion placement was lower in the same cue ($-.26$) than in the different cue (.04) condition [$F(1, 38) = 15.6$, $MSE = .115$, $p < .001$, $\eta^2 = .291$]. The main effect of pair type [$F(1, 38) = 1.59$, $MSE = .431$, $p = .215$, $\eta^2 = .04$] and the interaction between cue and pair type, $F(1, 38) < 1$, were not reliable.

The results of Experiment 5 show that when the encoding of the single words of each study pair was emphasized, discrimination was similar for targets from CW and NCW pairs in tests of both single item and cued item recognition. Not surprisingly, in cued item recognition discrimination was also greater when the same study cue was presented at test rather than a different study cue. These results stand in contrast to the results of Experiments 2 and 4B where item recognition was worse for words from CW than for those from NCW pairs. Thus, when participants are encouraged to encode CW pairs as individual units, item recognition is similar to that of NCW pairs. Essentially, when unitization is prevented (or substantially reduced), item information for CW pairs is similar to that for NCW pairs. Conversely, when unitization is encouraged at encoding, item information is reduced for words in CW compared to NCW pairs. Thus, unitization of CW pairs represents a gestalt where the whole is greater than the sum of the parts.

GENERAL DISCUSSION

The goal of the current study was to examine how unitization of intraitem associations affects associative recognition. Compound words, known from studies of the conjunction effect in item recognition to be falsely recognized due to their familiarity, were used in both yes–no and forced-choice tests of associative recognition.

In tests of yes–no associative recognition, a concordant effect was found; hit and false-alarm rates were significantly greater for CW pairs than for NCW pairs with no overall difference in discrimination. These results replicate Giovanello et al.'s (2006) Experiment 2 findings for their nonamnesic control group. However, the lack of a discrimination advantage for CW pairs contrasts with Greve et al.'s (2007) finding of both a concordant effect and a discrimination advantage for semantically related pairs.

The pair recognition results of Experiment 2 also showed that the false-alarm rate was less for half-old (i.e., feature lures) than for rearranged (i.e., conjunction lures) pairs. Together, the results of Experiments 1 and 2 provide an associative recognition analogue of the compound word effect seen in item recognition. In both the item and associative recognition versions of the compound word effect, there is a higher false-alarm rate for conjunction lures than for feature lures (cf. Jones & Jacoby, 2001; Reinitz et al., 1996).

Jones and Jacoby's (2001) familiarity-based explanation of the conjunction memory effect seen in item recognition is also consistent with the concordant effect for CW pairs in associative recognition. Both intact and rearranged CW pairs would have a greater degree of familiarity than NCW pairs because of their preexperimental history. In addition, unitization of the CW pairs would provide a basis for participants to use familiarity to make their associative recognition decisions in the same way as they can use familiarity in making recognition judgements for individual words. This interpretation of the CW pair effect is similar to Greene's (1999) account of the familiarity effect in item recognition. Greene found that both hit and false-alarm rates were greater for the familiarized items than for the nonfamiliarized items.

Experiments 3A and 3B provide further evidence in support of a familiarity-based account of associative recognition for CW pairs. The results of Experiment 3A demonstrated a recognition advantage for CWs in a two-alternative

forced-choice recognition test, indicating that the concordant effect seen in yes–no recognition is more likely due to familiarity rather than simply a response bias, although response bias could also contribute to the concordant effect. In contrast to the overall results of Experiments 1 and 2, however, the compound word effect found in Experiment 3A was seen as a discrimination advantage; CW pairs were more accurately recognized than NCW pairs. This discrimination advantage was also accompanied by faster correct response times for CW pairs. Interestingly, the nature of the distractor test pair had no effect on the recognition of CW pairs, whereas rearranged CW pair distractors reduced recognition performance for NCW pair targets. The results of Experiment 3B, using a familiarity-based recognition procedure developed by Quamme et al. (2007), replicated the general pattern of accuracy and response time advantages for CW pairs seen in Experiment 3A and provided further support for a familiarity interpretation of the compound word effect in associative recognition.

The finding of a discrimination advantage for CW pairs in the forced-choice tests of Experiments 3A and 3B but not in the yes–no tests of Experiments 1, 2, and 4A was unexpected. The difference in discrimination with test format, however, can be explained by the role of familiarity in each task. A number of researchers have argued that familiarity makes a greater contribution to recognition in the forced-choice than in the yes–no test procedure (e.g., Aggleton & Shaw, 1996; Bastin & Van der Linden, 2003; Clark, Hori, & Callan, 1992; Parkin, Yeomans, & Bindschaedler, 1994; Patterson & Hertzog, 2010). One way to test whether familiarity-based responses contribute more to forced-choice than yes–no associative recognition is to test older adults' associative recognition in both test formats. Since a number of researchers have suggested that older adults have impaired use of recollection, but intact familiarity (Bastin & Van der Linden, 2003; Jennings & Jacoby, 1997; Patterson & Hertzog, 2010), older adults should show higher associative recognition performance in the forced-choice than in the yes/no test. Bastin and Van der Linden (2003)

examined whether the contribution of familiarity to recognition decisions varied by type of test format for both young and older adults. They had both young and older adults study photographs of faces followed by a yes/no or forced-choice recognition test for target and distractor faces. After making their recognition decision, participants also made remember–know judgement to indicate whether their recognition decision was based on recollection or familiarity in the absence of recollection. The researchers found that both young and older adults relied more on familiarity (know responses) in the forced-choice task than in the yes–no task. They also found that the older participants relied more on familiarity than recollection and performed better in the forced-choice task, whereas younger participants showed the opposite pattern.

The findings from Experiments 3A and 3B can also be explained in terms of the greater contribution of familiarity-based decisions in the forced-choice procedure. A discrimination advantage was shown for CW pairs in the forced-choice tests but not in yes/no tests because familiarity contributed to a greater extent to the discrimination advantage for unitized pairs in the forced-choice tests.

In Experiment 4A, the effects of unitization of CW pairs were compared to strengthened associations brought about by repeating NCW pairs. There was a replication of the CW concordant effect as shown by higher hits and higher false-alarm rates for CW pairs than for once-presented NCW pairs with no difference in discrimination. Interestingly, the hit rate was higher, and the false-alarm rate was lower for R-NCW pairs than for CW pairs, and discrimination was highest for R-NCW than for both CW and NCW pairs. The fact that presenting NCW pairs four times during the study phase led to a different pattern of results from that for associative recognition of CW pairs suggests that unitization cannot be brought about by mere repetition of unrelated pairs during the study phase.

In the framework of dual-process theory, repeating NCW would lead to higher familiarity and recollection. Hits were highest for repeated

NCW pairs because both familiarity and recollection contributed to the correct old responses. False alarms were lower for repeated NCW pairs than for CW pairs because the increase in recollection would serve to help oppose the increase in familiarity of the rearranged pairs. Experiments 2 and 4B were designed to test the prediction that the encoding of CW pairs that emphasizes the unitized whole results in an encoding deficit for the individual components of these pairs. Hockley and Cristi ([1996](#)) demonstrated that the encoding of item information does not suffer when the encoding of associative information between unrelated words is emphasized. The results of Experiments 2 and 4B showed that, while there was no difference in associative discriminability between CW and NCW pairs, single item recognition was lower for words studied in CW than for those in NCW pairs. That is, there was an encoding trade-off between item and associative information for the CW pairs. Experiment 4B also showed that single item recognition was highest for words from repeated NCW pairs, providing further evidence that repetition at study does not produce unitization. The results of Experiments 2 and 4B provide strong empirical support for the assumption that participants encode CW pairs as unitized constructions and that the unitized whole is greater than the sum of its parts.

Finally, in Experiment 5, a cued item recognition procedure was implemented to determine whether the recognition deficit for the components of CW pairs could be eliminated when the encoding task emphasized the individual items rather than their association. Discrimination performance was similar in both tests of single and cued item recognition for items from CW and NCW same pair conditions. This finding contrasts with the results of Experiments 2 and 4B where single item recognition was significantly worse for items from CW than for those from NCW pairs. Thus, the unitized encoding of CW pairs, and the encoding trade-off between item and associative information for CW pairs, is not obligatory. Rather, it depends on the nature of the information emphasized by the encoding task.

In summary, the results of the current study provide a demonstration of familiarity-based associative recognition decisions for unitized pairs. The results of the present experiments support the idea that the compound word effect is due to familiarity arising from unitization. The associative recognition analogue of the compound word effect seen in item recognition is a concordant effect in yes–no recognition and a discrimination advantage for CW pairs in forced-choice recognition. The comparison of associative recognition of CW with R-NCW pairs shows that strong associations arising through repetition are not the same as unitized pairs. Finally, the results also demonstrate that item recognition can be a reliable test of unitization. For unitization to have occurred, item recognition should be significantly lower for the components of unitized than nonunitized pairs.

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Improving associative memory in older adults with unitization

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Improving associative memory in older adults with unitization

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Overview of experiments

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

Experiment 1

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

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

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

Method

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

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

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

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

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

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

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

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

Results

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

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

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

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

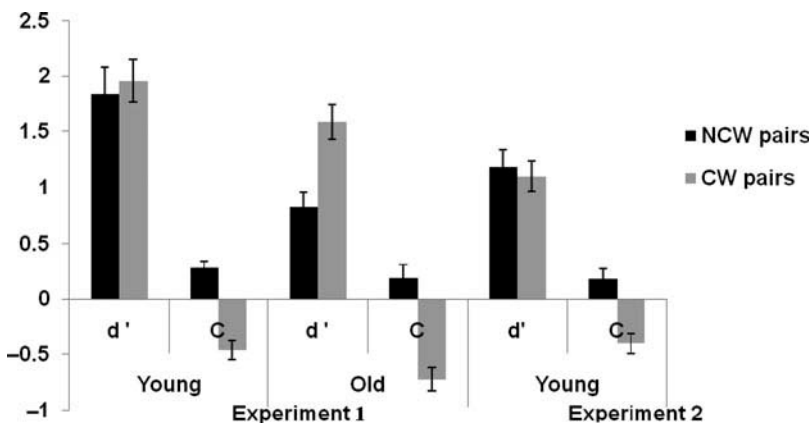Note: Standard deviations of the means are given in parentheses.

