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# The role of structural prediction in rapid syntactic analysis

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**Abstract**

A number of recent electrophysiological studies of sentence processing have shown that a subclass of syntactic violations elicits very rapid ERP responses, occurring within around 200 ms of the onset of the violation. Such findings raise the question of how it is possible to diagnose violations so quickly. This paper suggests that very rapid diagnosis of errors is possible specifically in situations where the diagnosis problem is tightly constrained by specific expectations generated before the critical word is presented. In an event-related potentials (ERP) study of visual sentence reading participants encountered violations of a word order constraint (*...Max's of...*) that has elicited early ERP responses in previous studies. Across conditions the illicit sequence was held constant, while sentence context was used to manipulate the expectation for a noun following the possessor *Max's*, by manipulating the possibility of ellipsis of the head noun. Results showed that the anterior negativity elicited by the word category violation was attenuated when the availability of ellipsis reduced the expectation for a noun in the position of the offending preposition *of*, with divergence between conditions starting around 200 ms after the onset of the violation. This suggests a role for structural expectations in accounting for very fast syntactic diagnosis processes.


*Keywords:* Event-related potentials; Parsing; Syntax; ELAN; Ellipsis; Structural prediction

## 1. Introduction

It has been known for at least thirty years that some portion of syntactic structure building in language comprehension happens very quickly. Marslen-Wilson's speech-shadowing experiments (Marslen-Wilson, 1973, 1975) showed that people who were shadowing spoken sentences at latencies as short as 250 ms were able to make corrections to inappropriate syllables, and crucially, that the rate of success in correction depended on the syntactic and semantic congruency of the word with its context. Eye-tracking studies investigating the immediate effects of sentence processing on eye movements (e.g., Sussman & Sedivy, 2003), as well as studies of error-detection using speed-accuracy tradeoff paradigms and electrophysiological brain recordings (e.g., McElree & Griffith, 1995; Neville, Nicol, Barss, Forster, & Garrett, 1991) have provided further evidence for syntactic processes occurring within 300 ms of word onset.

The psycholinguistic evidence for rapid syntactic processing is consistent with the subjective experience of immediate language comprehension, and it has become common to assume that most syntactic processing occurs rapidly. However, while it is clear that some syntactic processing does occur very quickly, the scope and nature of these 'syntactic processes' has largely remained unspecified. The classic speech-shadowing studies do not specify whether all syntactic contexts were equally amenable to correction, or whether rapid correction was restricted to a subclass of contexts. In addition, there has been little work on the mechanisms that make such rapid processing possible. In the 200–300 ms estimate, very little time is left over for syntactic processing once time is allowed for low-level sensory processing, lexical access, and response planning, suggesting that the mechanisms employed in syntactic processing within 200–300 ms of a word onset must be highly constrained and specialized.

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In this paper, we seek to contribute to a more explicit account of early syntactic processes through an investigation of Event-related potentials (ERP) responses to grammatical category violations. We provide a more detailed description of which syntactic processes occur most rapidly, and use these findings to suggest how these processes are able to proceed so quickly.

Studies in both English (Neville et al., 1991) and German (e.g., Friederici, Pfeifer, & Hahne, 1993; Hahne & Friederici, 1999) have shown that grammatical category violations like those shown in (1a) and (2a) elicit an increased left anterior negativity with a latency of 100–250 ms, relative to grammatical sequences like (1b) and (2b). The critical word is italicized in each example. This early response component has come to be known as the *Early Left Anterior Negativity* (ELAN).

(1) (a) *The scientist criticized Max's *of* proof the theorem.
(b) The scientist criticized Max's proof *of* the theorem.
(2) (a) *Die Kuh wurde im *gefüttert*.
*The cow was in-the fed.*
(b) Die Kuh wurde im Stall *gefüttert*.
*The cow was in-the barn fed.*

