



# The effects of unitization on the contribution of familiarity and recollection processes to associative recognition memory: Evidence from event-related potentials



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## ABSTRACT

Familiarity and recollection are two independent cognitive processes involved in recognition memory. It is traditionally believed that both familiarity and recollection can support item recognition, whereas only recollection can support associative recognition. Here, using a standard associative recognition task, we examined whether associative retrieval of unitized associations involved differential patterns of familiarity and recollection processes relative to non-unitized associations. The extent of engagement of familiarity and recollection processes during associative retrieval was estimated by using event-related potentials (ERPs). Twenty participants studied compound words and unrelated word pairs during encoding. Subsequently, they were asked to decide whether a presented word pair was intact, rearranged, or a new pair while electroencephalogram (EEG) was recorded. ERP results showed that compound words evoked a significant early frontal old/new effect (associated with familiarity) between ERPs to intact and rearranged word pairs, whereas this effect disappeared for the unrelated word pairs. In addition, the left parietal old/new effect (associated with recollection) between ERPs to intact and rearranged word pairs was greater for compounds than for unrelated word pairs. These findings suggest that unitization enhances the contribution of both familiarity and recollection processes to associative recognition.

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## 1. Introduction

Recognition memory refers to the ability to identify previously experienced events. Dual-process theories propose that recognition memory is supported by familiarity and recollection (Mandler, 1980; Yonelinas, 2002). Familiarity is a fast-acting process that occurs without retrieval of the details of an event or stimulus. Recollection refers to a slower process which requires conscious retrieval of the details about an event or stimulus. Event-related potential (ERP) studies have provided support for the dual-process theory by identifying distinct ERP old/new effects that are independently associated with the effects of familiarity or recollection. Specifically, the early mid-frontal old/new effect from 300 to 500 ms has been thought to reflect familiarity-based recognition (Curran, 2000; Curran and Cleary, 2003; Rugg and Curran, 2007)

while a later left parietal old/new effect from 500 to 800 ms is linked to recollection-based recognition (Rugg and Curran, 2007).

Associative recognition tasks and item recognition tasks are traditionally believed to be supported by different retrieval processes. Whereas both familiarity and recollection can support item recognition, only recollection can support associative recognition (Yonelinas, 2002). In a typical associative recognition task, the participants study unrelated word pairs during an initial study phase (e.g., umbrella–bread, map–rose, tiger–sand), and make a distinction between the intact pairs (e.g., umbrella–bread) and the rearranged pairs (e.g., map–sand) during a subsequent test phase. Using remember/know (R/K) procedure (Tulving, 1985), Hockley and Consoli (1999) found that associative recognition was associated with more “R” judgments (index of recollection), whereas item recognition was associated with more “K” judgments (index of familiarity). Receiver operating curves (ROCs) were curvilinear for item recognition, but were linear for associative recognition, suggesting that both familiarity and recollection contribute to item recognition, whereas only recollection contributes to associative recognition (Yonelinas, 1997). In ERP studies, Donaldson and Rugg

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(1998, 1999) found that associative recognition of word pairs evoked a parietal old/new effect associated with recollection.

Though these studies supported the proposal that associative recognition memory solely depended on recollection, recent studies have demonstrated that familiarity could also contribute to associative recognition when the to-be-remembered stimuli were perceived as a “unitized” representation (Mecklinger and Jäger, 2009; Yonelinas, 2002). This is referred to as the “unitization hypothesis” (Quamme, 2004). “Unitization” means the condition where two or more items are integrated into a single unit (Graf and Schacter, 1989).

Several ERP studies supported this hypothesis by revealing significant familiarity-related early frontal old/new effect only for unitized associations. For example, Jäger et al. (2006) asked participants to perform a forced-choice recognition task of face pairs, during which participants initially made an old/new judgment for the initially-presented face; if they made a correct “old” judgment, a follow-up forced-choice decision was required for the second face. The results showed that the familiarity-related frontal old/new effect was only evoked in the unitized condition (i.e., both faces were from the same person); in contrast, the recollection-related parietal old/new effect was only significant in the non-unitized condition (i.e., the faces were from different persons), suggesting that familiarity is sufficient to support associative recognition when the to-be-remembered information can be unitized, but that only recollection could support non-unitized associative recognition.

Rhodes and Donaldson (2007) examined associative recognition using word pairs which included two types, namely associated word pairs (e.g., traffic–jam), and semantically related word pairs (e.g. violin–guitar). During the test phase, participants needed to discriminate between the intact, rearranged, and new word pairs. The results showed that only the associated word pairs, which were rated as more easily unitized into a single unit, evoked a significant bilateral frontal old/new effect, whereas the left parietal old/new effect was evoked equally by both word pairs. Further work from this group (Rhodes and Donaldson, 2008) found that the semantically-related word pairs could evoke a greater frontal old/new effect when encoded with a strategy encouraging unitization (i.e., interactive imagery) compared with the non-unitized strategy (i.e., item imagery); however, the strategy did not influence the recollection-related left parietal old/new effects.