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

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

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

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

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

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

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

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

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

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

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

Experiment 2

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

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

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

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

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

Method

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

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

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

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

Results

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

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

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

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

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

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

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

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

Younger adults: comparison of presentation time

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

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

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

Younger versus older adults

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

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

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

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

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

Experiment 3

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

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

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

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

Method

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

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

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

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

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

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

Results and discussion

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

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

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

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

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

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

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

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

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

General discussion

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Notes

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

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Chapter 4

The Increase in Familiarity from Unitization of Compound Word Pairs is Not Based on Fluency

of Processing

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Abstract

Ahmad and Hockley (2014) found in yes-no associative recognition, both hits and false alarm rates were greater for compound word pairs (CW; e.g., *store keeper*) compared to noncompound word pairs (NCW; e.g., *needle birth*) with no difference in discrimination. They concluded increased reliance on familiarity from unitization of CW pairs was responsible for this CW effect. Previous research has also shown that familiarity produced from fluency of processing did not contribute to associative recognition of unrelated pairs that were unitized using a definitional encoding instruction (Lloyd, Hartman, Ngo, Ruser, Westerman & Miller, 2015). The present study examined if fluency of processing contributes to associative recognition of unitized preexperimental associations (i.e., CW pairs). In Experiment 1, when perceptual fluency was minimized by presenting the words of each pair one at a time, the CW effect was not diminished. In Experiments 2A and 2B, conceptual fluency was examined by comparing transparent (e.g., *hand bag*) and opaque (e.g., *rag time*) CW pairs in lexical decision and associative recognition tasks. Lexical decision was shown to be faster for transparent compared to opaque CW pairs (Experiment 2A) but in associative recognition, the CW effect did not differ for each pair type (Experiment 2B). The CW effect in yes-no associative recognition is due to a reliance on enhanced familiarity of unitized CW pairs and not based on fluency of processing.

Key words: compound word effect, perceptual fluency, conceptual fluency, unitization

The Increase in Familiarity from Unitization of Compound Word Pairs is Not Based on Fluency of Processing

Researchers favoring the dual process view assume recognition involves two different processes, one based on familiarity and the other on recollection. Recollection is typically defined as the retrieval of vivid detailed information of a previous experience, whereas familiarity is seen as a less specific feeling of knowing (e.g., Wixted, 2007; Yonelinas, 2002). Item recognition is believed to be based on both recollection and familiarity whereas recollection is usually considered to be essential for discrimination in associative recognition (e.g., Hockley & Consoli, 1999).

In associative recognition, at study unrelated pairs of items are presented and participants are instructed to form a relation between them. At test, participants discriminate between intact pairs (both items previously studied together) and rearranged pairs (both items previously studied but as part of different pairs) (e.g., Hockley & Consoli, 1999; Humphreys, 1978). Participants must retrieve the associations between the items encoded at study in order to correctly identify intact pairs and to reject rearranged pairs. Thus, retrieval of relational information is necessary for successful associative recognition.

Researchers have shown, however, that when pairs of items are unitized, familiarity can support associative recognition (Ahmad & Hockley, 2014; Bastin, Diana, Simon, Collette, Yonelinas & Salmon, 2013; Giovanello, Keane, & Verfaellie, 2006; Haskins, Yonelinas, Quamme & Raganath, 2008; Lloyd et al., 2015; Quamme, Yonelinas & Norman, 2007; see Murray & Kensinger, 2013, for a review). Unitization occurs when two items are integrated into a coherent whole, so that the integrated whole is more familiar then its components (Graf & Schacter, 1989). It can be achieved by providing compound definitions of the word pairs (e.g., Haskins et al., 2008; Quamme et al., 2007) or with preexperimental associations such as with

compound word pairs (e.g., Giovanello et al., 2006; Ahmad & Hockley, 2014). There is an increased reliance on familiarity in a manner similar to item recognition for associative recognition of unitized pairs (Murray & Kensinger, 2013).

Recently, Ahmad and Hockley (2014) examined the effects of unitization on associative recognition in a yes-no associative recognition test by comparing the discrimination of compound word (CW) and noncompound word (NCW) pairs in a standard yes/no associative recognition procedure with young adults. The two syllables of the CW pairs and the two words of the NCW pairs were presented with six spaces between them (e.g., CW pair: door knob; NCW pair: bridge   string). Before the study phase, participants were instructed to form a relation between the two words of each pair by either forming an image or a sentence combining the two items. The word pairs were then presented one at a time on the screen. At test, participants were presented with both intact and rearranged CW and NCW pairs for which they made an old or new judgement.

The hit and false alarm rates were higher for CW compared to NCW pairs with no difference in overall discrimination. Ahmad and Hockley (2014) referred to this pattern of results as the CW effect and concluded that this effect is due to the higher familiarity of unitized CW pairs. They indicated the familiarity of CW pairs was from two sources, preexperimental (based on familiarity due to prior experience) and study-induced (based on studying CW pairs during the experiment). Ahmad and Hockley suggested the higher preexperimental familiarity and unitization of CW pairs produces the CW effect.

An alternative interpretation of the CW effect considered by Ahmad and Hockley (2014) is response bias. Participants may be predisposed to classify CW pairs as old due to their preexperimental familiarity or meaningfulness thereby increasing both the hit and false alarm

rates of CW pairs compared to NCW pairs without affecting discrimination. To test this possibility, Ahmad and Hockley (2014) compared associative recognition of CW versus NCW pairs in a two-alternative forced-choice task. In the forced-choice test, response bias based on pair type is minimized when the target and distractor pairs are of the same type. In contrast to yes-no associative recognition, Ahmad and Hockley found young adults showed a discrimination advantage for CW pairs over NCW pairs in forced-choice associative recognition. They suggested that young adults' forced-choice recognition decisions are based on familiarity to a greater extent than yes-no recognition decisions (e.g., Bastin & Van der Linden, 2003; Patterson & Hertzog, 2010). This increased use of familiarity produced a discrimination advantage for CW pairs.

This conclusion is supported by an examination of the CW effect in older adults. Ahmad, Fernandes, and Hockley (2015) found older adults, who rely mostly on familiarity for recognition, also showed higher hit and false alarm rates for CW compared to NCW pairs in yes-no recognition. More importantly, older adults also showed a discrimination advantage for CW pairs in both yes-no and forced-choice associative recognition tests. The findings of a discrimination advantage for young adults in forced-choice recognition, and the discrimination advantage in both yes-no and forced-choice recognition for older adults indicate that the CW effect is not due to response bias, but a result of greater reliance on familiarity for associative recognition of CW pairs.

In the framework of Dual process theory, in the yes-no associative recognition test, an increase in hit rates for intact CW pairs occurred due to an increase in familiarity or combination of familiarity and recollection, but an increase in false alarm rates occurred due to increased use of familiarity for rearranged CW compared to NCW pairs. The increase in familiarity did not

eliminate the possibility that recollection also influenced memory decisions after unitization of CW pairs, but suggested there was heightened familiarity due to unitization.

The enhanced familiarity of unitized CW compared to NCW pairs leading to the CW effect, however, may not be due to unitization per se, but rather due to the processing fluency of the preexperimentally familiar unitized CW pairs. That is, the CW pairs were processed more fluently (i.e., quickly) than NCW pairs and, as consequence, there were more 'old´ responses provided for CW pairs. This result can be explained by the fluency processing account. According to this account, participants use a fluency heuristic when they process items more fluently than other items (Jacoby & Dallas, 1989; Jacoby & Whitehouse, 1989; Jacoby, 1991; Westerman, 2001). That is, people are often willing to attribute fluent processing of a stimulus as evidence of past experience with that stimulus. Ahmad and Hockley (2014) found that response time for associative recognition decisions was faster for CW compared to NCW pairs. Therefore, the higher hit and false alarm rates characteristic of the CW effect could be explained by the more fluent processing of CW compared to NCW pairs.

Giovanello et al. (2006) also suggested that perceptual or conceptual fluency may underlie the CW effect. Similar to Ahmad and Hockley (2014), they had found a CW effect for their control participants and a discrimination advantage for CW pairs in patients with amnesia. They concluded that the enhanced familiarity of CW pairs was due to unitization and could be perceptually or conceptually based. Perceptually-based familiarity arises from repetition at study and test of the same orthographic representation, allowing for more fluent processing on repetition (Giovanello et al., 2006). Such perceptual fluency would be enhanced for CW pairs compared to NCW pairs, leading to the CW effect. Giovanello et al. suggested placing a space between two words of the CW would minimally reduce the effect of perceptual based familiarity,

because access to the orthographic representation would still be present. Ahmad and Hockley (2014) further minimized perceptual fluency of CW pairs by separating the two words of CW pair by six spaces, however as noted access to orthographic representation would still be present.

In addition, Giovanello et al. further suggested the CW effect could be due to enhanced conceptual fluency of CW pairs compared to NCW pairs. That is, processing of the meaning of CW pairs would be more fluent than that of NCW pairs due to pre-existing conceptual integration leading to a CW effect. Based on Giovanello et al.'s suggestion, it would be logical to examine, as our current study does, if enhanced familiarity produced from the greater perceptual and conceptual fluency of CW compared to NCW pairs could account for the CW effect.

There have been a number of studies that have examined the effects of fluency on item recognition performance (e.g., Jacoby & Whitehouse, 1989; Whittlesea, Jacoby & Girard, 1990; Lanska, Olds, & Westerman, 2014; Rajaram, 1993; Rajaram & Geraci, 2000; Westerman, 2001; Westerman, Miller & Lloyd, 2003). Perceptual fluency has been manipulated by presenting words in greater perceptual clarity as in light compared to heavy masking conditions (Whittlesea et al. 1990), and by a change in perceptual form from study to test (Westerman et al, 2003).

Jacoby and Whitehouse (1989) examined the effects of perceptual fluency on item recognition using a priming procedure. Test trials consisted of presentation of a word or prime prior to presentation of the test word for which participant would provide an old or new response. When the test word was preceded by a prime which matched it, the test word was processed more fluently as shown by faster naming times compared to when the test word was preceded by a non-matching prime. Importantly, more "old" responses were made when the test word was preceded by a matching word compared to when the test word was preceded by a non-matching word. The hit and false alarm rates were higher for tests preceded by a matching prime.

Conceptual fluency has also been examined in item recognition using the priming procedure. Rajaram and Geraci (2000) manipulated conceptual fluency by varying the semantic relationship between the prime and target words at test. Using the remember and know procedure, Rajaram and Geraci found participants made more know judgments (characteristic of familiarity-based decisions) to items with semantically related primes than unrelated primes.

In contrast to item recognition, we know of only two studies that have examined the influence of processing fluency in associative recognition. Both Westerman (2001) and Lloyd, Hartman, Ngo, Ruser, Westerman, & Miller (2015) used the Jacoby-Whitehouse priming procedure to investigate if fluency of processing effects familiarity-based decisions in associative recognition. Westerman (2001) tested participants' item and associative recognition for words and word pairs that were primed. In addition, both item and associative recognition tests were presented in speeded and non-speeded form. The rationale being the speeded task would encourage greater use of familiarity for fluently based items. A priming effect was reflected in increased number of "old" responses in the speeded and non-speeded item recognition tests. However, a priming effect was shown only in the speeded associative recognition test. That is, both hits and false alarms were higher for the matched compared to the mismatched word pairs. Westerman (2001) concluded that recollection is relied on more than familiarity in associative recognition.

Lloyd et al. (2015), however, suggested Westerman (2001) found that processing fluency played no role in self-paced associative recognition because when participants had more time, they prioritized recollected details and chose not to attribute fluency to past experience. Lloyd et al. based this interpretation in light of the findings of their own study examining the effects of priming on associative recognition of unitized and non-unitized unrelated word pairs.

