CORTEX XXX (2014) 1–14

Available online at www.sciencedirect.com

ScienceDirect

Journal homepage: www.elsevier.com/locate/cortex

Research report

The neural bases of argument structure processing revealed by primed lexical decision☆

Donghoon Lee[a], Benjamin Pruce[b] and Sharlene D. Newman[b,*]

[a] Department of Psychology, Pusan National University, Busan, South Korea
[b] Department of Psychological and Brain Sciences, Indiana University, Bloomington, IN, USA

ARTICLE INFO

Article history:
Received 30 May 2013
Reviewed 22 July 2013
Revised 8 January 2014
Accepted 21 April 2014
Action editor Stefano Cappa
Published online xxx

Keywords:
Priming
fMRI
Argument structure

ABSTRACT

Previous studies have reported anticipatory effects during sentence processing. However, the source of these effects has not been clearly characterized. This study investigated the hypothesis that one source of anticipatory effects, particularly during verb processing, is the automatic triggering of argument structure processes. If argument structure processes are automatically triggered it was hypothesized that the task need not require the initiation of the process, as such a primed lexical decision task was used that examined the neural priming of cross-grammatical class prime pairs (e.g., verb-noun priming). While previous studies, as does the current study, have revealed behavioral priming for cross-grammatical class and within-class (noun–noun and verb–verb) prime/target pairs, the current results revealed significant activation differences. Enhancement effects were observed for cross-grammatical class priming in the language network, particularly the inferior frontal gyrus (BA 47), and the posterior temporal cortex. Both regions have been linked to argument structure processing previously. Within-class priming resulted in neural suppression of the inferior temporal/occipital regions. Together, the data presented suggest the automatic triggering of argument structure representations and demonstrate that priming is a fruitful mechanism to explore aspects of sentence processing.

1. Introduction

The language processing system has been characterized by a set of separate processing modules which include systems that process orthographic, phonological, syntactic, and semantic information (Levelt et al., 1999). However, there is overwhelming evidence indicating that comprehenders use linguistic and non-linguistic information to anticipate or predict upcoming information (Altmann & Kamide, 1999; Chambers & San Juan, 2008; Delong, Urbach, & Kutas, 2005; Ferretti, McRae, & Hatherell, 2001; Kukona, Fang, Aicher, Chen, & Magnuson, 2011). One of the first studies demonstrating anticipatory effects in sentence comprehension was reported by Altmann and Kamide (1999) using the visual world paradigm. When participants listened to a sentence that contained the verb *eat* while viewing a scene that contained a cake, ball, train and car, they immediately directed their gaze

☆ This is an original work that has not been published elsewhere.

* *Corresponding author*. Department of Psychological and Brain Sciences, Indiana University, Bloomington, IN 47405, USA.
E-mail addresses: sdnewman@indiana.edu, sharlenenewman93@gmail.com (S.D. Newman).

http://dx.doi.org/10.1016/j.cortex.2014.04.013
0010-9452/

to the object in the scene that was edible (e.g., a cake) instead of the inedible objects (e.g., ball, train, car). However, when the utterance contained the verb *move* participants delayed fixation until the direct object was fully specified. The anticipatory effect observed at the verb was interpreted to suggest that "the processor can predictively activate representations corresponding to a verb's arguments" (p. 262). In other words, the verb primes the nouns that potentially act as its arguments, demonstrating significant interactions between semantic and syntactic processing modules.

Behavioral priming studies also support the hypothesis that anticipatory effects impact sentence comprehension (Ferretti et al., 2001; McRae, Hare, Elman, & Ferretti, 2005). Many of the constraints that drive anticipatory effects are thought to be provided by the verb (Altmann & Kamide, 1999; Kukona et al., 2011; McRae et al., 2005). In fact, McRae and colleagues argue that accessing the verb also activates "highly specific knowledge about the entities that typically participate in the event that they encode" (page 1176); thereby driving the priming of nouns. However, nouns can also drive anticipatory effects in that they also activate the events that they typically are involved in (i.e., nouns also prime verbs). In a series of studies it has been demonstrated that verbs prime nouns (Ferretti et al., 2001) and that nouns prime verbs (McRae et al., 2005). Although these previous studies show that cross-grammatical class priming (e.g., nouns priming verbs) has similar behavioral effects as within-class priming (e.g., nouns priming nouns), it is not at all clear whether different mechanisms are responsible for the effect. If, as suggested by Altmann and Kamide (1999) the anticipatory effects observed for cross-grammatical class priming are related to filling thematic roles instead of a semantic association between the verb and the object then different mechanisms may be expected for cross-compared to within-grammatical class priming.