The ELAN response has been elicited only in very specific contexts. To date it has primarily been elicited by the syntactic sequences illustrated in (1) and (2) and minor variants upon them in Spanish (Hinojosa, Martin-Loeches, Casado, Muñoz, & Rubia, 2003), French (Isel, Hahne, & Friederici, 2004), and German (Rossi, Gugler, Hahne, & Friederici, 2005). The specificity of the ELAN is unusual when compared to the several other ERP components that have been shown to be associated with syntactic anomalies, including the anterior negativity with an onset of about 300–500 ms and the relatively long-lasting late positivity with characteristic onset of about 500–900 ms. The anterior negativity is generally known as the *Left Anterior Negativity* (LAN), since it often has a left-lateralized distribution, and it has been observed in response to inflection/agreement violations in some studies (Coulson, King, & Kutas, 1998; Friederici et al., 1993; Gunter, Stowe, & Mulder, 1997; Kaan, 2002; Kutas & Hillyard, 1983; Münte, Matzke, & Johannes, 1997; Osterhout & Mobley, 1995), and in some instances of case violations (Münte & Heinze, 1994), word category violations (Friederici, Hahne, & Mecklinger, 1996; Hagoort, Wassenaar, & Brown, 2003), violations of constraints on wh-fronting (Kluender & Kutas, 1993a, 1993b), and syntactic garden-paths (Kaan & Swaab, 2003). The late positivity is generally known as the *P600* (alternatively 'Syntactic Positive Shift'), although its latency shows substantial variation across studies, and has been elicited by a wide range of syntactic anomalies, including category and agreement violations (Friederici et al., 1993; Hagoort, Brown, & Groothusen, 1993; Hahne & Friederici, 1999; Kaan, 2002), syntactic garden-paths (Friederici et al., 1996; Kaan & Swaab, 2003; Osterhout, Holcomb, & Swinney, 1994), and subcategorization violations (Friederici & Frisch, 2000; Osterhout & Holcomb, 1992). In recent years, the P600 has also been elicited in well-formed sentences in response to ambiguity (Frisch, Schlesewsky, Saddy, & Alpermann, 2002), the construction of long-distance dependencies (Fiebach, Schlesewsky, & Friederici, 2002; Kaan, Harris, Gibson, & Holcomb, 2000; Phillips, Kazanina, & Abada, 2005), and in cases of unexpected mappings between noun phrases (NPs) and thematic roles (Kim & Osterhout, 2005; Kuperberg, Sitnikova, Caplan, & Holcomb, 2003; van Herten, Kolk, & Chwilla, 2005). In light of the wide variety of manipulations that elicit the later syntax-related ERP components, the specificity of the ELAN is all the more interesting.

Subsequent to the original demonstrations of the ELAN in English (Neville et al., 1991) and German (Friederici et al., 1993), Friederici and colleagues have confirmed its robustness in a number of studies. In a study using the same materials with the MEG methodology a response peak with a similar latency was observed (Friederici, Wang, Herrmann, Maess, & Oertel, 2000). The ELAN appears not to be sensitive to task manipulations (Hahne & Friederici, 2002) or to the experiment-wide probability of the violation (Hahne & Friederici, 1999), in contrast to the P600 component, which is affected by both. In other work, it has been shown that an ELAN response is not observed in ambiguous sentences disambiguated to the less frequent structure, even when this structure is strongly dispreferred (Ainsworth-Darnell, Shulman, & Boland, 1998; Friederici et al., 1996). Thus, it appears that the early response is not elicited in cases where successfully integrating the item into a phrase structure is merely difficult or unlikely.

An account of the ELAN must explain how the response can be generated so quickly as well as the reason why only a narrow set of contexts elicit the response. The earliness of the ELAN response is even more striking when the time needed for basic perceptual processes is subtracted out. For example, a rough estimate of the time needed for visual information about a word to reach the brain areas that process lexical information is 60 ms (Sereno & Rayner, 2003). Thus, in the ERP studies that found early responses using visual presentation, only around 100 ms is available for the necessary syntactic information associated with the word to be accessed. The time window for syntactic analysis narrows further when one considers that estimates in the literature for the earliest processes involved in lexical access often fall in the 200 ms range (Allopenna, Magnuson, & Tanenhaus, 1998; van Petten, Coulson, Rubin, Plante, & Parks, 1999).

Across studies, there is some variation in the latency of the anterior negativity elicited by grammatical category violations. The response has an onset in the 100–200 ms range in a number of studies, including the original report on English by Neville et al. (1991) and most of the German auditory-based studies by Friederici et al. in which the offending participle is clearly marked by the prefix *ge-*