Brain Research 1667 (2017) 46–54

Contents lists available at ScienceDirect

Brain Research

journal homepage: www.elsevier.com/locate/bres

Research report

Event-related potentials during encoding: Comparing unitization to relational processing

Hsiao-Wei Tu, Emma E. Alty, Rachel A. Diana *

Psychology Department, Virginia Tech, 890 Drillfield Drive, Blacksburg, VA 24061, USA

ARTICLE INFO

Article history:
Received 14 November 2016
Received in revised form 5 April 2017
Accepted 1 May 2017
Available online 8 May 2017

Keywords:
Source recognition
ERP
Familiarity
Recollection
Encoding strategy
Unitization

ABSTRACT

Context details are typically encoded into episodic memory via arbitrary associations to the relevant item, known as relational binding. Subsequent retrieval of those context details is primarily supported by recollection. Research suggests that context retrieval can rely on familiarity if the context details are "unitized" and thereby encoded as features of the item itself in a single new representation. With most investigations into unitization focusing on the contributions of familiarity and recollection during retrieval, little is known about unitization during encoding. In an effort to begin understanding unitization as an encoding process, we used event-related potentials to monitor brain activity while participants were instructed to encode words with color information using relational association or unitization. Results showed that unitization-based encoding elicited significantly more *negative* potentials in the left parietal region than relational encoding during presentation of the second segment of strategically-specific sentences. This difference continued through presentation of the third sentence segment, becoming less lateralized, and ended before the final two segments were presented. During the mental imagery period, unitization-based encoding elicited significantly more *positive* potentials than relational encoding in the first 200 ms centrally and from 400 through 1000 ms in left fronto-temporal and parieto-occipital regions. Our findings indicate that unitization and relational processing diverged at approximately the time that the context item was presented in the relational condition. During mental imagery, unitization diverged from relational processing immediately, suggesting that unitization affected the nature of the item representation, and possibly the brain regions involved, during memory encoding.

1. Introduction

Recognition memory is the ability to identify an object or an event encountered previously. It is supported by both familiarity, which is based on the quantitative signal strength of an item, and recollection, which is based on subjective judgments of the type of information retrieved about the prior event (for review see Yonelinas, 2002). Typical encoding processing allows familiarity, recollection, or a combination of the two to support single item retrieval, whereas retrieval of the association between two random items strongly relies on recollection (Hockley and Consoli, 1999; Jacoby, 1991; Yonelinas, 1997). Likewise, memory for the arbitrary association between an item and its context details is strongly supported by recollection under typical encoding conditions, which have been termed "relational encoding" (Cohen and Eichenbaum, 1993; Davachi, 2006). However, if arbitrary item-item or item-context pairs are encoded as a single meaningful and cohesive representation through a strategy termed "unitization" (Graf and Schacter, 1989; Yonelinas et al., 1999), the associations can be recognized via familiarity processes (Diana et al., 2008; Giovanello et al., 2006). For example, imagine that you store your USB drive and your grocery "rewards" card on your key chain. You might remember the association between those two separate items as an arbitrary, non-meaningful relationship (relational processing), or as a unitized representation of "things on my keychain," which includes information about both items within a single representation.[1]

Unitization and relational association have been investigated extensively using behavioral paradigms (e.g. Diana et al., 2008; Quamme et al., 2007; Tu and Diana, 2016) and functional magnetic resonance imaging both at encoding (e.g. Davachi et al., 2003; Staresina and Davachi, 2006) and at retrieval (e.g. Bader et al., 2014; Ford et al., 2010). In these studies, participants have typically

* Corresponding author.
E-mail address: rdiana@vt.edu (R.A. Diana).

[1] These representations can also co-exist. It is likely that relational associations are more flexible than unitized representations and therefore the two types are useful in different situations.

http://dx.doi.org/10.1016/j.brainres.2017.05.003
0006-8993/

been instructed to make random associations between two words (or a word and its background color) on "non-unitized" trials and to imagine a new meaning for a combination of the two items (or a meaningful combination of the item with its context details) on "unitized" trials. Increased activity in the perirhinal cortex (PRC) has been associated with encoding of unitized word pairs when compared to relationally-bound pairs (Haskins et al., 2008; Staresina and Davachi, 2010), which is consistent with the finding of PRc involvement during subsequent retrieval of unitized information (Diana et al., 2007; Ford et al., 2010). On the other hand, hippocampal activation was greater during relational encoding as compared to unitized encoding (Davachi et al., 2003), and activation of both parahippocampal cortex (PHC) and the hippocampus were correlated with recollection-based retrieval of relationally bound, non-unitized, context details (Ranganath et al., 2004; Weis et al., 2004).

