Brain & Language 120 (2012) 135–162

Contents lists available at SciVerse ScienceDirect

Brain & Language

journal homepage: www.elsevier.com/locate/b&l

On the early left-anterior negativity (ELAN) in syntax studies

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ARTICLE INFO

Article history:
Available online 14 September 2011

Keywords:
Event-related potentials (ERPs)
Syntax
Early left-anterior negativity (ELAN)
Phrase structure violations
P600
N400
LAN
Blocking effects
Syntax-first models
Baseline problems

ABSTRACT

Within the framework of Friederici's (2002) neurocognitive model of sentence processing, the early left anterior negativity (ELAN) in event-related potentials (ERPs) has been claimed to be a brain marker of syntactic first-pass parsing. As ELAN components seem to be exclusively elicited by word category violations (phrase structure violations), they have been taken as strong empirical support for syntax-first models of sentence processing and have gained considerable impact on psycholinguistic theory in a variety of domains. The present article reviews relevant ELAN studies and raises a number of serious issues concerning the reliability and validity of the findings. We also discuss how baseline problems and contextual factors can contribute to early ERP effects in studies examining word category violations. We conclude that – despite the apparent wealth of ELAN data – the functional significance of these findings remains largely unclear. The present paper does not claim to have falsified the existence of ELANs or syntax-related early frontal negativities. However, by separating facts from myths, the paper attempts to make a constructive contribution to how future ERP research in the area of syntax processing may better advance our understanding of online sentence comprehension.

1. Introduction

The focus of the present inquiry is on an influential neurocognitive model of sentence processing, proposed by Friederici (1995, 2002; Friederici & Kotz 2003; Friederici & Weissenborn 2007), and in particular on this model's interpretation of a brain response revealed in studies of syntactic processing using event-related potentials (ERPs), namely the early left anterior negativity or "ELAN". ERP data have strongly contributed to the development and refinement of this serial, syntax-first model which offers a detailed characterization of incremental processing of sentences in terms of three phases which apply consecutively for each individual word. Further, each phase is claimed to be reflected by distinct ERP components within specific latency ranges after relevant types of word information become available.

In **phase-1** (100–300 ms), initial phrase structure (**PS**) building based exclusively on syntactic word category information takes place. Disruptions of this fast, highly automatic, first-pass parse due to word category violations are claimed to be reflected by ELAN effects, which are argued to uniquely index the action of brain systems underlying PS generation (e.g., Hahne & Friederici, 1999).

During **phase-2** (300–500 ms), both (i) morpho-syntactic processing (including feature checking) as well as (ii) lexical/conceptual-semantic integration take place. Processing difficulties in morpho-syntax tend to elicit left anterior negativities (LANs; e.g., verb inflection violations, see Gunter, Stowe, & Mulder (1997) among others) or N400s (e.g., argument structure violations; Friederici & Frisch, 2000), whereas lexical-semantic difficulties generally yield N400 components (Kutas & Hillyard, 1980; Kutas & Federmeier, 2000; Lau, Phillips, & Poeppel, 2008). These two processing streams take place in parallel, such that LAN and N400 can co-occur if both streams encounter difficulties. However, as both streams need to be licensed by the intact phrase structure generated in phase I, N400s and LANs are claimed to be BLOCKED in presence of a word category violation if the latter co-occurs with semantic or morpho-syntactic violations. In such 'double' violations, ELANs are predicted not to co-occur with LANs or N400s.[1]

In **phase-3** (500–1000 ms or later), different streams of information are integrated. If this integration process encounters anomalies involving the sentence structure, additional controlled (i.e., less automatic) reanalysis and repair processes are required and elicit P600 components (Osterhout & Holcomb, 1992), which have also been referred to as syntactic positive shifts (SPS, Hagoort,

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[1] Note that there are cases in the literature of apparent early left anterior negativities for contrasts involving "single" PS-violations (i.e., not "double" violations) which are followed by later negativities, the status of which remains rather unclear (e.g., Neville, Nicol, Barss, Forster, & Garrett, 1991 – see also Footnote 3).

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doi:10.1016/j.bandl.2011.07.001

Brown, & Groothusen, 1993). Hence, ELANs and LANs are typically followed by a P600, while garden path sentences and complex structures without violations may elicit only P600s.[2]

1.1. Objectives and motivations for the present inquiry

The central contribution of the model compared to others lies in its emphasis on the distinct role of word category information during phase-1 and its unique power to unidirectionally block subsequent processes. Therefore, the link between the elicitation of ELANs and syntactic word category violations as well as the power of PS violations in phase-1 to block the putatively "downstream" semantic (and morpho-syntactic) processes are the most crucial and distinctive features of the model.

Here we aim to critically evaluate two important but under-discussed general problems in the ELAN literature. Despite concerns which have previously been raised elsewhere (see, e.g., Dikker, Rabagliati, & Pylkkanen, 2009; Hagoort, 2003; Hagoort, Wassenaar, & Brown, 2003; Hasting & Kotz, 2008; Lau, Stroud, Plesch, & Phillips, 2006; Osterhout, McLaughlin, Kim, Greenwald, & Inoue, 2004; Steinhauer & Connolly, 2008; Yamada & Neville, 2007), we are not aware of a single article systematically examining these problems in sufficient detail to demonstrate just how serious they may be.