In their study, Lloyd et al. (2015) examined if processing fluency rather than unitization of unrelated or preexperimental associations pairs could be the source of the enhanced familiarity associated with unitized pairs. To promote unitization of unrelated pairs, participants were instructed to encode unrelated word pairs by using a definition. That is, unrelated word pairs (e.g., author elbow) were presented with a definition (e.g., "Joint pain caused by writing too much"). In contrast, for the non-unitized condition, a sentence with blanks for the word pair was provided to associate the two words (e.g., "The__injured his_while swimming."). Loyd et al. found in their first experiment that participants in the speeded test showed a discrimination advantage for word pairs encoded as definitions (i.e., unitized) indicating that participants relied more on familiarity to make their recognition decisions.

To determine if fluency was the source of the enhanced familiarity from definitional encoding, Loyd et al. included the Jacoby-Whitehouse priming procedure during a self-paced associative recognition test. They found a similar proportion of old responses in matched and mismatched primed conditions for intact and rearranged unitized and non-unitized pairs. In addition, there was no discrimination difference between unitized and non-unitized pairs. This finding was consistent with other researchers that had found unitization increased reliance on familiarity in associative recognition (e.g., Giovanello et al., 2006; Quamme et al., 2007). Lloyd et al. concluded fluency of processing did not contribute to the reliance on familiarity in associative recognition of unitized unrelated pairs. They suggested the failure to see a priming effect was likely due to participants being able to discount fluency as a cue to memory decisions.

Relevant to the purpose of the current study, there are key similarities and differences between Lloyd et al. (2015) and Ahmad and Hockley (2014) study that warrant an investigation of the effect of processing fluency of CW pairs in associative recognition. Similar to Lloyd et al.,

Ahmad and Hockley found no discrimination difference between unitized and non-unitized pairs. After conducting several experiments examining the effects of priming on associative recognition, Lloyd et al. concluded the greater reliance on familiarity in associative recognition of unitized pairs was not due to fluency of processing. Ahmad and Hockley (2014) also concluded there was a greater reliance on familiarity in associative recognition decisions for unitized CW pairs, but they did not test if processing fluency could have led to the CW effect.

In contrast to Lloyd et al. (2015), Ahmad and Hockley (2014) examined associative recognition of unitized CW pairs, for which no compound definition needs to be given. As noted earlier, CW pairs when unitized as compound words are both perceptually and conceptually fluent. The unitization of unrelated word pairs by providing a compound definition at study would provide only a limited opportunity to increase the perceptual and conceptual fluency of these pairs. This would make CW pairs certainly much more fluent than unrelated word pairs unitized by an instructional manipulation. Therefore, the null findings of Lloyd et al. (2015) raise a strong need for an investigation in determining whether the increased reliance on familiarity in associative recognition of unitized CW pairs is due to the processing fluency of unitized CW pairs.

However, if we find there is a minimal role of fluency in the CW effect, we can suggest the form of unitization found with CW pairs is similar to that of unrelated word pairs unitized using a compound definition. Therefore, in the current study, we examined the role of processing fluency in the CW effect. Our aim was to determine whether the CW effect reported by Ahmad and Hockley (2014) and Giovanello et al. (2006) is due to the enhanced familiarity produced by the fluency of CW pairs. Experiment 1 and 2 were designed to evaluate the role of perceptual and conceptual fluency in the CW effect. In the first experiment, we minimized perceptual

fluency by presenting CW and NCW pairs, one word at a time at study and test. We predicted an attenuation of the CW effect if perceptual fluency has an influence. In Experiment 2, we examined the role of conceptual fluency in the CW effect by comparing transparent and opaque CW pairs in both lexical decision and associative recognition tasks. We predicted a higher CW effect for transparent compared to opaque CW pairs, because of the higher conceptual fluency of transparent CW pairs.

<div align="center">**Experiment 1: Perceptual Fluency**</div>

Both Giovanello et al. (2006) and Ahmad and Hockley (2014) attempted to reduce the perceptual fluency of CW pairs by separating the individual components by one or six spaces. However, as Giovanello et al. noted, even with separation between individual elements, perceptual fluency would still be present as shown by the higher familiarity of the orthographic representation of CW compared to NCW pairs. In Experiment 1, perceptual fluency was minimized by presenting CW and NCW pairs one word at a time on different screens at study and at test. We predicted the CW effect would be attenuated to the extent that perceptual fluency plays a role.

Method

Participants. All participants in each experiment were undergraduate students enrolled in a psychology course at Wilfrid Laurier University who participated for course credit. A total of 28 students participated in Experiment 1.

Materials and Apparatus. The experiment was run on PC compatible laboratory computers equipped with 17'' LCD monitors. SuperLab 4.0 software (Cedrus corp.) was used to control stimulus presentation and response recording. The stimuli were the same as constructed by Ahmad and Hockley (2014) and were based on the set of 160 compound words provided by

Jones (2005). To create the NCW pairs, the left word from one CW pair was paired with the right word from another CW pair. This was done to equate the individual words of the compound and NCW pairs. To create the rearranged CW pairs, the first member of the parent CW pair was paired with the second member of another CW pair. For example, the rearranged CW pair *check-point* was made from the parent CW pairs, *check-list* and *needle-point*. Two sets (A and B) were constructed to counterbalance the components of the CW and NCW pairs across participants.

Procedure. At the beginning of the study phase, participants were told they would be presented with word pairs. It was emphasized that each word of the pair would be presented one at a time on the computer screen. The first word of each pair would be presented on the left side of the first screen and the second word would be presented on the right side of the second screen. Participants were instructed to form an association between the first and second word of the word pair by either forming an image or a sentence combining the two words in the pair as this would help them remember the word pair at test. The critical portion of the study list consisted of 48 CW and 48 NCW pairs. In addition, there were two buffer pairs, one CW pair and one NCW pair, at the beginning and end of each study list to minimize primacy and recency effects. The order of the study pairs (excluding buffers) was random, with a different random order for each subject. The first word of a pair was presented on the left side of first screen for 2000 ms, followed by the second word of the pair presented on the right side of the next screen for 2000 ms.

After the study phase was completed, for approximately 1 min duration, the experimenter presented the test instructions to the participants. They were informed of the difference between old (intact) and new (rearranged) test pairs and instructed to press the "/" and "z" keys for old

and new judgments, respectively, after the second word of the pair appeared. They were also asked to respond as accurately as possible. Response time was not mentioned. In addition, they were instructed to provide a confidence judgment for old and new responses. That is, after participants entered their old or new response, they made a confidence judgment by pressing 1 for 'not sure', 2 for 'sure' or 3 for 'very sure'. During the test phase, there were 16 intact and 16 rearranged CW pairs, and 16 intact and 16 rearranged NCW pairs presented in a different random order for each participant. The first word of each test pairs was presented for 2000 ms. The second word of each pair remained on the screen until a response was made. Response time was measured from the onset of the presentation of the second word of the test pair until the old-new recognition response.

Design. Experiment 1 represented a 2 (test probe type: old or new) x 2 (word pair type: CW or NCW) within-subjects design. The dependent variables were proportion of old responses, mean confidence judgments, and response time.

Results and Discussion

The mean proportion of hits and false alarms for CW and NCW pairs are presented in Table 1.

Proportion of Old Responses. A 2 (test probe type) X 2 (word pair type) repeated measures analysis of variance (ANOVA) was conducted on the proportion of old responses. There was a significant main effect of test probe [$F(1, 27) = 168$, $MSE = .04$, $p < .001$, $\eta^2 = .86$]. The hit rate was significantly higher than the false alarm rate showing that overall discrimination was above chance. There was also a significant main effect of word pair type [$F(1, 27) = 35$, $MSE = .01$, $p < .001$, $\eta^2 = .57$]. Overall old responses were higher for CW pairs than NCW pairs.

The interaction between probe and word pair type was not significant [$F(1, 27) = 1.84$, *MSE* = .019, $p = .186$, $\eta^2 = .064$].

Discrimination. To assess discrimination, estimates of d´ and criterion placement (*C*) were calculated. These mean estimates are also given in Table 2. A paired-sample t-test indicated no difference in discrimination (i.e., *d´*) between the CW and NCW pairs, [$t(27) = .695$, $p = .493$]. There was a significant difference in criterion placement indicating a more liberal criterion for CW pairs and a more conservative criterion for NCW pairs [$t(27) = -6.21$, $p < .001$].

Confidence. Mean confidence was calculated for hits and correct rejections for CW and NCW pairs. A 2 (test probe type) x 2 (word pair type) repeated ANOVA was conducted on these results. There was no significant main effect of word pair type [$F(1, 27) = 2.50$, *MSE* = .29, $p = .126$, $\eta^2 = .085$], or test probe [$F(1, 27) = .029$, *MSE* = .009, $p = .866$, $\eta^2 = .001$]. However, there was a significant interaction between probe and pair type [$F(1, 27) = 9.816$, *MSE* = .532, $p = .004$, $\eta^2 = .267$]. Paired sample t-tests showed there to be significantly higher confidence in hits for CW (M = 2.50, S.D = .40) compared to NCW pairs (*M* = 2.26; *S.D* = .38) [$t(27) = 3.19$, $p = .004$], but no difference in confidence ratings for correct rejection of CW (*M* = 2.38, *S.D* = .40) and NCW pairs (*M* = 2.41; *S.D* = .34) [$t(27) = -.446$, $p = .66$].

Response time. Means of median response time for correct responses (hits and correct rejections) for both pair types are also presented in Table 1. A 2 (test probe type) x 2 (word pair type) repeated measures ANOVA revealed a main effect of probe [$F(1, 27) = 36.3$, *MSE* = 174375, $p < .001$, $\eta^2 = .574$]. Mean response time for hits was faster than correct rejections. There was also a significant main effect of pair type [$F(1, 27) = 5.08$, *MSE* = 103804, $p < .05$, $\eta^2 = .158$]. Mean response times for CW pairs were faster than NCW pairs. These main effects were qualified by a significant interaction between probe and pair type [$F(1, 27) = 6.65$, *MSE* =

196789, $p < .05$, $\eta^2 = .198$]. Follow-up paired t-tests showed response times for hits were faster

for CW than NCW pairs [$t(27) = 5.3$, $p < .001$], whereas response times for correct rejections

were similar for CW and NCW pairs [$t(27) = .604$, $p = .551$].

In summary, contrary to our prediction, there was a CW concordant effect, when

perceptual fluency of the CW pairs was minimized. This concordant effect was seen in higher hit

and false alarm rates for CW compared to NCW pairs and was similar to the concordant effect

observed by Ahmad and Hockley (2014, Exp 1). Refer to Table 1. The pattern of response time

was also the same as observed by Ahmad and Hockley (2014, Exp. 1). Faster response time for

hits is consistent with the view that the concordant effect for CW pairs is based in large part on

familiarity. The lack of a difference in response time for correct rejections could reflect the

opposing influence of recollection that must mitigate the influence of familiarity to correctly

reject rearranged CW pairs. The fact that response times were much slower in Experiment 1 of

the current study compared to Ahmad and Hockley's (2014) study suggests perceptual fluency

was significantly reduced at encoding (study phase) and retrieval (test phase) in Experiment 1

when the words of the pairs were presented separately. Interestingly, studied CW pairs were

recognized with higher confidence than NCW pairs, but confidence for correct rejection was

similar for CW and NCW pairs. As predicted, the results of Experiment 1 showed minimizing

perceptual fluency by presenting word pairs one at a time at both study and test did not eliminate

the CW effect.