Event-related potentials (ERPs) have also been adopted to provide information about the timecourse of unitized or relational processing during retrieval, with participants being asked to recognize context details encountered earlier (see review in Rugg and Curran, 2007). The FN400, an early onset (300–500 ms) bilateral frontal component, has been correlated with familiarity-based recognition in item memory (Curran, 2000) and was modulated by unitized word pair retrieval (e.g., traffic-jam) rather than retrieval of semantically-associated word pairs (e.g., bread-cereal) (Rhodes and Donaldson, 2007). This component has also been interpreted as a correlate of conceptual or semantic processing (Stróżak et al., 2016; Voss and Federmeier, 2011; Voss and Paller, 2009). The LPC, a late onset (400–800 ms) parietal component, has been associated with recollection-based recognition in item memory (Curran, 2000) and was modulated by retrieval of word pairs in both conditions, regardless of the level of unitization (Rhodes and Donaldson, 2007). Similar ERP effects with delayed latencies were found in a paradigm that tested item-context unitization rather than item-item unitization (Diana et al., 2011). Participants were instructed to adopt either a "high unitization" strategy or a "low unitization" strategy to encode individual words and their associated background colors. During retrieval, participants showed a parietally-distributed positivity correlated with recollection-based source memory in both high and low unitization trials, whereas a frontally-distributed positivity was only correlated with high unitization trials, indicating the contribution of familiarity to source recognition.

Although previous studies have demonstrated dissociable ERP responses when retrieving unitized and non-unitized information, ERP techniques have not been used to examine the temporal characteristics of unitization-based encoding as compared to relational encoding. One difficulty in examining this question is the challenge to pinpoint *when* unitization actually occurs during encoding. Unitized encoding is defined by re-conceptualizing previously unrelated items into a single, unified representation. In item unitization, participants have been required to unitize two random words by a reason for why/how they are presented together as a compound word (e.g. Quamme et al., 2007). In item-context unitization, participants have been required to imagine the item as if it were the same color as the background and create a meaningful explanation for that imagery (Staresina and Davachi, 2006; Tu and Diana, 2016). Both processes require several seconds, making it difficult to precisely measure the temporal correlates elicited by unitization.

The current study used a unique procedure that allowed us to time-lock the unitization/relational scenarios and unitization/relational mental imagery with ERP recording. Specifically, the meaningful explanation for the unitized representation was provided by the experimenter, via a sentence, thus removing the additional creative demands present in some previous unitization paradigms. We also presented the sentences in segments that were visible for 800 ms each, rather than presenting a complete sentence and being unable to determine when the participant finished reading the scenario. Pilot data indicated that this segmentation-based presentation forced participants to read and collect sentence fragments before they could begin imagining the described scene and

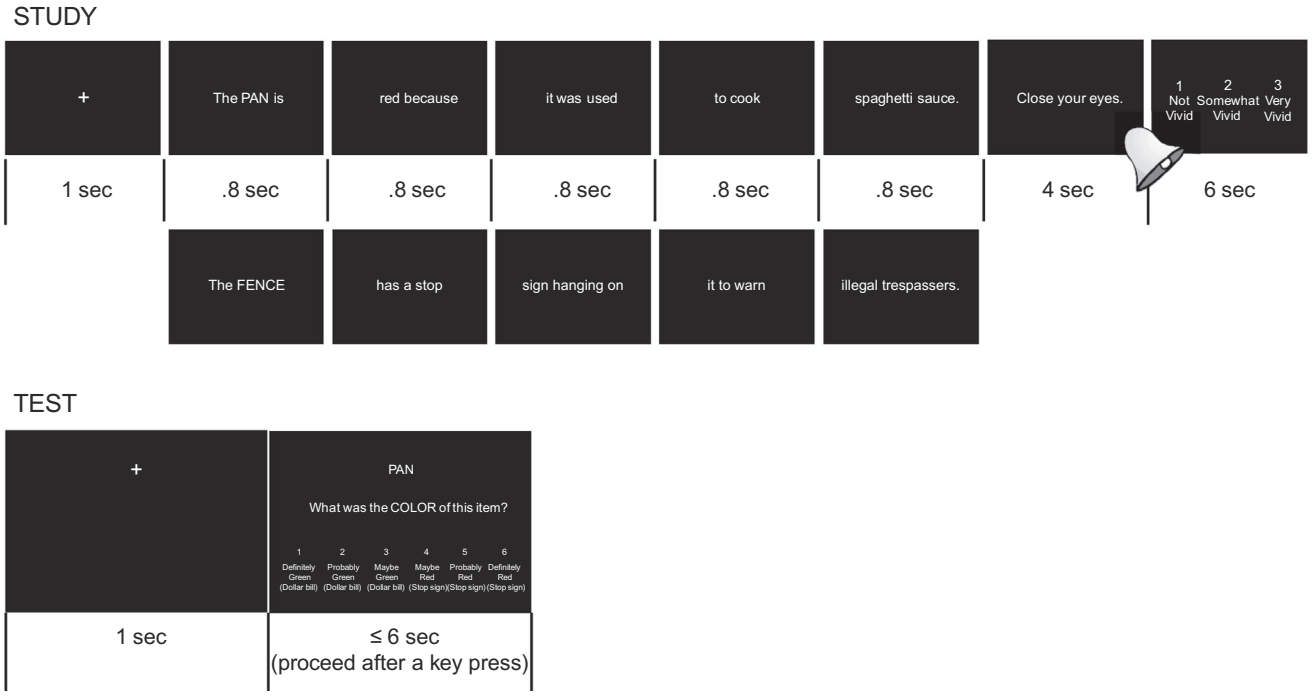

Fig. 1. Experimental procedure. Each participant went through four study sessions, followed by four test sessions. There were two unitized study sessions and two relational study sessions, organized in an ABBA design. All 240 words were pooled and randomly assigned to the four test sessions. The top line shows an example of a stimulus from the Unitized condition and the second line shows an example of a stimulus from the Relational condition.