Semantic relations differentially impact associative recognition memory: Electrophysiological evidence

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A B S T R A C T

Though associative recognition memory is thought to rely primarily on recollection, recent research indicates that familiarity might also make a substantial contribution when to-be-learned items are integrated into a coherent structure by means of an existing semantic relation. It remains unclear how different types of semantic relations, such as categorical (e.g., *dancer–singer*) and thematic (e.g., *dancer–stage*) relations might affect associative recognition, however. Using event-related potentials (ERPs), we addressed this question by manipulating the type of semantic link between paired words in an associative recognition memory experiment. An early midfrontal old/new effect, typically linked to familiarity, was observed across the relation types. In contrast, a robust left parietal old/new effect was found in the categorical condition only, suggesting a clear contribution of recollection to associative recognition for this kind of pairs. One interpretation of this pattern is that familiarity was sufficiently diagnostic for associative recognition of thematic relations, which could result from the integrative nature of the thematic relatedness compared to the similarity-based nature of categorical pairs. The present study suggests that the extent to which recollection and familiarity are involved in associative recognition is at least in part determined by the properties of semantic relations between the paired associates.

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1. Introduction

Human memory enables us to store and access general world knowledge, such as concepts, facts and interrelations, collectively referred to as semantic memory (Hodges & Graham, 2001; Squire & Zola, 1998). While semantic memory is a store of crystallized, common knowledge, episodic memory refers to the storage of personalized information associated with a specific spatiotemporal context that can be "re-experienced" during retrieval (Tulving, 1985, 2002). According to dual-process models of episodic recognition memory (Aggleton & Brown, 2006; Eichenbaum, Yonelinas, & Ranganath, 2007; Jacoby, 1991; Mandler, 1980; Rugg & Yonelinas, 2003; Yonelinas, 2002; Yonelinas, Aly, Wang, & Koen, 2010) recognizing that an item or an event was previously experienced can be mediated by two qualitatively distinct processes, termed familiarity and recollection. Fast-acting and relatively automatic familiarity is based on a subjective feeling of prior encounter that can vary in strength but does not bring to mind specific details of a study episode (Mandler, 1980; Mecklinger, 2006; Rugg & Yonelinas, 2003; Yonelinas, 2002). In contrast, recollection provides access to detailed information about the prior occurrence of an

item and its associated episodic context (Rugg & Curran, 2007; Rugg & Yonelinas, 2003; Woodruff, Hayama, & Rugg, 2006; Yonelinas, 2002). Episodic memory is known to benefit from the active access to and elaboration of semantic memory representations (Craik, 2002; Craik & Lockhart, 1972), for example, making use of semantic relational information enhances the recognition of associations between elements of an event (Badham, Estes, & Maylor, 2012; Naveh-Benjamin, Hussain, Guez, & Bar-On, 2003; Patterson, Light, Van Ocker, & Olfman, 2009). Here, we consider the way in which semantic memory impacts upon episodic recognition and, specifically, how particular semantic relationships might differentially interact with familiarity and recollection.

Event-related potentials (ERPs) provide a useful tool for investigating processes involved in episodic recognition. In old/new recognition tests, correctly recognized old items typically elicit more positive-going waveforms than correctly rejected new items between 300 and 600 ms post-stimulus over frontal electrodes and 500–800 ms over parietal electrodes. These early midfrontal and left parietal old/new effects are generally taken to reflect the contributions of familiarity and recollection, respectively, to episodic recognition memory (Curran, 2000; Rugg & Curran, 2007; for an alternative perspective see Voss & Paller, 2009). A common way to probe associative recognition is to ask participants to study a list of paired associates and at test, to present them with another list for which they have to discriminate between the pairs previously seen in the same combination (old), studied in different

combinations (rearranged), and completely new pairs. By including rearranged pairs at test, such experiments ensure that participants identify old pairs by retrieving a relational link and not by simply recognizing individual items as old (Hockley & Consoli, 1999). Whilst early ERP studies provide evidence for a critical contribution of recollection in associative recognition tasks of this type (Donaldson & Rugg, 1998), there now exist a number of reports in the literature demonstrating that familiarity may also play an important role when associations emphasize semantic processing (Opitz & Cornell, 2006; Rhodes & Donaldson, 2008). In one such investigation, Greve, van Rossum, and Donaldson (2007) reported that semantic relatedness of to-be-learned associations promotes familiarity-based recognition. Participants first studied paired associates that either shared a categorical membership (e.g., *rabbit–mouse*) or were unrelated (e.g., *hair–radio*). These were preceded by a category label which was related to the word pairs in the semantic condition and unrelated in the non-semantic one. Subsequently participants were given a recognition test during which old and rearranged/new word pairs, cued by category labels, had to be discriminated. As is typical of associative recognition experiments, the results revealed a robust left parietal old/new effect in both conditions, in line with a comparable contribution of recollection to associative recognition of categorical and unrelated pairs. In contrast, the early midfrontal old/new effect was larger for categorically-related than for unrelated word pairs leading Greve et al. to conclude that the presence of a coherent semantic structure boosts familiarity-based associative recognition. Though plausible, it may be worth replicating this outcome under standard associative recognition conditions which circumvent double priming (once by a category label, the second time by a within-pair) that could have also contributed to the enhanced early midfrontal old/new effect in the categorical condition.

