Prospective and retrospective semantic processing: Prediction, time, and relationship strength in event-related potentials

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ABSTRACT

Semantic context effects have variously been attributed to prospective processing – predictions about upcoming words – or to retrospective appreciation of relationships after reading both context and target. In two experiments, we altered the core variable distinguishing prospective from retrospective processing, namely time. Word pairs varying in strength of relationship were presented sequentially, to allow time for anticipation of the second word, or simultaneously. For both sorts of presentation, the amplitude of the N400 component of the event-related potential was graded from Unrelated to Moderate/Weak to Strong associates. Strong associates showed a temporal advantage over weaker associates – an earlier context effect – only during sequential presentation. Spatial distributions of the N400 context effects also differed for simultaneous versus sequential presentation.

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1. Introduction

Semantic context effects are evident across a broad swath of dependent measures in cognitive psychology. Whether the context is a single word or a sentence fragment, words preceded by related contexts can be accurately identified with briefer exposure durations or higher levels of noise than words preceded by unrelated contexts (Miller & Isard, 1963; Tulving & Gold, 1963), and receive faster responses in a variety of tasks including deciding whether a letter string is actually a word (*lexical decision*, Meyer & Schvaneveldt, 1971), naming aloud (Jacobson, 1973), and semantic judgments such as whether the item refers to an animate or concrete entity (McRae, de Sa, & Seidenberg, 1997). Across several decades, many functional mechanisms have been proposed to account for these effects, and these accounts can be categorized in a variety of ways. Here, we focus on one sort of division, namely the role of **time**.

1.1. Prospective versus retrospective accounts of semantic context effects

Prospective explanations of semantic context effects stipulate that, after presentation of a related context, some aspect of the target word is pre-activated, so that the target has already been partially processed in advance of its physical occurrence. Prospective theories vary in their description of what, exactly, is pre-activated, from discrete individual words in models with localist representations of items in a mental lexicon, to semantic features of words in models with more distributed representations. Localist versions include both passive spreading activation along links between related words (Collins & Loftus, 1975), and more active anticipation of related words (Becker, 1980; Neely, 1977). Distributed versions include partial pre-activation of the target word's meaning due to semantic features that are shared with the context (Masson, 1995; Plaut, 1995; Sharkey, 1989), or activation of event-based schemas that include instruments, objects and actors that might participate in the same activity, such that "broom" can prime "floor" (Hare, Jones, Thomson, Kelly, & McRae, 2009; Moss, Ostrin, Tyler, & Marslen-Wilson, 1995). These accounts vary dramatically in their assumptions about how words and semantic knowledge are represented in long-term memory, and in their applicability to single-word versus sentence contexts (see Van Petten & Kutas, 1991 for discussion). Prospective explanations are, however, united by the idea that the critical activity leading to facilitated processing of a target word occurs in the interval between the presentation of the context and the target.

In contrast to such prospective accounts, retrospective accounts of semantic context effects stress the idea that readers and listeners spontaneously try to find relationships among sequential words, and that performance of many tasks is improved (or at least not hindered) when such relationships can be found. For instance, one influential retrospective account is the *compound cue* model,

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which states that sequentially presented words are combined in working memory, and the combination matched to the contents of long-term memory. Compound cues formed from related words are better matches – better retrieval cues – than unrelated pairs or the target alone (Ratcliff & McKoon, 1988, 1995). Other retrospective accounts are more closely linked to particular tasks. For the lexical decision task that has dominated behavioral experiments, it has long been noted that finding a relationship between the target item and the preceding context serves as a clear signal that the target cannot be a nonword and should receive a "yes" decision (de Groot, 1983; Neely, Keefe, & Ross, 1989). The defining feature of retrospective accounts is that semantic context effects can arise from the comparison and combination of word meanings **after** both the context and target have been presented.

The earliest reports of semantic context effects on accuracy and reaction time were interpreted as evidence for active prediction of upcoming words (e.g., Miller & Isard, 1963; Tulving & Gold, 1963), but prospective accounts became generally less popular in the late 1970s and early 1980s (e.g., Forster, 1981; see Van Petten & Luka, 2012 for review). Over the last decade, researchers using behavioral methods have once again begun to favor the idea that readers and listeners actively anticipate the semantic features of upcoming words, at least, and perhaps individual words as well (Kamide, Altmann, & Haywood, 2003; Pickering & Garrod, 2007; Roland, Yun, Koenig, & Mauner, 2012).