Experiment 2A: Conceptual Fluency in Lexical Decision

Perhaps the effect of minimizing perceptual fluency on the CW effect in Experiment 1 of

the current study was not seen because the CW effect may be due more to conceptual than

perceptual fluency. Due to the conceptual nature of the associative recognition task, conceptual

not perceptual fluency of CW pairs may cause the CW effect. Although the effects of conceptual fluency have not been investigated in associative recognition, there has been recent research on the factors that mediate the effects of fluency on item recognition.

Lanska et al. (2014) found the effect of conceptual and perceptual fluency on item recognition to be dependent on encoding and test factors. When the perceptual features of the stimuli were emphasized during encoding, there was a stronger influence of perceptual fluency on recognition decisions than conceptual fluency. In contrast, conceptual fluency was increased by drawing participants' attention to the meaning of the word during study. Interestingly, they also found that the type of test instructions influenced the contribution of perceptual compared to conceptual fluency manipulations on recognition judgments. When the test instructions were meaning based as in synonym recognition rather than standard recognition, the influence of conceptual fluency was larger.

Experiment 2 was designed to assess the role of conceptual fluency in the CW effect. This was done by comparing two types of compound words, transparent and opaque, that have been shown to differ in their conceptual fluency. The purpose of Experiment 2A was to confirm differences in conceptual fluency of transparent and opaque CW pairs using a lexical decision task. A lexical decision task assesses speed of lexical access by measuring response time to identify a letter string as a word or a non-word. Faster response times are found for identification of highly frequent compared to less frequent words, since high frequency words are processed more fluently than low frequency words. Several researchers have used the lexical decision task to investigate semantic memory and lexical access (e.g., Libben, Gibson, Yeo Boom, & Dominek. 2003; Meyer, & Schavaneveldt, 1971; Perea & Pollatesk, 1998).

Libben, Gibson, Yeo Bom and Dominek (2003) investigated the processing of compound words classified by their semantic transparency in a lexical decision task. Semantic transparency is defined by the semantic overlap of the compound words and their lexemes. There are two types of compound words that differ in their semantic transparency. Transparent compound words contain lexemes which contribute to overall meaning of the compound word (e.g., snowstorm) whereas in opaque compound words one or both lexemes do not contribute to the overall meaning of the compound word (e.g., ragtime). In their study, four types of compound words were presented to participants: Transparent-Transparent (e.g., *car-wash)*; Opaque-Transparent (e.g., *strawberry)*; Transparent-Opaque (e.g., *jailbird)*; and Opaque-Opaque (e.g., *hogwash*).   Half were presented as compound words and half were presented with a space between the two lexemes.

Libben et al. reasoned the spacing manipulation would represent morphological decomposition by separating the compound into its constituents. As a result, faster response times would be shown for more semantically transparent non-spaced compounds. Libben et al. predicted recognition time for an opaque compound word such as hogwash with spaces between the morphemes would be greater than response times to a transparent word such as carwash under the same presentation conditions, because semantic transparency plays a role in determining whether a compound word was decomposed into its components. At the beginning of the experiment, participants were told they would be presented with single words presented on the screen. They were instructed to press the 'yes key' if they had ever seen the word before and press the 'no key' if they had never seen the word before. They found when compound word pair types are presented in split form, they took longer to recognize. Importantly, the Transparent-Transparent and Opaque-Transparent compounds were faster to recognize compared to

Transparent-Opaque and Opaque-Opaque compounds. Similarly, for our lexical decision task, we expected faster response times for Transparent CW than Opaque CW pairs because of higher conceptual fluency of transparent CW pairs.

We used a lexical decision task to determine if conceptual fluency was higher for our sample of transparent compared to opaque compound words. Our transparent and opaque compound words were taken from Wong and Rotello's (2010) stimuli list. The list primarily contained a mixture of Transparent-Transparent and Opaque-Opaque compound words. We hypothesized there would be faster lexical decision for transparent compared to opaque compound words, similar to the effect found by Libben et al. (2003) in a different type of lexical decision task. That is, in our lexical decision task, participants were asked to indicate as quickly as possible whether the word pair presented was a compound word (e.g., catwalk) or not a compound word (e.g., beeball). Participants were also told before the lexical decision task what a compound word was. Moreover, only non-spaced compound and noncompounds were presented.

Method

Participants. A total of 19 undergraduates participated in Experiment 2A.

Materials and Apparatus. The apparatus was the same as in Experiment 1. However, for stimuli, 24 Transparent CW, 24 Opaque CW, 24 Transparent NCW and 24 Opaque NCW pairs were constructed from a list containing 60 transparent and 60 opaque compound words provided by Wong and Rotello (2010). This same list was also used in Experiment 2B to test the effect of conceptual fluency on the CW effect.

As in Experiment 1, two sets (A and B) were constructed to counterbalance the components of the CW and NCW pairs across subjects. NCW pairs were created by combining first word of one CW pair with the second word of another CW pair. For example, from the

transparent CW pairs, *door knob* and *tear drop,* the Transparent NCW pair *door drop* would be created. Due to limited number of compound words, rearranged Transparent CW and Opaque CW pairs were created by pairing the first member of the parent NCW pair with the second member of another NCW pair. For example, *table cloth* would be created from *table nail* and *thumb cloth*. Both the CW and NCW pairs were presented as compound and noncompound words. For example, *ragbread* is an opaque noncompound word and *wallflower* is an opaque compound word. Examples of the intact and rearranged Transparent CW, Opaque CW, Transparent NCW and Opaque NCW pairs in Sets A and B are shown in Table 2.

Procedure. The compound and noncompound words were presented one at a time on the screen. Participants were told they would see words on the screen. They must indicate if the word is a compound word by pressing the 'z' key or is not a compound word by pressing the '/' key on the keyboard. Participants were instructed to be as accurate and fast as possible in their response. Participants were also told what a compound word was and provided with some examples. Following the instructions, 24 Transparent CW, 24 Opaque CW, 24 Transparent NCW and 24 Opaque NCW words were presented until a response was made. Immediately after the participant's response, the next compound or noncompound word appeared on the screen. The order of presentations was random with a different order for each participant.

Design. Experiment 2A represented a 2 (word: CW or NCW) X 2 (transparency: Transparent or Opaque) within-subjects design. The dependent variables were proportion of correct responses and response time.

Results and Discussion

The means for correct responses for Transparent CW, Opaque CW, Transparent NCW and Opaque NCWs are presented in Table 3.

Proportion of Old Responses. A 2 (compound vs. noncompound words) x 2 (transparent vs. opaque) repeated measures ANOVA was conducted on proportion of correct responses. There was a significant main effect of pair type [$F(1, 18) = 26. 08$, $MSE = .001$, $p < .001$, $\eta^2 = .591$. Participants showed higher accuracy for noncompound compared to compound words. There was no significant effect of transparency [$F(1, 18) = 2.55$, $MSE = .000$, $p = .127$, $\eta^2 = .591$]. Moreover, the interaction between transparency and pair type was not significant [$F(1, 18) = 3.47$, $MSE = .001$, $p = .08$, $\eta^2 = .162$].

Response time. The means of median response time for correct responses for Transparent CW, Opaque CW, Transparent NCW and Opaque NCW pairs are presented in Table 3. A 2 (CW vs. NCW pairs) x 2 (Transparent vs. Opaque pairs) repeated measures ANOVA was conducted on response times. There was a significant main effect of pair type [$F(1, 18) = 9.82$, $MSE = 360449$, $p = .006$, $\eta^2 = .353$] indicating faster response times for CW pairs than NCW pairs. There was also a trend for faster response times for transparent compared to opaque pairs [$F(1, 18) = 3.925$, $MSE = 101375.482$, $p = .063$, $\eta^2 = .189$]. The interaction between pair type and transparency, however, was significant [$F(1, 18) = 5.14$, $MSE = 161949.156$, $p = .036$, $\eta^2 = .056$]. Paired sample t-tests confirmed lexical decision time was faster for Transparent CW than Opaque CW pairs [$t(18) = 3.7$, $p = .002$], but did not differ significantly between Transparent NCW and Opaque NCW pairs [$t(18) = .305$, $p = .764$].

The results of Experiment 2A showed conceptual fluency influenced speed of lexical access. Lexical decision times were faster for Transparent CW compared to Opaque CW pairs indicating conceptual fluency was higher for Transparent CW pairs.

Experiment 2B: Conceptual Fluency in Associative Recognition

The purpose of Experiment 2B was to examine if conceptual fluency of CW pairs increased the CW effect. Ahmad and Hockley (2014) presented CW and NCW pairs in a yes-no associative recognition test and found a CW effect. However, they did not control for conceptual fluency between CW pairs. Their CW pairs were a mixture of both transparent and opaque CW pairs. It is possible the CW effect in their study was due to semantic transparency rather than the familiarity due to unitization of CW pairs. Recently, Wong and Rotello (2010) investigated in the conjunction memory paradigm the effect of semantic transparency of compound words on false alarms. In the conjunction memory paradigm, compound words such as *brainwash, hailstorm* and *watchtower* are presented at study. In the following item recognition test, participants would discriminate between *brainwash* (a studied target), *brainstorm* (a conjunction lure), *watchmaker* (a feature lure), or *stockyard* (a new compound word). The proportion of old responses is typically higher for targets, next highest for conjunction lures, followed by feature lures, and then new stimuli (i.e., old > conjunction > feature > new) (Jones & Jacoby, 2001; Reinitz, Lammers & Cochran, 1992; Reinitz, Verfaellie & Milberg, 1996). The conjunction effect refers to the increase in the false alarm rate for conjunction lures. Jones and Jacoby (2001) argued greater familiarity of conjunction lures was the cause of the higher false alarm rate for conjunction lures compared to new words.

Wong & Rotello (2010) reasoned the degree of semantic transparency of CWs would have an effect on conjunction errors, since greater use of familiarity would be present with an increase in semantic transparency. Participants studied individual elements of compound words (e.g., *draw* and *back*). In addition, they were presented transparent and opaque compound words in a random order. Participants were tested in an item recognition test. They made old and new judgments on compound words and assembly lures (e.g., *drawback*) which were created from

words at study. Wong and Rotello found higher false alarm rates to transparent compared to opaque assembly lures indicating transparent assembly lures were associated with greater familiarity. Although not a finding of interest in their study, they found no difference in discrimination between transparent and opaque compound words.

In Experiment 2B, we presented participants with the transparent and opaque compound words that were used by Wong and Rotello (2010) but as CW pairs in an associative recognition task. We predicted if conceptual fluency between CW pairs played a role in the CW effect, a larger CW effect would be shown for Transparent CW compared to Opaque CW pairs. That is, more 'old´ responses would be provided for the more fluently processed Transparent than Opaque CW pairs.

<div align="center">Method</div>

Participants. A total of 23 undergraduates participated in Experiment 2B.

Materials and Apparatus. The apparatus and stimuli were the same as in Experiment 2A.

