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The N400 as a correlate of interpretively relevant linguistic rules: Evidence from Hindi

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ABSTRACT

Classical views on the electrophysiology of language assume that different event-related potential (ERP) components index distinct linguistic subdomains. Hence, left-anterior negativities are often viewed as correlates of rule-based linguistic knowledge, whereas centro-parietal negativities (N400s) are taken to reflect (non-rule-based) semantic memory or aspects of lexical–semantic predictability. The present ERP study of case marking in Hindi challenges this clear-cut dichotomy. Though determined by a grammatical rule, the choice of subject case in Hindi is also interpretively relevant as it constrains the range of possible interpretations of the subject. For incorrect subject cases, we observed an N400, which was followed by a late positivity under certain circumstances. This finding suggests that violations of rule-based knowledge may engender an N400 when the rule is interpretively relevant.

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1. Introduction

Since Kutas and Hillyard's (1980) seminal discovery of the first language-related event-related brain potential (ERP) component, the notion that different subdomains of linguistic knowledge can be associated with distinct ERP signatures has been a major driving force behind many electrophysiological investigations of human language processing. For example, ERP distinctions have featured prominently in the debate on whether rule-based linguistic knowledge can be dissociated from non-rule-based linguistic knowledge (McClelland & Patterson, 2002; Pinker & Ullman, 2002). In this context, transient left-anterior negativities (LANs) are often taken to index rule violations (cf. Ullman, 2004) whereas centro-parietal negativities within the same time range (N400 effects) are typically viewed as correlates of non-rule-based, lexically stored information (cf. Kutas & Federmeier, 2000). As an illustration, consider an ERP study by Weyerts, Penke, Dohrm, Clahsen, and Münte (1997), who observed LAN effects when a regular (default) plural suffix (-s)

was illegally combined with an irregular noun stem in German (e.g. for *Bärs vs. Bären, 'bears'), whereas the combination of a regular stem with an irregular plural suffix (-en) yielded an N400 (e.g. for *Wracken vs. Wracks, 'wrecks'). Along with a number of similar findings in different languages (see Bornkessel-Schlesewsky & Schlesewsky, in press, for a recent overview), these results have been interpreted as showing that the overapplication of a morphological rule – as in “regularized” irregular words – correlates with a LAN, whereas the N400 in “irregularized” regulars reflects the fact that these words are treated like pseudowords (i.e. as they are non-decomposable, they result in a failure of lexical access because they do not have an entry in the mental lexicon).

A related component distinction is often drawn for language comprehension at the sentence level, with lexical–semantic integration difficulty or the degree of lexical–semantic predictability thought to be reflected in the N400, while other levels of linguistic analysis (e.g. syntax) are assumed to manifest themselves in qualitatively distinct ERP components such as LANs or late positivities, P600s (for a recent overview, see Kutas, Van Petten, & Kluender, 2006).

However, these relatively clear-cut functional interpretations of language-related ERP effects are challenged by several observations. First, LAN effects are not always observable in the face of violations that should be clearly rule-based (e.g. subject–verb

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agreement, cf. Nevins, Dillon, Malhotra, & Phillips, 2007). Second, a number of relatively recent studies have reported P600 effects for seemingly *semantic* rather than syntactic manipulations (e.g. Hoeks, Stowe, & Doedens, 2004; Kim & Osterhout, 2005; Kolk, Chwilla, van Herten, & Oor, 2003; Kuperberg, Sitnikova, Caplan, & Holcomb, 2003). In view of findings such as these, some researchers favor more general interpretations of language-related ERP components, e.g. in terms of working memory-related processes for the LAN (e.g. King & Kutas, 1995; Kluender & Kutas, 1993) and of conflict monitoring for the P600 (e.g. van Herten, Chwilla, & Kolk, 2006; Vissers, Kolk, van de Meerendonk, & Chwilla, 2008).

For the N400, however, the non-rule-based, lexical-semantic perspective has been maintained more strongly. In particular, while it is clear that this component is modulated by a range of influencing factors (e.g. grammatical gender, Wicha, Moreno, & Kutas, 2004; or the broader discourse environment, cf. Hagoort & van Berkum, 2007, for an overview), all of these findings remain compatible with the notion that the N400 reflects the degree of predictability of a particular lexical item and the information associated with it (e.g. gender).¹ Notably, this view of the N400 is shared by a number of otherwise divergent neurocognitive models of language processing (e.g. Hagoort, 2005; Friederici, 2002; Ullman, 2004).

Yet there have also been reports of N400 effects elicited by manipulations that are not straightforwardly lexical-semantic in nature. For example, Frisch and Schlesewsky (2001) observed an N400 for a violation of case marking in German, and Bornkessel, McElree, Schlesewsky, and Friederici (2004) reported an N400 for word order reanalysis in certain types of German sentences (cf. also Haupt, Schlesewsky, Roehm, Friederici, & Bornkessel-Schlesewsky, 2008, for a demonstration of the reliability and generalizability of this finding).²

How should such “unexpected” component observations (Kutas et al., 2006) be interpreted? One possibility is to view the presence of an N400 as evidence for the non-rule-based nature of the linguistic manipulation in question (cf. Ye, Zhan, & Zhou, 2007, who argue for a lexically stored grammatical *construction* due to the finding of an N400). However, this line of argumentation brings with it the danger of circularity: since the classical functional interpretation of the N400 was based on a priori assumptions about which linguistic manipulations are rule-based/non-lexical or non-rule-based/lexical, it appears problematic to now apply the inverse line of argumentation to argue for the lexical status of manipulations that would traditionally be considered rule-based.