The N400 component of the event-related potential is also very sensitive to semantic context, such that words preceded by congruent sentence fragments or by related single words elicit smaller N400s that those preceded by unrelated contexts (see Kutas, Van Petten, & Kluender, 2006 for review). N400 context effects have been observed with a variety of assigned tasks including lexical decision, monitoring for a target semantic category (e.g., occasional animal names in a stream of words), detecting repeated words or sentences, preparing to answer comprehension questions that occur after sentences, preparing to judge whether a probe letter occurred in the previous word, or similarly, preparing to judge whether a probe word occurred in the previous sentence. Critically, N400 context effects can also be observed in situations that do not require any specific choices or decisions imposed by the laboratory task, with instructions only to read for comprehension. Although N400 context effects are not impervious to requirements to perform additional tasks that might detract from semantic processing (see Van Petten, 2014 for recent review), it is clear that the sensitivity of this component to semantic context is not tied to a particular task-specific strategy. Nonetheless, there have been debates about the contribution of prospective versus retrospective mechanisms to N400 context effects or, more specifically, about the confirmation of predictions about upcoming words versus the ease of semantic integration across multiple words after they have occurred (Chwilla, Brown, & Hagoort, 1995; Holcomb, 1993; Lau, Phillips, & Poeppel, 2008; Osterhout & Holcomb, 1995).

As in the behavioral literature, recent N400 studies have emphasized the anticipation of upcoming words and/or their meanings (see Van Petten & Luka, 2012 for review). Many N400 sentence-processing results have been interpreted as evidence for anticipation of semantic features, if not words *per se* (Federmeier, 2007; Szewczyk & Schriefers, 2013; Thornhill & Van Petten, 2012; Wlotko, Federmeier, & Kutas, 2012; see also Federmeier, Kutas, & Schul, 2010 for similar interpretation of a word-pair study). Other results are more plausibly interpreted as evidence for prediction of full words. For instance, DeLong et al. have examined ERPs to the articles "a" and "an" in English (DeLong, Groppe, Urbach, & Kutas, 2012; DeLong, Urbach, & Kutas, 2005). These articles have identical (minimal) meaning, so that they should never create difficulty for semantic integration. However, given a sentence about someone flying something, if "kite" was the most favored sentence completion, then the word "a" in penultimate position elicited a smaller N400 than the word "an" (as in "an airplane", an acceptable but less preferred ending). These results suggest that the subjects were actively predicting a specific word, over and above some class of fly-able nouns. Similarly, Laszlo and Federmeier (2009) observed smaller N400s for semantically incongruent sentence completions when these were orthographic neighbors of a congruent word (as compared to incongruent words that were not neighbors), which may also suggest that semantically-based predictions extend to visual word forms.

1.1.1. Revisiting the utility of retrospective processing

Despite the clear evidence for prospective contributions to the N400, it seems premature to dismiss the importance of retrospective evaluation of semantic relationships. Language is used not only to refer to information known to both the speaker/writer and the listener/reader, but also to communicate novel concepts that cannot be fully appreciated or predicted in advance. Much of everyday language comprehension is likely to involve a complex interplay between the retrieval of existing concepts from memory and the construction of new meaning from these building blocks (Coulson, 2006). Some ERP studies indicate that the overall context of a sentence or an extended passage of discourse can override relationships that are likely to be pre-stored. Word-pair relationships that ordinarily reduce N400 amplitude can be made ineffective if the pair relationships conflict with the newly-constructed meaning of an entire sentence. For instance, although "olive-OIL" elicited a smaller N400 than "olive-SHOES" for isolated pairs, this pattern of results was reversed given a sentence frame like "Although they were uncomfortable to walk in, she loved her olive …" (Coulson, Federmeier, Van Petten, & Kutas, 2005). A similar reversal was observed for full sentences depending on discourse context. Although the final word of "The peanut was in LOVE" elicited a larger N400 than "The peanut was SALTED" in a list of unconnected sentences, a story about the adventures of a peanut character produced the opposite pattern of results (Nieuwland & van Berkum, 2006). In these two studies, it is difficult to determine **when**, exactly, the novel relationships were constructed given the strong constraints imposed by the preceding context. A different experiment provides stronger evidence for the retrospective appreciation of meaning. Chwilla and colleagues found that, given an appropriate lead-in – such as a protagonist's strong desire to go canoeing despite the absence of paddles – readers were able to make sense of a novel scenario like paddling a canoe with a Frisbee. As compared to equally unpredictable but uninterpretable combinations (like paddling with a pullover), the newly-constructed interpretations yielded a smaller N400 (Chwilla, Kolk, & Vissers, 2007). Because of the very weak predictability of words like "Frisbee", this result shows a clear influence of retrospective (although relatively rapid) appreciation of semantic relations. At the same time, other studies suggest a cost for new meaning construction as compared to relationships that are more likely to be pre-stored. As compared to more familiar or more conventional combinations, novel metaphors and novel combinations of literal word meanings have variably shown larger N400s (Arzouan, Goldstein, & Faust, 2007; Coulson & Van Petten, 2002, 2007) or enhancements of a later frontal positivity (Davenport & Coulson, 2011, 2013). Overall, the existing literature suggests contributions of both anticipatory processes and of successful integration performed after all the input has occurred.

1.2. The current study: prediction, time, and association strength

The current study uses much simpler materials than the sentence experiments that have suggested roles for both predictive