Procedure. The procedure was similar to Experiment 1 with a few notable differences. Word pairs were presented on the same screen separated by six spaces (ex: *brain   storm*) during both study and test. Twenty-four Opaque CW pairs, 24 Transparent CW pairs, 24 Transparent NCW pairs, and 24 Opaque NCW pairs were presented during the study phase. In addition, there were two buffer pairs, one CW pair and one NCW pair, at the beginning and end of each study list to minimize primacy and recency effects. Study pairs were shown for 4 s in a different random order for each participant. During the test phase 12 intact and 12 rearranged pairs for each CW and NCW pair type were presented. Each test pair was displayed in the center of the screen. The test pairs remained on the screen until the participants responded, and response time was measured from the onset of presentation until the response was made.

Design. Experiment 2B represented a 2 (test probe type: old or new) x 2 (word pair type: CW or NCW) x 2 (transparent or opaque) within-subjects design. The dependent variables were proportion of old responses, mean confidence judgments, and response time.

Results and Discussion

The mean proportion of hits (correct old responses to intact pairs) and false alarms (incorrect old responses to rearranged test pairs) for Transparent CW, Opaque CW, Transparent NCW and Opaque NCW pairs are presented in Table 4.

Proportion of Old Responses. A 2 (old vs. new test) x 2 (CW vs NCW pairs) x 2 (transparent vs opaque) repeated measures ANOVA was conducted on the proportion of old responses. There was a significant main effect of test probe [$F(1, 22) = 255.48$, $MSE = 14.43$, $p < .001$, $\eta^2 = .921$]. The hit rate was significantly higher than the false alarm rate. There was also a significant main effect of word pair type [$F(1, 22) = 56.76$, $MSE = 1.19$, $p < .001$, $\eta^2 = .721$]. Overall old responses were higher for CW pairs. There was no significant difference between transparent and opaque pairs [$F(1, 22) = 1.126$, $MSE = .028$, $p = .300$, $\eta^2 = .049$]. There was no significant interaction between probe and word pair type [$F(1, 22) = .543$, $MSE = .011$, $p = .469$, $\eta^2 = .024$]. The transparent versus opaque manipulation did not interact with test probe [$F(1, 22) = 1.017$, $MSE = .010$, $p = .324$, $\eta^2 = .044$], or word pair type [$F(1, 22) = .693$, $MSE = .011$, $p = .414$, $\eta^2 = .031$]. The interaction between probe, word pair type, and level of transparency was also not significant [$F(1, 22) = .001$, $MSE = 1.184$, $p = .971$, $\eta^2 = .000$].

Discrimination. Mean estimates of d´ and C are also shown in Table 4. A 2 (CW vs. NCW pairs) x 2 (transparent vs. opaque) repeated measures ANOVA conducted on d´ showed that the main effects and interaction of pair type and transparency were not significant (*Fs* < 1). Discrimination was similar for all pair types including level of transparency. A similar analysis

was done on estimates of criterion placement. There was a main effect of pair type [$F(1, 22) =$ 1.38, $MSE = .27$, $p < .05$, $\eta^2 = .720$]. There was a more liberal bias for CW compared to NCW pairs. However, there was no main effect of transparency [$F(1, 22) = 1.38$, $MSE = .25$, $p = .25$, $\eta^2 = .06$], and no interaction between transparency and pair type [$F(1, 22) = .032$, $MSE = .130$, $p = .860$, $\eta^2 = .001$].

Confidence. Mean confidence was calculated for hits and correct rejections for CW and NCW pairs. A 2 (old vs. new tests) x 2 (CW vs. NCW pairs) x 2 (transparent vs. opaque) repeated ANOVA was conducted on the results. There was a significant main effect of test probe [$F(1, 22) = 32.24$, $MSE = 5.68$, $p < .001$, $\eta^2 = .594$] showing confidence for hits was higher than correct rejections. There was no significant main effect of pair type [$F(1, 22) = 1.7$, $MSE = .120$, $p = .206$, $\eta^2 = .072$] or transparency [$F(1, 22) = 3.09$, $MSE = .055$, $p = .09$, $\eta^2 = .123$]. However, there was a significant interaction between probe and pair type [$F(1, 22) = 27.39$, $MSE = 1.86$, $p< .001$, $\eta^2 = .555$]. As was seen in Experiment 1, mean confidence for hits was significantly higher for CW ($M = 2.79$, $S.E = .05$) compared to NCW pairs ($M = 2.23$, $S.E = .074$). However, mean confidence for correct rejections was similar for CW ($M = 2.39$, $S.E = .075$) compared to NCW pairs ($M = 2.53$, $S. E = .065$). There were no significant interactions for probe and transparency, pair type and transparency and the three way interaction ($Fs < 1$).

Response time. The means of median response time for hits and correct rejections for both pair types are shown in Table 5. A 2 (old vs. new test) x 2 (CW vs. NCW pairs) x 2 (transparent vs. opaque) repeated measures ANOVA was conducted on response time. There was a main effect of probe [$F(1, 22) = 20.7$, $MSE = 1851968$, $p< .001$, $\eta^2 = .485$], indicating that response times for hits were significantly faster than for correct rejections. There was also a main effect of pair type [$F (1, 22) = 4.63$, $MSE = 587443.686$, $p = .043$, $\eta^2 = .174$]. Response times for

CW pairs were significantly faster than NCW pairs. Importantly, there was no main effect of transparency [F < 1] and all interactions did not approach significance [$F(1, 22) = 2.86$, $MSE = 637636.89$, $p = .105$, $\eta^2 = .115$; $F(1, 22) = .005$, $MSE = 301240.54$, $p = .945$, $\eta^2 = .000$; $F(1, 22) = .307$, $MSE = 245644.11$, $p = .585$, $\eta^2 = .014$].

A comparison of Google frequency for Transparent and Opaque CWs and CW pairs. In order to assess whether word frequency would account for the contrasting results of Exp 2A and Exp 2B, a word frequency search was conducted using google search engine for the word frequency of compound words and compound word pairs. The number of hits in the google search for the compound word or the compound word pair was recorded. Table 6 shows the mean frequency for the nonspaced compound words (CWs) and spaced compound words (CW pairs) according to google search.

In order to assess the difference in mean frequency between transparent and opaque CWs or between transparent and opaque CW pairs, two repeated measures ANOVA analyses were conducted. A 2 (old vs. new test) x 2 (transparent CW vs. opaque CW) repeated measures ANOVA was conducted on google hits. The main effects of test probe and CW type and their interaction were not significant [$Fs < 1$].

A second similar two way repeated measures ANOVA analysis was conducted but for google hits to Transparent and Opaque CW pairs. There was no significant main effect of test probe [$F(1, 23) = .019$, $MSE = 1.722E13$, $p = .892$, $\eta^2 = .001$]. There was a significant main effect of pair type [$F(1, 23 = 4.50$, $MSE = 7.120E13$, $p = .045$, $\eta^2 = .164$]. Mean google hits were higher for transparent compared to opaque CW pairs. There was no significant interaction between test probe and pair type [$F(1, 23) = .025$, $MSE = 4.748E11$, $p = .875$, $\eta^2 = .001$]

The results of Experiment 2B replicated the accuracy and response time results of Experiment 1. A CW effect reflected in higher hits and false alarms was shown for both transparent and opaque CW pairs compared to NCW pairs. Moreover, the pattern of confidence ratings for hits and correct rejections was the same for transparent and opaque CW pairs. Similar to Experiment 1, confidence for hits were higher for CW compared to NCW pairs. In addition, response times were faster for CW compared to NCW pairs. Thus, the manipulation of transparency in Experiment 2B did not affect the pattern of results found in Experiment 1. The results of Experiment 2B showed that conceptual fluency associated with the type of CW pair did not increase or influence the CW effect. For both transparent and opaque CW pairs, the CW effect was similar in magnitude. Moreover, participants showed no difference in discrimination or response time between transparent and opaque CW pairs.

Lastly it is clear the frequency of the compound words or compound word pairs did not play a role in both lexical decision and associative recognition, as was shown from the analysis of word frequency.

General Discussion

The goal of the current study was to examine if the processing fluency of unitized CW pairs was the source of the enhanced familiarity that characterizes the CW effect. Three experiments were conducted to examine the effects of both perceptual and conceptual fluency on the CW effect. In Experiment 1, perceptual fluency was minimized by presenting one word of each word pair in a sequence both at study and test. We found a CW effect as shown by higher hit and false alarm rates for CW compared to NCW pairs with no difference in discrimination between CW and NCW pairs. Moreover, when comparing the magnitude of the CW effect with that of Experiment 1 in Ahmad and Hockley (2014), we found no difference. The increase in hit

rates for CW pairs in Experiment 1 of the current study and Ahmad and Hockley (2014, Exp. 1) was similar (.15 and .16, respectively). In addition, there was no difference in the increase in false alarm rates for CW pairs between both experiments (.12 and .11, respectively). We also found in both experiments confidence ratings for hits to be higher for CW compared to NCW pairs. However, there was no difference in confidence ratings for correct rejections for CW compared to NCW pairs.

 One could argue the findings of Experiment 1 of the current study would support Whittlesea and Williams (2000, 2001b) discrepancy attribution account. According to this account, people engage in an attributional process when the quality of processing is discrepant from that which is expected. When the perceived discrepancy is attributed to prior experience, the feeling of familiarity occurs. As a result, the source of familiarity is not fluency per se but from perceiving a discrepancy between the actual and expected fluency of processing. For example, Whittlesea and Williams (2000) showed that items perceived as familiar in isolation are instead perceived as novel when presented in a rhyme or in a semantic context.

In our first experiment, a brief pause between the first and second word might have increased the surprise due to unexpected circumstances associated with the facilitation in processing. That is, the surprise associated with presentation of components of CW pairs on separate screens would be larger than for NCW pairs, and this effect could have led to a sense of enhanced familiarity for CW pairs. However, the fact that the CW effect was similar in magnitude when word pairs were presented on the same screen (Ahmad & Hockley, 2014) does not support a discrepancy account of the CW effect in Experiment 1 of the current study.

Since minimizing perceptual fluency did not influence the CW effect, we examined whether there was an effect of conceptual fluency between transparent and opaque CW pairs on

the CW effect in associative recognition. We assumed that associative recognition is largely a conceptual task, and therefore conceptual rather than perceptual fluency would influence performance (cf., Lanska et al., 2014). In Experiment 2A, we conducted a lexical decision task to confirm differences in conceptual fluency of transparent and opaque compound words. In a compound word lexical decision task, we found faster response times for transparent compared to opaque compound words. This result replicates similar findings by Libben et al. (2003) who found a response time advantage for transparent compound words in a more traditional lexical decision task. Also to note, our lexical study used a procedure different from researchers investigating lexical access for compound words. Rather than the participant making a word or non-word judgment, participants in our lexical decision experiment indicated if the word presented was a compound or not a compound word. Together, these results indicate that conceptual fluency is greater for transparent compared to opaque compound words.