Even arbitrary word pairs, when encoded with a unitized strategy, can engage familiarity in subsequent associative retrieval. Bader et al. (2010) asked participants to encode semantically unrelated word pairs either along with a definition combining the word pair into a new concept (unitized definition condition) or together with a sentence frame separating the word pair as disconnected components (non-unitized sentence condition). The results showed that the early old/new effect was only significant in the unitized condition, suggesting that familiarity could contribute to the associative recognition when the word pairs are unitized. Consistent with Jäger et al. (2006), the parietal old/new effect was only significant in the non-unitized condition.

These ERP studies consistently found a familiarity-related frontal old/new effect evoked by the unitized condition. However, it should be noted that all these ERP studies quantified the ERP old/new effects by comparing intact with new pairs. Whereas the associative recognition task should refer to the discrimination of intact from rearranged pairs, rather than that of intact from new pairs (Hockley, 1992; Speer and Curran, 2007). Thus, the old/new effects between ERPs to intact and new pairs may be confounded by item memory, and the observed frontal old/new effect evoked by unitized condition might not be related to associative memory, rather to item memory. Therefore, it is necessary to examine whether familiarity indeed can support associative recognition after unitized encoding, by comparing the ERPs evoked by intact with those evoked by rearranged pairs.

Reports of the left parietal old/new effect under the unitized condition have also shown some variability. On the one hand, the

recollection-related parietal old/new effect was equivalent for both unitized and non-unitized conditions (Rhodes and Donaldson, 2007, 2008), suggesting that recollection can support associative recognition of both conditions. On the other hand, this old/new effect was only observed for the non-unitized condition (Bader et al., 2010; Jäger et al., 2006), which was interpreted as evidence that the recollection process was not necessary when the associations were unitized during encoding. The exact reason for the different patterns of the parietal old/new effect, however, remains unclear. Also, similar to the previous case, as these studies only analyzed the old/new differences between intact pairs and new pairs, these results could still be confounded by item recognition.

In the present study, we aimed to further examine the effects of unitization on the extent to which familiarity and recollection contribute to associative recognition. Based on previous studies (Giovanello et al., 2006; Rhodes and Donaldson, 2007), compound words were used in the unitized condition, and semantically unrelated word pairs were manipulated in the non-unitized condition. In a standard associative recognition task, we measured two types of old/new effects (i.e., both the intact vs. rearranged old/new effects and the intact vs. new old/new effects) to quantify the contributions of familiarity and recollection to associative retrieval. If familiarity can support associative recognition of unitized word pairs, the frontal old/new effect between ERPs to intact and rearranged pairs evoked by compounds should be greater than those of unrelated word pairs. It is traditionally thought that recollection contributes to discrimination of intact from rearranged pairs, so we expected that the parietal old/new effects between ERPs to intact and rearranged pairs would be similar for compounds and unrelated word pairs. We also performed analyses of old/new effects between ERPs to intact and new pairs for both compounds and unrelated word pairs, which may help to elucidate conflicting reports in the literature as previously described.

## 2. Methods

### 2.1. Participants

Twenty right-handed healthy university students (mean age 22 years, education levels 15.9 years) participated in the study. All participants were native Chinese speakers with normal or corrected-to-normal vision and were free from neurological and psychiatric disorders. Each participant signed informed consent documentation and was paid for participation. The study was approved by the Ethics Committee of the Institute of Psychology, Chinese Academy of Sciences.

### 2.2. Materials

The stimuli consisted of 144 compound words and 144 unrelated word pairs, the components of which were two-character Chinese nouns with low-to-high word frequency (range 1–472 occurrences per million) selected from the Dictionary of Modern Chinese words in Common Use (Liu, 1990). The mean word frequency for compounds and unrelated pairs was matched (58.6 and 61.5 per million, respectively).

Based on the protocol of previous studies (Kriukova et al., 2013; Rhodes and Donaldson, 2007), the degree to which word pairs could be unitized was assessed. Ten young adults (6 male, mean age 22.6 years, mean education 15.8 years) were asked to judge how well the two words could be bound into a single new concept using a scale from 1 (lowest ratings)–7 (highest ratings); none of these raters subsequently participated in the formal ERP experiment. Pairwise contrasts revealed that compounds ( $6.52 \pm 0.28$ ) were rated more unitized than unrelated word pairs ( $1.62 \pm 0.54$ ,  $p < .001$ ).

Each of the 144 compounds was assigned an unrelated word pair as its complementary “partner” item. A compound and its complementary partner could be rearranged to form another compound and

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