The primary goal of the current study was to determine whether these anticipatory or priming effects observed in noun/verb priming are the result of attempts to fill the argument roles of the verb. Verbs play a key role in sentence level syntactic processing. One important lexical-syntactic feature of verbs is its complement (entities that denote the participants involved in the event described by the verb) structure. Another important feature of verbs is the number and types of thematic roles (e.g., agent) the verb assigns to the complements. Essentially thematic roles describe "who did what to whom" in a sentence. This argument structure information, both the complement and thematic role information, are thought to be represented in the lexical entry of the word (Boland, 1993; Boland et al., 1990; Holmes, 1987; Shapiro et al., 1987, 1993; Shetreet, Palti, Friedmann, & Hadar, 2007; Tanenhaus et al., 1989; Trueswell et al., 1993). Therefore, it is reasonable to hypothesize that this information becomes active when the verb is activated. The question addressed here is does the activation of this information automatically trigger the process of filling those argument roles. Q2

The majority of the studies examining cross-grammatical class priming have used behavioral methods. While they have consistently reported behavioral priming effects, it is unclear what the source of the priming effect is. The aim of the current study was to examine the neural architecture that supports the behavioral priming effects observed in cross-grammatical class priming with the goal of determining whether syntactic, argument structure processes are evoked when nouns prime verbs and vice versa. To accomplish this goal we explored within- and cross-grammatical class priming. Cross-grammatical priming here refers to noun-verb and verb-noun priming in which the verb is an action that can be performed by the noun and therefore the noun is a potential thematic argument of the verb. In addition to examining the neural bases of cross-grammatical priming, the current study also compared it to within-class priming. The within-grammatical class priming was used here as a control condition. Because there are a number of previous studies that have examined within-class priming, using it as a control provided a point of comparison. The within-class priming examined noun–noun and verb–verb pairs in which the noun–noun pairs were animals with similar characteristics (e.g., spider-scorpion) and the verb–verb pairs were manner of motion verbs depicting a similar motion (e.g., scoot-scram). Q3

fMRI priming studies have two potential responses, suppression or enhancement effects. Suppression, decreased activation for the related compared to the neutral or unrelated baseline condition, during fMRI priming studies has been interpreted to indicate overlap between the prime and target, either overlapping semantic features or processes (Henson, 2003; Schacter, Wig, & Stevens, 2007). Enhancement, on the other hand, is increased activation compared to the baseline for the primed target and is thought to be due to different or additional processes related to the formation of new representations (Henson, 2003; Raposo, Moss, Stamatakis, & Tyler, 2006). There have been a number of fMRI studies of semantic priming and the results have been mixed. Many of these neuroimaging studies have reported activation suppression for the primed target (Copland, et al., 2003; Gold, et al., 2006; Kotz, Cappa, von Cramon, & Friederici, 2002; Mummery, Shallice, & Price, 1999; Rissman, Eliassen, & Blumstein, 2003; Ruff, Blumstein, Myers, & Hutchison, 2008; Wheatley, Weisberg, Beauchamp, & Martin, 2005). The cortical region most often found to show suppression effects is the inferior occipital/temporal region. However, there are also studies that report enhancement effects (Kotz et al., 2002; Raposo et al., 2006; Rossell, Price, & Nobre, 2003). The enhancement effects have been in the right hemisphere, left middle temporal cortex and inferior parietal cortex. It has been suggested that the differences across studies may be due to differences in methods, tasks and materials (Raposo et al., 2006). However, by using the same task in the same participants and overlapping stimuli, it should make comparing within- and cross-grammatical class priming more reliable.

Cross-grammatical class priming was predicted to reveal significant enhancement effects. These effects were predicted to result from integration processes that are automatically triggered when a thematically-related noun and verb are presented. Activation enhancement was predicted in the regions implicated in complement processing, such as middle and superior temporal cortex (Assadollahi, Meinzer, Flaisch, Obleser, & Rockstroh, 2009; Bornkessel, Zysset, Friederici, von Cramon, & Schlesewsky, 2005) and thematic role assignment, which involves the left inferior frontal gyrus (Hirotani, Makuuchi, Ruschemeyer, & Friederici, 2011, Newman, Ikuta,

Please cite this article in press as: Lee, D., et al., The neural bases of argument structure processing revealed by primed lexical decision, Cortex (2014), http://dx.doi.org/10.1016/j.cortex.2014.04.013