In Experiment 2B, we examined the effect of conceptual fluency in associative recognition. Conceptual fluency was equated with semantic transparency of compound words, since we presumed the more semantically transparent the compound word pair is, the higher it's conceptual fluency. Transparent and opaque CW pairs were presented at study along with NCW pairs that were formed from elements of either transparent or opaque CW pairs. We predicted a larger CW effect would be shown for transparent CW compared to opaque CW pairs, if conceptual fluency played a role in the CW effect. We found no such effect of conceptual fluency within CW pairs on the CW effect. Moreover, we found no difference in discrimination between the two types of CW pairs.

These results are consistent with Wong and Rotello's (2010) findings. They also found no difference in discrimination between transparent and opaque compound words, but in an item recognition task.

However, the frequency of the compound words not conceptual fluency could have accounted for results of Experiment 2A and 2B. That is, for experiment 2A, the transparent compound words had a higher word frequency in the lexicon compared to opaque compound words and as a result, there was faster lexical decision time for transparent compared to opaque compound words. In contrast, spacing the compound words as presenting them as compound word pairs, may have resulted in similar frequency for transparent and opaque compound word pairs. Our search of frequency for nonspaced and spaced compound words by using a google search engine did not support such results.

In fact, for compound words, we found the word frequency was the same for transparent and opaque compound words. Yet, in the lexical decision task, response time was found to be faster for transparent compared to opaque compound words. Moreover, for the compound word pairs, we found the frequency of the co-occurrence of the two words of the compound word pairs was higher for transparent compared to opaque CW pairs. However, we found similar proportion of old responses in associative recognition of transparent and opaque compound pairs

These results show that conceptual fluency not word frequency determined performance in Experiment 2A. In the case of Experiment 2B, even though transparent CW pairs were more conceptually fluent, we found no difference in discrimination between transparent and opaque CW pairs in the associative recognition task.

It is worthwhile to note that a recent study by Han, Huang, Lee, Kuo, and Cheng (2014) also examined if semantic transparency has an effect on both lexical decision and yes-no item

recognition test. However, they presented Chinese opaque and transparent compound words in their study. In the acquisition phase, participants made lexical decisions for opaque and transparent words and non-words. Following a distractor task, participants were given an unexpected yes-no recognition test for the studied compound words (presented during the lexical decision task) and new compound words. They also provided remember or know responses for their old judgments. Similar to our study, Han et al. (2014) found participants showed faster response times for transparent compared to opaque compound words in the lexical decision task.

In contrast to Wong and Rotello (2010), Han et al. found on the item recognition test that participants showed higher discrimination for opaque compound words (due to higher hits and lower false alarms) than transparent compound words. Han et al. suggested the incongruence between the meanings of the opaque words and their constituent characters marked the representations of opaque compound words during encoding which led to the greater distinctiveness of the opaque words. Moreover, Han et al. suggested the reason they found higher discrimination for opaque compound words unlike Wong and Rotello (2010) was because no singletons were presented during the study phase. They suggested the presentation of singletons during the study phase in Wong and Rotello's study led participants to pay attention to the meanings of both opaque and transparent compound words. This led to decreasing the distinctiveness of opaque compound words.

Relevant to our study, both Han et al. (2014) and Wong and Rotello (2010) found that the higher semantic transparency of transparent compared to opaque compound words did not provide any advantage for item recognition. We also found that the higher semantic transparency (i.e., conceptual fluency) of transparent compared to opaque compound words did not confer any advantage in yes-no associative recognition.

The results of Experiment 1 and 2 in our study are supportive of Ahmad and Hockley's (2014) interpretation of the CW effect. That is, the familiarity of intact and rearranged CW pairs is greater than NCW pairs because of the preexperimental association of CW pairs. Therefore, similar to Lloyd et al. (2015), we suggest unitization increased reliance on familiarity during associative recognition. Fluency of unitized pairs is unlikely to be attributed as evidence of previous occurrence in associative recognition. Unitization would provide a means to use familiarity to make an associative recognition decision in the same way as single items would be recognized in an item recognition test. Similar to Lloyd et al., we argue that perhaps fluency was discounted by participants as a cue for enhanced familiarity of the CW pairs in our study. The enhanced familiarity of the CW pairs compared to NCW pairs in our associative recognition task is different from the familiarity attributed to fluency of processing of compound words. Similar to Westerman (2001) and Lloyd et al. (2015), we argue participants do not attribute fluency as evidence of previous occurrence in an associative recognition test.

One question to address is what familiarity is enhanced for unitized CW pairs? Lloyd et al. (2015) indicated they were not sure what familiarity was increased for unrelated word pairs unitized by a compound definition if it did not lead to a fluency attribution. They indicated previous work has suggested that familiarity may take a number of forms that may be distinct from fluency (e.g., Wagner and Gabrieli (1998)) or related but not equal to it (Dew & Cabeza(2011). The enhanced familiarity shown for unitized CW pairs may be of the type suggested by the Yonelinas model (see Yonelinas, 2002, for a review). Familiarity in this model reflects the assessment of "quantitative" memory strength information in a manner similar to described by signal detection theory.

Two recent studies provide additional evidence that unitization leads to greater use of familiarity in associative recognition decisions. The enhanced familiarity from unitization of CW pairs has shown to benefit older adults with reduced recollection as reflected in older adults' discrimination advantage for CW pairs (Ahmad & Hockley, 2014). Ahmad and Hockley suggested older adults can use the familiarity of the unitized pairs (not the familiarity of the individual items) as the basis of their associative recognition decisions. The familiarity associated with unitized study pairs would exceed the familiarity associated with rearranged test pairs and lead to increased discrimination in associative recognition.

Bastin et al. (2013) also examined if unitization benefited associative memory in older adults, but in source memory task. Bastin et al. found older adults showed a reduced source memory deficit when words were unitized with background color. Moreover, younger adults showed no discrimination difference between item (unitization) and context detail conditions. Bastin et al. attributed older adults' reduced source memory deficit to unitization benefiting intact familiarity present in older adults.

Evidence for unitization providing a means to use familiarity to make an associative recognition decision in the same way as in an item recognition test, is shown by the similarity of the CW effect to the concordant effect found by Greene (1999) in an item recognition task. In his first experiment, Greene (1999) compared recognition of words that were repeated four times before study (i.e., familiarized) and words only presented once during study (i.e., non-familiarized). Greene found a concordant effect for the familiarized words as in higher hits and false alarm rates compared to non-familiarized words. He concluded familiarity was used more for recognition of repeated study items.

Our results, however, show the increase in hit and false alarm rates are similar resulting in similar discrimination between CW and NCW pairs. In the framework of Dual process theory, an increase in hit rates for intact CW pairs occurred due to an increase in familiarity or combination of familiarity and recollection, however an increase in false alarm rates occurred due increased use of familiarity for rearranged CW compared to NCW pairs.

In conclusion, the results of the present study did not support a fluency of processing account of the CW effect. Perceptual and conceptual fluency of CW pairs are secondary to unitization in eliciting greater familiarity for CW pairs in an associative recognition task. The familiarity of intact and rearranged CW pairs is greater than NCW pairs because of the preexperimental association of CW pairs.

The findings of the current study point to the need of research to examine how participants are able to discount fluency as the source of familiarity in an associative recognition task that involves both unitized and non-unitized pairs. Discounting fluency may be a process essential for recognition of studied information and rejection of similar information. Moreover, it would be beneficial to investigate whether this discounting of fluency is similar for associative recognition of unitized preexperimental associations compared to unitized unrelated word pairs. Future research should examine if there is a more effortful analytic process required for discounting fluency of CW compared to unitized unrelated word pairs.

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Authors' Note

Table 1

Experiment 1: Mean hit (HR) and false alarm (FAR) rates, mean of median response times for hit rates and correct rejections (CR), estimates of discrimination (d´) and criterion placement (C) for compound (CW), noncompound (NCW) word pairs. Standard deviations of the means are given in parentheses. Also included are the results of Experiment 1 from Ahmad & Hockley (in press) study for the purpose of comparison.

Pair type	HR	RT	FAR	CR RT	d´	C
CW	.86 (.11)	3307 (423)	.32 (.17)	3999 (768)	1.90 (1.01)	-.40 (.47)
NCW	.70 (.17)	3660 (570)	.21 (.16)	3920 (787)	1.74 (1.42)	.17 (.40)
Experiment 1 (Ahmad & Hockley, 2014)						
Pair type	HR	HR RT	FAR	CR RT	d´	C
CW	.84 (.11)	1489 (392)	.36 (.23)	2183 (780)	1.67 (1.24)	-.37 (.47)
NCW	.69 (.14)	1768 (502)	.24 (.17)	1983 (505)	1.47 (1.03)	0.19 (0.39)

Table 2

Experiment 2:Examples of transparent compound words (TTCW), opaque compound words (OPCW), transparent noncompound words (TTNCW) and opaque noncompound words (OPNCW) used as words in Experiment 2A and word pairs in Experiment 2B. For clarity, words shown in italics formed the rearranged words. Those in the CW study list formed rearranged NCWs and those in the NCW study list formed rearranged CWs. All words or word pairs were presented in non-italic form and in randomized order in the experiment.

Set A — Study

TTCW	OPCW	TTNCW	OPNCW
barbershop	beeline	bedhole	blackwash
bloodstain	mothball	bookrobe	brainwalk
battlefield	blockhead	buttonbone	dashfare
nosebleed	pineapple	flagyard	catcast
doorknob	*greenhorn*	*pushcracker*	*pepperluck*
teardrop	*tightwad*	*nutcart*	*potmint*
fingertip	*hamstring*	*tablenail*	*ragbread*
toothpick	*treadmill*	*thumbcloth*	*shorttime*
hailstorm	*highlight*	*brothercrow*	*billboat*

Set A — Test

TTCW (Intact)	OPCW (Intact)	TTCW (Rearranged)	OPCW (Rearranged)
barbershop	Beeline	nutcracker	peppermint
bloodstain	Mothball	pushcart	potluck
battlefield	Blockhead	tablecloth	ragtime
nosebleed	Pineapple	thumbnail	shortbread

TTNCW (Intact)	OPNCW (Intact)	TTNCW (Rearranged)	OPNCW (Rearranged)
bedhole	Blackwash	doordrop	greenwad
bookrobe	Brainwalk	tearknob	tighthorn
buttonbone	Dashfare	fingerpick	hammill
flagyard	Catcast	toothtip	treadstring

Set B — Study

TTCW	OPCW	TTNCW	OPNCW
bathrobe	blackmail	beeball	barberstain
bedroom	brainwash	mothline	bloodshell
bookshelf	broadcast	blockapple	battleshop
buttonhole	catwalk	pinebell	nosefield
cheekbone	*dashboard*	*doordrop*	*greenwad*
crossroad	*peppermint*	*tearknob*	*tighthorn*

Set B — Test

TTCW (Intact)	OPCW (Intact)	TTCW (Rearranged)	OPCW (Rearranged)
bathrobe	Blackmail	doorknob	greenhorn
bedroom	Brainwash	teardrop	tightwad
bookshelf	Broadcast	fingertip	treadmill
buttonhole	Catwalk	toothpick	hamstring

TTNCW (Intact)	OPNCW (Intact)	TTNCW (Rearranged)	OPNCW (Rearranged)

drainpipe	*potluck*	*fingerpick*	*treadstring*
flagpole	*ragtime*	*toothtip*	*hammill*
graveyard	*shortbread*	*lampdog*	*kingback*

Intact		Rearranged	
barberstain	Beeball	cheekroad	peppertime
bloodshell	Mothline	crossbone	potboard
battleshop	Blockapple	flagyard	ragbread
nosefield	Pinebell	gravepole	shortluck

Table 3

Experiment 2A: Mean proportions of correct responses and mean correct median response times for transparent, opaque compound (CW) and noncompound (NCW) words in the lexical decision task. Standard deviations of means are presented in parentheses.