> Problem #1: Taking existing data in the ELAN literature *at face value*, several of the core claims of the model can be argued to be unsustainable.
>
> Problem #2: There are serious methodological problems which actually recommend we exercise some caution in taking previous ELAN interpretations in the literature *at face value*.

Our critical discussion is motivated by the strong impact the model has had, and continues to have, on the field. Since its first formulation (Friederici, 1995) the model has received impressive empirical support. It inspired dozens of ERP (and other brain imaging) studies whose additional findings led to more refined recent versions (Friederici, 2002; Friederici & Kotz, 2003; Friederici & Weissenborn, 2007). With some 450 citations to date (ISI Web of Science), the 2002 article alone has been cited once every week on average since it went to press.

This enormous impact stems largely from the strikingly coherent network of empirical findings from a broad range of language-related investigations that all appear to converge on this model, and in particular on the central role of the ELAN. Since the more robust 'syntactic' P600/SPS component *follows* the 'semantic' N400 in time and has been shown (contra initial suggestions, see Hagoort et al., 1993) to not be syntax-specific (see, e.g., Münte, Heinze, Matzke, Wieringa, & Johannes, 1998; Patel, Gibson, Ratner, Besson, & Holcomb, 1998), the ELAN has turned out to constitute *the* electrophysiological bedrock for claims that the syntactic sub-component of language processing constitutes a "module" in Fodor's (1983, 2000) sense (see also Friederici, 1990). Friederici's model has thus played an extremely prominent role in the larger arena of (often otherwise ideological) debates about modularity, information flow, and cognitive architecture. Also of importance is the attractive link that Friederici's model established with Frazier's influential (syntax-first) garden path model (Frazier, 1987).

Further, imaging data have been argued to suggest a direct association between the ELAN component and Broca's area, for some the very brain area for syntax (Friederici, Hahne, & von Cramon, 1998) or even the location where the universal grammar module may implemented (Sakai, Hashimoto, & Homae, 2001). The combined data fit well with those from Broca's aphasics and late second language learners (who do not seem to show an ELAN; Friederici et al., 1998; Hahne, 2001). Finally, the idea of ELAN components reflecting automatic parsing has influenced a number of other neurocognitive models (Clahsen & Felser, 2006; Hagoort, 2003; Ullman, 2001), including Bornkessel-Schlesewsky and Schlesewsky's (2006, 2008, 2009) increasingly influential *extended Argument Dependency Model* (eADM), which differs in many other respects from Friederici's framework.

An obvious strength of Friederici's model, which no doubt also helps to account for its pervasive influence, lies in the clarity of its easy to falsify predictions. But, remarkably, what has happened over the past 15 years is that it has continued to gain in influence *without ever changing any of its central assumptions*. It is difficult to avoid the impression that, even if some of the model's specific claims may not survive the further tests of time, most of its core claims must be more-or-less correct.

2. Critique

The critical discussion that follows comes in three parts. In the first two sections (Section 2.1 and 2.2) we confront Problems #1 and #2 in order. However, independent of the ELAN is the idea that phase-1 violations suppress the engagement of phase-2 processing systems ("blocking") – this is addressed in the third part of our critique (Section 2.3). In addition, in the Appendix, we also provide a tabular summary of the findings of the ERP studies most relevant to ELAN and blocking effects, including both reading (Table A1) and auditory (Table A2) experiments.

2.1. Problem #1: empirical concerns

ELAN responses are violation effects thought to be elicited by clashes involving major syntactic category divisions (e.g., nouns versus verbs). How are these effects investigated? The seminal work of Neville et al. (1991), for example, tested (1a/b) in a reading study and reported (among other, later effects) a very early left lateralized relative negativity for (1a) versus (1b) (their "N125").[3]

(1)	a.	*The scientist criticized Max's *__of__ proof the theorem.*
	b.	*The scientist criticized Max's proof __of__ the theorem.*

Encountering the possessive-marked proper name (*Max's*) leads human parsing mechanisms to strongly predict that the next word will be an open-class/content element (e.g., the head noun, as in *Max's* <u>*proof*</u> in (1b)). Instead, in the violation condition (1a), a preposition is encountered that seems to violate the local phrase structure (but see Lau et al., 2006). Since this type of design holds the critical target word constant across conditions in which the preceding context is manipulated, we will refer to this as the context manipulation approach.

A similar context manipulation approach has also been employed in most of the German ELAN studies (henceforth referred to as 'the German paradigm'), both in the auditory and the visual modalities (e.g., Friederici, Pfeifer, & Hahne, 1993; Friederici, Steinhauer, & Frisch, 1999; Hahne & Friederici, 1999), most of which re-

[2] The status of P600-type effects has, however, been undergoing much in the way of theoretical reinterpretations (see Friederici, Mecklinger, Spencer, Steinhauer & Donchin (2001), Kuperberg (2007), and Bornkessel-Schlesewky & Schlesewsky (2008, 2009) for discussion).

[3] The other two effects following the N125 in Neville et al. (1991) were: (i) a left lateralized temporal negativity (300–500 ms) and (ii) a subsequent P600. Note that the label "ELAN" post-dates the Neville et al. (1991) study by nearly half a decade, and subsequent work by Neville and colleagues has actually argued against the idea that ELAN effects index the action of an encapsulated syntactic processor (Yamada & Neville, 2007).