It is also possible that different types of semantic relations differentially modulate episodic memory. This prospect was examined here, by focusing on categorical relations, such as those employed by Greve and colleagues, and thematic relations which have been shown to provide a distinct mechanism for organizing conceptual knowledge. Categorical relatedness, one of the major organizing principles of conceptual structure, refers to the way in which items that are conceptually or perceptually similar are often organized under the same category, e.g., *cherry–plum*, whilst distinct items fall into different categories (Estes, Golonka, & Jones, 2011; Hampton, 2000; Lin & Murphy, 2001; Markman and Wisniewski, 1997; Rosch, 1975). The defining characteristic of categorical relations is feature similarity; categorically related concepts of the same ontological level typically share many dimensions on which they can be compared (Wisniewski & Bassok, 1999) and are characterized by high semantic feature overlap as shown in a number of similarity-rating studies (Estes & Jones, 2009; Perraudin & Mounoud, 2009; Wisniewsky and Bassok, 1999). In contrast, high feature overlap is not a characteristic of thematic relations, which refer to relationships that emerge between entities participating in the same event or scene (Estes et al., 2011; Lin & Murphy, 2001). Experiments on categorization (Greenfield & Scott, 1986; Lin & Murphy, 2001; Saalbach & Imai, 2007) and priming (Estes & Jones, 2009; Hare, Jones, Thomson, Kelly, & McRae, 2009; Moss, Ostrin, Tyler, & Marslen-Wilson, 1995; Sass, Sachs, Krach, & Kircher, 2009) have shown that thematic relations provide an important alternative basis for structuring human conceptual knowledge. Rather than grouping concepts according to their internal features, thematic relations group concepts according to the complementary roles that they play in a common external scenario (Estes et al., 2011; Lin & Murphy, 2001; Murphy, 2001). For example, these might be functional (e.g., *knife–bread*), temporal (e.g., *morning – coffee*), spatial (e.g., *ceiling – lamp*), containment (e.g., *milk–jar*) or causal (e.g., *joke – laughter*) (Estes et al., 2011; Lin & Murphy,

2001; Sachs et al., 2011; Wisniewski & Bassok, 1999). Estes and Jones (2009) demonstrated that whenever two concepts which fit a common theme are encountered, they are rapidly integrated, as evidenced by facilitated processing of a target word in a priming paradigm (for a similar finding see Badham et al., 2012). Thematic relations between items might emerge spontaneously from the affordances of the current situation. For instance, a *lipstick* and *note*, typically unrelated to one another, are functionally related in a situation where it is necessary to leave a note and, in the absence of a pen, lipstick might be the only available means of writing (Estes et al., 2011). The focus of the present work however is on conventional thematic relations – salient relations with well-established representations in semantic memory (Estes et al., 2011; Lin & Murphy, 2001), e.g., *pen–note*. The conventionalization of relations occurs as interacting items frequently reappear in the same real-world situation (Estes et al., 2011), such as pen and note repeatedly co-occur in an office-scene. Through multiple exposures to the same contextual item combination, items become tightly associated and subsequently integrated into coherent representations (Opitz & Cornell, 2006) with prototypical context serving as "the 'glue' that binds objects in coherent scenes" (Bar, 2004, p. 617).

The integrative nature of thematic relations makes them interesting from the standpoint of studies on associative recognition, which show that recognition of several items encoded as a unified meaningful structure can be supported by familiarity (Giovanello, Keane, & Verfaellie, 2006; Quamme, Yonelinas, & Norman, 2007; Rhodes & Donaldson, 2007). Most studies on unitization have used existing or newly formed lexical compounds whose constituent parts have lost their individual representations and fused into a single meaningful structure. Unlike compound words of this kind, thematically related word pairs preserve their individual meanings and yet form a joint representation or theme. This characteristic of thematic relation appears to impact recognition memory. Some evidence in support of this comes from an ERP study by Opitz and Cornell (2006). In that study, participants learned quadruplets of words where three words were pre-experimentally related via frequent contextual co-occurrence, e.g., *desert, camel, oasis* alongside a fourth unrelated filler word. Participants studied the quadruplets while making contextual fit judgments which encouraged them to think about a common theme, or while making size judgments which promoted non-semantic processing. Subsequently, participants were given a single item recognition test. The results revealed that only words studied in the context of the thematic fit task elicited an early midfrontal old/new effect. These data thus suggest that processing relations in terms of themes can foster familiarity-based recognition of single items.

The goal of the present experiment was to explore whether categorical and thematic relations differentially modulate the episodic processes involved in associative recognition. As the experiment was designed to investigate the impact of semantic relations between individual concepts per se and not the impact of unitization, the study task was designed to deliberately discourage unitization (compound-formation) strategies by requiring participants to perform a separate item imagery task on sequentially presented words. Afterwards, participants performed an associative recognition test in which they had to discriminate between old, rearranged, and new pairs. By manipulating the kind of semantic relation between the paired concepts and recording ERPs during the test phase, we aimed to obtain electrophysiological signatures of familiarity and recollection during the associative recognition of the two relation types. The greater capacity of thematic relations to support holistic processing was expected to lead to a greater contribution from familiarity-based recognition, reflected in a larger early midfrontal old/new effect relative to that for categorical pairs. The predictions concerning the behavior of the left-parietal