Pair type	Proportion Correct	Mean Response Time
Opaque CW	0.86 (0.03)	949 (168)
Transparent CW	0.88 (0.03)	783 (123)
Opaque NCW	0.90 (0.03)	1288 (461)
Transparent NCW	0.90 (0.04)	1308 (758)

Table 4

Experiment 2B: Mean hit (HR) and false alarm (FAR) rates, and estimates of discrimination (d´) and criterion placement (C) for transparent and opaque compound (CW) and noncompound (NCW) word pairs. Standard deviations of the means are given in parentheses.

Pair type	HR	FAR	d´	C
Transparent CW	.85 (.11)	.29 (.21)	2.01 (.91)	-.303 (.66)
Opaque CW	.88 (.11)	.28 (.16)	2.18 (.98)	-.413 (.56)
Transparent NCW	.66 (.216)	.13 (.16)	2.06 (1.19)	.53 (.59)
Opaque NCW	.71 (.15)	.15 (.16)	2.04 (1.02)	.39 (.55)

Table 5

Experiment 2B and Experiment 1 (Ahmad, Fernandes & Hockley, 2015): Mean median response times (msec) (RT) for hits (HR) and correct rejections (CR) for transparent and opaque compound (CW) and noncompound (NCW) word pairs. Standard deviations of the means are given in parentheses.

Pair type	HR RT	CR RT
Transparent CW	1547 (585)	2238 (817)
Opaque CW	1440 (397)	2416 (1200)
Transparent NCW	1928 (733)	2425 (1303)
Opaque NCW	1943 (709)	2316 (836)

Table 6

Experiment 2B: Comparison of word and word pair frequency as found by google search for non-spaced intact and rearranged transparent and opaque compound words (CW) and spaced compound words (CW pairs).

Non-spaced (CWs)	Transparent	Opaque
Intact	84307558 (1.872E8)	1.31E8 (2.921E8)
Rearranged	31776759 (4639752)	91694458 (2.269E8)
Spaced (CW pairs)		
Intact	4356250 (723134)	566833 (301886)
Rearranged	566833 (301886)	591541 (723134)

Chapter 5

General Discussion

A brief summary of results from each of the experiments presented in this dissertation is provided in Table 1. In thirteen experiments, I examined the effects of unitization of pre-experimental semantic associations (i.e., compound word pairs) on item and associative recognition. I found younger adults consistently showed no difference in discrimination between CW and NCW pairs in yes-no associative recognition. Secondly, in tests that emphasized familiarity-based judgments as in the standard forced-choice and speeded forced-choice tests, younger adults showed a discrimination advantage for CW pairs. Thirdly, older adults showed a discrimination advantage for CW pairs in a standard yes-no associative test, whereas younger adults did not. Lastly, I found no evidence that processing fluency of CW pairs had an effect on associative recognition.

Effects of unitization of CW pairs compared to other methods

There are certainly some differences and similarities between my findings compared to other studies that raise questions whether some of the other methods are valid and reliable methods to induce unitization. One key difference should be mentioned. Firstly, none of the methods of unitization used by researchers has consistently shown similar discrimination for unitized and non-unitized pairs.

Although Quamme, Yonelinas and Norman (2007) and Lloyd, Hartman, Ngo, Ruser, Westerman and Miller (2015) showed there was no discrimination difference between pairs unitized by compound definition and non-unitized pairs, Haskins, Yonelinas, Quamme and Raganath (2008) found a discrimination advantage for unitized pairs with a similar manipulation. In addition, researchers have consistently shown higher discrimination for semantically related

word pairs compared to unrelated word pairs, even though ERP correlates show greater use of familiarity than recollection for associative recognition of semantically related word pairs (Greve, van Rossum & Donaldson, 2007; Rhodes and Donaldson, 2008). Moreover, there is a discrimination advantage for repeated unrelated word pairs as I showed repeating unrelated word pairs led to a discrimination difference. I found that participants showed a discrimination advantage for repeated NCW pairs (Ahmad & Hockley, 2014). Furthermore, participants showed higher item recognition for repeated unrelated word pairs compared to CW pairs.

Secondly, similar to other researchers I found for younger adults, the degree of familiarity-based judgments encouraged by the recognition test can determine the effect of unitization (Ahmad & Hockley, 2014; Ahmad, Fernandes & Hockley, 2015). That is, if the associative recognition test encourages greater use of familiarity, there will be a discrimination advantage for compound word pairs. Researchers examining the effects of unitization in the form of within domain associations or with use of compound definition have shown younger adults show greater familiarity-based judgments for unitized pairs in a speeded yes-no associative recognition test than in a standard yes-no associative recognition test (Bastin, van der Linden, Schnakers, Montaldi & Mayes, 2010; Quamme et al., 2007; Haskins et al., 2008; Lloyd et al., 2015). Similarly, I found young adults showed a discrimination advantage for compound word pairs in a forced-choice test but not in a yes-no associative recognition test. Even when presentation time was reduced young adults did not show a discrimination advantage for unitized pairs in a yes-no associative recognition test. Thirdly, consistent with other methods of unitization, older adults showed a discrimination advantage for unitized pairs in a yes-no associative recognition test. Naveh-Benjamin et al. (2007) found older adults showed improved associative memory for semantically related word pairs. Moreover, older adults showed

improved source memory for pairs unitized by interactive imagery (Bastin, Diana, Simon, Collette, Yonelinas & Salmon, 2013).

Unitization can exist as a dichotomous variable

Yonelinas, Aly, Wang and Koen (2010) argue that there are levels of unitization, but I argue that unitization can exist as a dichotomous variable given the proper tests of unitization are conducted. I showed procedures can be developed to enable researchers to test if their results were due to unitization. The use of CW pairs represents a condition where unitization is most likely to occur (i.e., CW pairs represent a less ambiguous unitization condition than one induced by compound definitional encoding).

I showed item recognition was lower for the components or individual items of CW compared to NCW pairs (Ahmad & Hockley, 2014). I consider item recognition as a valid way to test if pairs are unitized, because the encoding of only associative information is emphasized in unitization. In contrast, for unrelated word pairs, the encoding of both item and associative information is equally emphasized (Hockley & Cristi, 1996). As a result, item recognition is higher for non-unitized than unitized pairs. In consequence, researchers could examine if unitization has occurred using their technique by examining item recognition of possibly unitized pairs. For example, after giving a compound definition instruction or interactive imagery instruction, researchers can test participants' item recognition, if item recognition is lower for the pairs that were in the unitized condition, than this would suggest unitization did occur by the method chosen by the researcher.

I have discounted the suggestion by researchers that unitization of unrelated word pairs can occur by repeating pairs four times (Kilb & Naveh-Benjamin, 2011; Wixted & Mickes, 2007). I found participants showed a discrimination advantage in item recognition for unrelated

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word pairs that were repeated compared to non-repeated unrelated word pairs and compound word pairs. I also showed that the type of test could affect the degree young adults' base their recognition judgments on familiarity. It would be reasonable for researchers to examine if their methods of unitization also produce a discrimination advantage in tests such as the forced-choice test that encourages familiarity-based judgments.

Secondly, Yonelinas et al. (2010) suggest factors other than unitization could contribute to the enhanced familiarity in associative recognition of unitized pairs. I found two factors other than unitization of CW pairs that contributed to the enhanced familiarity in associative recognition of unitized pairs. One factor was the participant age group and the other was the test format. I found in general older adults showed greater use of familiarity for unitized pairs than younger adults in associative recognition (Ahmad, Fernandes & Hockley, 2015). Moreover, test format influenced younger adults' reliance on familiarity in associative recognition of unitized CW pairs.

Apart from achieving the aim of my dissertation, there were findings of my dissertation that were unique in that they validated and provided strong evidence that supported some conclusions made by previous researchers. Importantly, the findings from my dissertation should inform future research directions.

Unitization of preexperimental associations improves associative memory in older adults

Firstly, I found that older adult showed a discrimination advantage for pre-experimental associations in both yes-no associative recognition and forced-choice test. Previously, Giovanello, Keane and Verfaeillie (2006) showed that amnesic patients displayed a discrimination advantage for CW pairs. They concluded that these patients rely on familiarity, because of impaired recollection. As a result, there was a benefit in associative recognition of

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unitized pairs. I showed this benefit in associative memory was also present for older adults. I suggested ease of encoding of CW pairs and greater use of familiarity benefited older adults discrimination in yes-no associative test. These findings validates the claim by some researchers that the age-related associative deficit is due both to a failure in properly binding unrelated words in a pair (e.g., Naveh-Benjamin et al., 2003; Naveh-Benjamin, Barv & Levy, 2007) and a reliance on familiarity due to impaired recollection (e.g., Cohn, Emrich & Moscovitch, 2008; Naveh-Benjamin & Kilb, 2011).

Future research should examine ways that unitized representations can be presented to improve associative memory in older adults taking into account that the associative deficit is both due to a failure to bind at encoding and a reliance on familiarity during associative recognition. Another direction for future research is to examine how older adults screened with reduced frontal executive deficit would benefit from different methods of unitization. That is, if there is a difference in the effect of unitization when pre-experimental associations compared to unitized associations formed from instructional manipulation on associative recognition in older adults. Perhaps, due to the ease of encoding provided by CW pairs, older adults with a frontal executive deficit may find pre-experimental associations more beneficial to associative memory than other forms of unitized associations such as unrelated word pairs unitized by compound definition. Moreover, an fMRI study examining older adults' associative recognition of unitized pre-experimental associations compared to non-unitized pairs would aid in identifying brain areas and networks that are essential for familiarity and recollection in associative recognition.

The influence of test format on associative recognition

Another interesting finding from my studies was that the format of the recognition memory test had an influence on younger adults' discrimination of unitized pre-experimental

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semantic associations and unrelated word pairs. To my knowledge, no researcher has shown such

a strong dissociation between younger adults performance in the yes-no and the two-alternative

forced-choice test. Bastin and Van der Linden (2003) compared the performance of young and

older adults on both a yes-no and a forced-choice task for unfamiliar faces using the remember-

know procedure in the same study. They found older adults showed higher recognition in the

forced-choice than the yes-not test. Bastin and Van der Linden suggested familiarity contributed

more to recognition in the forced-choice test than in the yes-no test, as reflected in higher

number of know than remember responses in the forced-choice test. However, some researchers

have suggested the remember-know procedure is a subjective measure and should be

supplemented by confidence ratings in order to be a valid measure of familiarity and recollection

(Wixted & Mickes, 2010, Yonelinas, 2002). As a result, my comparison of younger adults'

performance in yes-no and forced-choice (Ahmad, Fernandes & Hockley, 2015), provides more

conclusive evidence for a difference in contribution of familiarity to associative recognition in

the yes-no and forced-choice test as I included unitized pairs that encourage greater reliance on

familiarity.