A second possibility is that LAN effects only index certain types of rule violations, namely those of *default* rules. For example, Bartke, Rösler, Streb, and Wiese (2005) observed N400 effects in response to the processing of morphological *subregularities* in German, i.e. to violations involving plural markers which are not the default form, but which are also not completely irregular. On the basis of this finding, these authors argued for an extension of the “rules vs. lexicon” distinction to a tripartite system in which rules are split up

into default and non-default rules. The precise organization of such an architecture was left open, however.

Interestingly, there also appears to be a third possibility. When the experimental manipulations that have engendered classical, rule-based LAN effects are contrasted with those that have given rise to seemingly “rule-based” N400 effects, the difference between the two sets of studies could be characterized as follows: in those studies that elicited N400 effects, the critical rule violation was in some way relevant to sentence interpretation, whereas LAN effects appear to correlate with purely formal violations. For example, Frisch and Schlesewsky (2001) argued that the N400 response to the case violations in their study reflected a thematic interpretation problem such that the processing system could not determine “who is acting on whom”. Likewise, the N400 effects observed for subject–object reanalyses (Bornkessel et al., 2004; Haupt et al., 2008) are clearly tied to interpretation at some level, because such reanalyses also involve a reinterpretation of which argument is the Actor (i.e. the participant primarily responsible for the state of affairs) and which is the Undergoer (i.e. the participant affected by the state of affairs). (For more details on the definition of Actor and Undergoer within a neurocognitive model of sentence comprehension, see Bornkessel & Schlesewsky, 2006; Bornkessel-Schlesewsky & Schlesewsky, 2009). By contrast, typical LAN-engendering manipulations like subject–verb agreement violations or overapplications of regular morphology are not associated with any clear interpretive consequences.

The aim of the present study was therefore to examine the hypothesis that seemingly “rule-based N400s” might be engendered by *interpretively relevant* rule-based information. To this end, we capitalized upon the properties of a language that has not yet been subjected to extensive neurocognitive investigation, namely Hindi.

2. The present study

As described in the preceding section, the classical functional interpretation of the N400 typically intertwines the notions of “non-rule-based” (or lexically stored) and “semantic”, contrasting with rule-based, formal aspects of linguistic knowledge. This dichotomy between rules and linguistic form on the one hand and stored representations and meaning on the other has a high intuitive plausibility from the perspective of most European languages: in English, German or French, for example, violations of linguistic form (e.g. inflection, word order, case marking, agreement) do not straightforwardly appear to be associated with any consequences for word or sentence meaning. Yet, as we will describe in more detail below, this observation no longer appears so clear-cut when a broader range of languages is considered. For this reason, a recent neurocognitive model of language comprehension (the extended argument dependency model, eADM) posits that many of the neural correlates of language comprehension across typologically different languages are best captured via the assumption of a syntax–semantics *interface*, rather than in terms of a strict form vs. meaning dichotomy (Bornkessel & Schlesewsky, 2006; Bornkessel-Schlesewsky & Schlesewsky, 2008, 2009).

Hindi, an Indo-Aryan language spoken in India, is a case in point.³ In this language, the case marking of subjects varies across sentence types: subjects are marked with nominative case in imperative sentences and with the so-called ergative case in per-

¹ This does not necessarily mean that the N400 is a language-specific response: since graded N400 responses indexing the degree of semantic fit into a prior context have also been observed for non-verbal stimuli such as line drawings (e.g. Federmeier & Kutas, 2001; Nigam, Hoffman, & Simons, 1992), some authors interpret the N400 as a domain-general correlate of semantic memory use (Kutas & Federmeier, 2000). It should, however, be noted that N400 effects elicited by different types of stimuli (e.g. words vs. line drawings) are associated with somewhat different topographical distributions (Federmeier & Kutas, 2001). Hence, Kutas and Federmeier argue that this component “reflects the activity of a spatially distributed but temporally interlinked set of brain areas in both hemispheres [...], whose function is to bridge modality-specific sensory information and integrated, conceptual-level representations” (Kutas & Federmeier, 2000, p. 469).

² Note that the overall data pattern on subject–object reanalyses is somewhat more complex. For comprehensive overviews, see Bornkessel and Schlesewsky (2006) and Haupt et al. (2008).

³ In 1995, an estimated number of 316 million people spoke Hindi or its sister language Urdu (spoken in Pakistan), thereby making it the language with the third-highest number of speakers globally (Graddol, 2004). Hindi is a verb-final language with a basic subject–object–verb (SOV) order, a relatively free word order (all six permutations of subject, object and verb are possible), and allowing argument drop.

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