Journal of Neurolinguistics 26 (2013) 129–148

Contents lists available at SciVerse ScienceDirect

Journal of Neurolinguistics

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

P600-like positivity and left anterior negativity responses are elicited by semantic reversibility in nonanomalous sentences

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ARTICLE INFO

Article history:
Received 18 August 2011
Received in revised form 14 April 2012
Accepted 13 June 2012

Keywords:
Syntax
EEG
Language
ERP
N400
LAN
Working memory
Reanalysis

ABSTRACT

ERPs are commonly elicited by semantic and syntactic violations in sentences, leading to proposals that they reflect neural activity underlying ordinary language comprehension. We examined ERPs in an auditory sentence-picture-matching task, using non-anomalous sentences that were either semantically reversible, (boy pushes girl) or irreversible, (boy eats apple). Timelocked to the end of the critical clause, which occurred in the middle of a longer sentence, we observed an enhanced central-posterior positivity in response to the reversible sentences. The topography of this response is consistent with the P600 potential reported in studies of syntactic anomalies and other manipulations related to sentence structure. Following the end of the sentence, during a memory delay period prior to picture onset, reversible sentences also evoked a protracted anterior negativity, predominantly on the left. This negativity was stronger for sentences containing relative clauses compared to simple active sentences, but did not differ between object-embedded and the less complex subject-embedded clauses. The observation of a P600 occurring selectively in reversible sentences supports the interpretation of that potential as reflecting the syntactic processing of thematic relationships, as irreversible sentences contained alternative cues for thematic roles. The left anterior negativity likely reflects later processes of rehearsal and reanalysis of sentence content in working memory.

Published by Elsevier Ltd.

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0911-6044/$ – see front matter Published by Elsevier Ltd.
http://dx.doi.org/10.1016/j.jneuroling.2012.06.001

1. Introduction

In the cognitive neuroscience of language, a large body of work has been devoted to the study of neural responses to linguistic anomalies. Anomaly paradigms have been very fruitful, yielding robust responses that relate to distinct aspects of sentence processing. For example, the N400 potential is reliably evoked by numerous manipulations involving the semantic expectedness of a given word. Originally observed in response to semantically incongruous sentence endings (Kutas & Hillyard, 1980), it was subsequently elicited in paradigms that do not involve anomalies. N400 amplitude is closely related to the amount of semantic priming of the eliciting word (Holcomb, 1988) and the ease of its integration into the overall sentence meaning (Kutas & Federmeier, 2000). Other ERP responses are typically evoked by anomalies other than semantic expectedness. For example, the Left Anterior Negativity (LAN) and a later centro-parietal positive wave, commonly called "P600," are often seen in response to syntactic anomalies such as violations of expected word order (Friederici, Hahne, & Mecklinger, 1996) or inflection (Osterhout & Mobley, 1995). Subsequent studies have also demonstrated P600 effects in a wide variety of contexts that are not, strictly speaking, syntactically anomalous. These include syntactically ambiguous "garden-path" sentences (Kaan & Swaab, 2003; Osterhout & Holcomb, 1992), violations of animacy restrictions (Kuperberg et al., 2003), and various others (see discussion). The observed dissociations between the N400 and P600 responses suggest that these two ERP components may serve as indices of the engagement of distinct neural systems involved in language processing.

Although anomalies serve as useful tools in the experimental study of language, they are by definition highly atypical instances of language input. This raises an important question: do the same neural mechanisms that give rise to anomaly responses also underlie the routine operations of ordinary language comprehension? To answer this question, some researchers have sought to examine ERPs to other nonanomalous linguistic manipulations. This is somewhat more difficult, as anomalies not only produce quantitatively large responses, but the anomaly typically emerges at one unique "violation point" in a sentence. ERP studies of language generally use the onset of a critical word as a timelocking point. When a sentence becomes anomalous or ambiguous (or unambiguous) at a specific word, timelocking of the response to that word's onset results in good alignment of the neural activity across trials, resulting in a robust ERP signal. However, neural activity related to more subtle manipulations of syntactic and semantic complexity may also emerge over a longer time scale, as the meaning of a sentence is built up over several words. In such cases, evoked potentials that are typically linked to single words, such as the N400 and the P600, may not be discernible even though the same neural networks may be involved in processing sentences over longer time scales.

Thus, studying neural activity on the time scale of portions of sentences (such as phrases and clauses) is a challenge in neuroscience. FMRI integrates activity over several seconds, limiting its usefulness in discriminating sub-sentence phenomena, while ERPs are best at revealing activity linked to individual words within a sentence. In the past, two main approaches have nonetheless been used to study activity over portions of sentences. One is to examine slow shifts in potential that emerge over the course of sentences, superimposed on the signals evoked by each individual word. This approach was used effectively by King and Kutas (1995) using visual presentation, and Muller, King, and Kutas (1997) using auditory presentation, revealing sustained negativity evoked by increased syntactic complexity during a sentence comprehension task. Specifically, these studies compared two kinds of sentences, containing the more complex object-embedded relative clauses (example 1, traditionally abbreviated "SO" for subject-object word order) and the less complex subject-embedded relative clause (example 2, traditionally abbreviated "SS" for subject–subject word order).

1) (SO) The reporter who the senator harshly attacked admitted the error.
2) (SS) The reporter who harshly attacked the senator admitted the error.

The SO sentences violate the usual tendency in English word order to put the agent of an action first, resulting in increased demands for syntactic processing. The studies discussed here revealed ERP activity related to this increased processing demand, and further showed a relationship with individual language comprehension abilities.

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