Not only is use of familiarity encouraged in the forced-choice test, but response bias is

also minimized. In the yes-no test, a concordant CW effect for unitized pairs could occur because

participants are biased to provide more old responses to unitized pairs. The participant compares

the familiarity of single test probe to a criterion. In contrast, in the forced-choice test, response

bias is minimized as the target and lure are presented together. The participant can base their

recognition decisions on the relative familiarity of the two alternatives (Major & Hockley, 2007;

Patterson & Hertzog, 2010). However, as I demonstrated in my study, to interpret participants'

performance in the forced-choice test, one must examine recognition in the pure pair test

condition. In the mixed pair test condition, the lure is of a different pair type. As a consequence the participant could still be biased to one pair type. In contrast, in the pure pair test condition, the target and lure are of the same pair type. As a result, there can be no response bias in pure pair test condition. I found both young and older adults showed a discrimination advantage for unitized pairs in the pure list test condition (Ahmad, Fernandes & Hockley, 2015).

No researcher using the forced-choice associative recognition procedure has taken into consideration that response bias can influence forced-choice test recognition depending on the type of test condition as in mixed or pure list test condition. Researchers using the forced-choice test would be wise to compare performance in pure and mixed pair test conditions in order to see if their results are due to participants being encouraged to use familiarity rather than being biased to a specific response.

The role of fluency of processing in associative recognition

 Furthermore, it is interesting that fluency of processing does not play a significant role in associative recognition of CW pairs even though the experience human beings have with CW pairs as compound words is very high compared to NCW pairs. As noted earlier, Lloyd et al. (2015) showed priming had no effect on associative recognition of unitized pairs. That is, they found a similar proportion of old responses in matched and mismatched primed conditions for intact and rearranged unitized and non-unitized pairs. In addition, they found no discrimination difference between unitized and non-unitized pairs.

Contrary to Lloyd et al. (2015), I did not use priming to examine if fluency was the source of familiarity for unitized CW pairs. Instead in two experiments I examined the effects of perceptual and conceptual fluency on associative recognition of unitized CW pairs (Ahmad & Hockley, 2014). To minimize perceptual fluency, I presented the two words of the CW pairs on

separate screens at both study and test. I found similar discrimination for CW and NCW pairs.

No researcher has examined perceptual fluency in such a way to examine its effect on associative

recognition. Importantly, I was able to show a dissociation of effect of conceptual fluency in

lexical and associative recognition. In the lexical decision task, participants showed faster

response times for the more fluent transparent CW pairs compared to the opaque CW pairs.

However, in the associative recognition task, the magnitude of the CW effect was similar for

transparent and opaque CW pairs. These findings indicated fluency has a minimal role in the CW

effect. The familiarity of CW pairs arises from both their pre-experimental and experimental

familiarity.

Why would fluency not have a significant role in associative recognition? Perhaps in the

associative recognition test, participants are able to distinguish fluency of the item and memory

of the studied item. As Lloyd et al. (2015) suggests there may be an analytic process present in

associative recognition than in a lexical decision task. Perhaps distinguishing intact from

rearranged word pairs requires an analytic process not seen in a lexical decision task. In the case

of CW pairs, participants would have also used an analytic process to differentiate unitized CW

pairs that were present in the study list from compound words they have seen pre-

experimentally. Indeed, the effects of fluency have been shown to be reduced when participants

are given a more analytic question (Whittlesea & Price, 2001). The self-paced nature of the

associative recognition may also serve to aid participants in their assessment of recognition of

the item or pair based on familiarity from being studied in study list rather than from prior

experience as would promote use of an analytic process to discriminate intact and rearranged

unitized pairs. Future research could compare participants' discrimination of unitized CW pairs

and non-unitized NCW pairs in speeded and self-paced associative recognition tests, to examine

if participants are able to discount fluency of unitized pairs as the source of familiarity due to self-paced nature of the associative recognition task.

Support for the Yonelinas dual process model of recognition memory

Finally, the findings from my dissertation have implications for dual process model theories of recognition memory. In particular, my findings are broadly consistent with the DPSD model of recognition. Firstly, semantic memory can support retrieval from episodic memory (Greve et al., 2007; Kruikova et al., 2013; Rhodes and Donaldson, 2008). Similar to Giovanello et al. (2006), I showed that pre-experimental semantic associations can support retrieval from episodic memory as evidenced by older adults showing a discrimination advantage for CW pairs in yes-no test and young adults showing a discrimination advantage for CW pairs in the forced-choice test. Therefore, there is a tendency to utilize semantic information inherent in the material that is studied and tested within an episodic memory paradigm (associative recognition).

Secondly, the greater use of familiarity for associative recognition of CW pairs was found not to arise from the fluency of processing of unitized CW pairs. Indeed, the magnitude of the CW effect for transparent and opaque CW pairs was similar. Importantly, the magnitude of CW effect for these CW pairs was similar to that of Experiment 1 of my first study. Therefore, familiarity can provide an indication that stimuli are studied even though they are of high processing fluency. Support for greater use of familiarity for unitized pairs was also provided from overall faster response times for unitized compared to non-unitized pairs. Therefore, both young and older adults rely more on familiarity than recollection in associative recognition of CW compared to NCW pairs. Unitization boosts the familiarity of the intact pair, thereby enabling discrimination from rearranged pairs that have lower familiarity. However, the benefit in associative memory for unitized pairs depends on two important factors. For older adults, they

rely on familiarity because of impaired recollection. As a result older adults show a discrimination advantage for unitized pairs in both the yes-no and forced-choice test. There is an ease of encoding for unitized pairs and greater use of familiarity for associative recognition of unitized pairs which benefits older adults' associative memory. In contrast, younger adults only show a discrimination advantage for unitized pairs, when reliance on familiarity is encouraged as in the case of a forced-choice test.

Conclusion

Unitization of pre-experimental associations in the form of CW pairs can improve associative memory in both young and older adults. I argue that unitization can exist as a dichotomous variable given the proper conditions. CW pairs represent the ideal unitized associations. Some of the procedures I have used across my thirteen experiments can be used by researchers to examine if their manipulation induces the formation of unitized associations. The item recognition test may be a reliable and valid test of unitization. Factors such as age and test format must be taken into consideration when examining the effects of unitization on associative recognition.

My research has shown that there is still more research needed to examine the effects of unitization on associative recognition and associative memory. I showed response bias must also be considered when evaluating associative recognition in the forced-choice test. Moreover, fluency of processing of unitized pairs may not play a significant role in associative recognition. Finally I showed both the encoding and retrieval processes used in associative recognition of unitized pairs are markedly different for young and older adults. Future research should use ROC procedures and compare other methods of unitization with pre-experimental associations to determine the extent of differences between young and older adults in associative recognition of

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unitized pairs. ERP and fMRI could be used to determine the differences in familiarity and

recollection networks young and older adults use in associative recognition of unitized compared

to non-unitized pairs. Improvements in our understanding of associative memory in young and

older adults can only come with understanding what factors combined with the process of

unitization affect associative recognition.

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Table 1: A brief summary of my completed Experiments

The Role of Familiarity in Associative Recognition of Unitized Compound Word Pairs			
Experiment	**Procedure**	**Description**	**Findings**
1	**Associative recognition yes-no**	Participants studied compound and non-compound word pairs. At test, made old and new judgments.	• Concordant Compound word (CW) pair effect as represented in higher hits and false alarm rates for CW pairs compared to NCW pairs. • There was also no difference in discrimination between both pair types.
2	**Associative and Item recognition**	Same as Experiment 1 but in a between subject design. Also included item recognition.	• The results of Experiment 1 were replicated. • Item recognition was lower for unitized CW compared to NCW pairs.
3A	**Forced choice accuracy**	Same study phase as Experiment 1, participants told what intact and rearranged pair is. However at test two choices were presented. For example, intact CW and rearranged CW.	• There was a recognition advantage for CW pairs. • No concordant CW effect was found. A discrimination advantage was found for CW pairs.
3B	**Forced choice modified remember/know**	Same as Experiment 2, but not told what intact and rearranged pairs. Instead base response only on level of familiarity and told to respond as quickly as possible.	• Similar results as Experiment 2, even though participants based judgements on the familiarity of the pair.
4A	**Yes-No Associative Recognition with ROC analysis**	Similar to Experiment 1, but now unrelated word pairs that were repeated four times at study were presented during the test phase.	• I found no discrimination difference between CW and NCW pairs. • However, there was a discrimination advantage for repeated NCW pairs.
4B	**Item recognition**	Similar design as Experiment 4A, but item recognition was tested for repeated NCW pairs, NCW pairs and CW pairs.	• Item recognition of CW pairs was impaired relative to repeated and non-repeated CW pairs. • Interestingly, item recognition was highest for repeated NCW pairs.

5	**Item and Cued recognition**	At study given word pairs. Subjects were told second word which was capitalized will need to remember for test. Item and Cued recognition at test.	• Similar item recognition for CW and NCW pairs. Concordant effect was eliminated with cued recognition. • Similar hit rate for items presented with old cues. Unitization reduced recognition of rearranged items.

Improving Associative Memory in Older Adults with Unitization			
Experiment	**Procedure**	**Description**	**Findings**
1	**Yes-No associative recognition test**	Young and Older adults were tested in associative recognition of CW and NCW pairs. Response times were also collected.	• Concordant CW effect was present. • Young adults showed no discrimination difference between CW and NCW pairs. • Importantly, older adults showed a discrimination advantage for CW pairs.
2	**Yes-No associative recognition test**	Reduced presentation of CW and NCW pairs from 4 ms to 1.5 ms. Tested associative recognition of younger adults.	• Younger adults did not show a discrimination difference between CW and NCW pairs. • There was an age-related associative deficit simulated in younger adults as shown by reduced discrimination for NCW pairs. • Interestingly, response times were similar for CW and NCW pairs compared to Older adults
3	**Forced-Choice test**	Tested associative recognition of young and older adults in a forced-choice test.	• Both young and older adults showed a discrimination advantage for CW pairs.

The Increase in Familiarity from Unitization of Compound Word Pairs is not Based on Processing Fluency			
Experiment	**Procedure**	**Description**	**Findings**

1	**Yes-No associative recognition test**	Perceptual fluency was reduced by presenting during both the study and test phases, the words of each pair one at a time.	• A CW effect of comparable magnitude to previous experiments was found.
2A	**Lexical decision task**	The effect of conceptual fluency of CW pairs was examined in a lexical decision task. Transparent and Opaque CW along with NCW words were presented one at a time on the screen and participants indicated if the word was a compound word or not a compound word.	• Lexical decision time was found to be faster for compound compared to noncompound words. • Importantly, faster lexical decision time was shown for transparent compared to opaque CW pairs.
2B	**Yes-No associative recognition**	Associative recognition was tested for transparent, opaque CW and NCW pairs.	• The CW effect did not differ for transparent and opaque CW pairs.