



## Cross-linguistic variation in the neurophysiological response to semantic processing: Evidence from anomalies at the borderline of awareness



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### ARTICLE INFO

#### Article history:

Received 23 December 2012

Received in revised form

2 January 2014

Accepted 9 January 2014

Available online 18 January 2014

#### Keywords:

Language processing

Cross-linguistic differences

Borderline anomalies

Shallow processing

N400

P600

Late positivity

Bidirectional coding account

Top-down

Bottom-up

### ABSTRACT

The N400 event-related brain potential (ERP) has played a major role in the examination of how the human brain processes meaning. For current theories of the N400, classes of semantic inconsistencies which do not elicit N400 effects have proven particularly influential. Semantic anomalies that are difficult to detect are a case in point (“borderline anomalies”, e.g. “After an air crash, where should the survivors be buried?”), engendering a late positive ERP response but no N400 effect in English (Sanford, Leuthold, Bohan, & Sanford, 2011). In three auditory ERP experiments, we demonstrate that this result is subject to cross-linguistic variation. In a German version of Sanford and colleagues’ experiment (Experiment 1), detected borderline anomalies elicited both N400 and late positivity effects compared to control stimuli or to missed borderline anomalies. Classic easy-to-detect semantic (non-borderline) anomalies showed the same pattern as in English (N400 plus late positivity). The cross-linguistic difference in the response to borderline anomalies was replicated in two additional studies with a slightly modified task (Experiment 2a: German; Experiment 2b: English), with a reliable LANGUAGE × ANOMALY interaction for the borderline anomalies confirming that the N400 effect is subject to systematic cross-linguistic variation. We argue that this variation results from differences in the language-specific default weighting of top-down and bottom-up information, concluding that N400 amplitude reflects the interaction between the two information sources in the form-to-meaning mapping.

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### 1. Introduction

In everyday life, we use language to express our thoughts and to comprehend those around us. We make use of language in such a natural and seemingly effortless way that we are mostly unaware of the complex cognitive system that makes this possible. When processing speech or written language, we are faced with a difficult task, requiring us not only to combine words to form complex meanings, but also to assess whether the state of affairs described is consistent with what we already know about the world.

While the matching of linguistic meaning to world knowledge may appear *prima facie* to be straightforward, it is not always performed completely. Rather, under certain circumstances, we miss violations of

our real world knowledge. A case in point is the so-called Moses illusion (Erickson & Matteson, 1981), a relatively robust failure to detect a distorted meaning in cases where a locally implausible phrase nevertheless exhibits a close fit to the global context. Erickson and Matteson asked people the now famous question “How many animals of each kind did Moses take on the Ark?” and reported that most people answered the question with “two” in spite of the fact that it was Noah, not Moses, who built and sailed the ark.

This type of “semantic illusion” has given rise to a great deal of research in theoretical linguistics and psycholinguistics, aiming to shed light on the linguistic basis of such illusions and the mechanisms involved in processing them (e.g. Ferreira, Ferraro, & Bailey, 2002; Sanford & Graesser, 2006; Sanford & Sturt, 2002). While the studies concerned with this particular phenomenon have employed a variety of materials and paradigms, there are several common results: First is that the Moses illusion effect generalises to other sentence materials (e.g. the “survivors illusion” in (1), cited from Sanford et al., 2011). Further, the illusion

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occurs at comparable rates independent of the number of times it is presented (detection rates at approximately 60%) or the task demands, i.e., incidental detection or an explicit judgement task (e.g. Barton & Sanford, 1993; Daneman, Reingold, & Davidson, 1995; Hannon & Daneman, 2001; Hannon & Daneman, 2004; Reder & Kusbit, 1991). However, detection rates are subject to more substantial variation when linguistic factors such as focus, sentence structure or semantic relatedness are manipulated (Büttner, 2007; Shafto & McKay, 2000). In accordance with the terminology in Sanford et al. (2011), we shall refer to sentences constructed in the spirit of the Moses Illusion (such as 1) as “borderline anomalies”, as an abbreviation of “anomalies at the borderline of awareness”.

(1) When an airplane crashes on a border with debris on both sides, where should the survivors be buried?

From the perspective of sentence understanding, a main interest in examining borderline anomalies such as (1) relates to questions about depth of processing. Specifically, it has been argued that referents with a good fit to the global discourse context (such as *survivors* in the context of an airplane crash) give rise to *shallow processing*, i.e. are not as deeply probed for their meaning in comparison to referents with a lower degree of contextual fit (Sanford & Garrod, 1998). In support of this proposal, Barton and Sanford (1993) found that the “survivor-anomaly” in (1) is detected much more readily in the context of a bicycle crash than in the context of an airplane crash, since, statistically, the word *survivors* is much more likely to be used in the latter case.

More recent studies have examined how borderline anomalies are processed during on-line comprehension, focusing particularly on whether they disrupt processing even when they are not detected. Results from both eye tracking (Bohan & Sanford, 2008) and event related brain potentials (Sanford et al., 2011) suggest that this is not the case: neither eye movement nor event-related potential (ERP) records reveal differences between the non-detected borderline anomalies and their plausible counterparts. On the basis of their results, Sanford and colleagues conclude that borderline anomalies are indeed subject to shallow processing, arguing against an alternative account in which such anomalies disrupt processing, but not enough to reach conscious awareness. A sample item from Sanford et al. (2011) is given in (2). ERPs were measured at the underlined word, with the context words differentiating between the borderline anomaly and the plausible control given in italics and curly brackets.

(2) Child abuse cases are being reported much more frequently these days. In a recent trial, a 10-year {sentence/care order} was given to the victim, but this was subsequently appealed.

Of particular interest is that the detected anomalies in Sanford et al.’s (2011) study engendered a late positivity but no N400 effect, when compared to control stimuli. These findings may contribute to a better understanding of N400 effects more generally, an important issue that is the subject of active debate, particularly related to the on-line processing of sentence meaning. Since first reported by Kutas and Hillyard (1980), the N400 has been viewed as a correlate of lexical-semantic processing. However, there are differing perspectives on the reasons for this correlation (for a recent review, see Lau, Phillips, & Poeppel, 2008). According to the “integration” view, N400 amplitude reflects the ease or difficulty with which a new word can be semantically integrated into an existing sentence context (e.g. Hagoort, 2008; Hagoort & van Berkum, 2007). By contrast, the “lexical pre-activation” view maintains that the N400 reflects the ease with which that word can be accessed in semantic memory (e.g. Brouwer, Fitz, & Hoeks, 2012; Kutas & Federmeier, 2000; Lau

et al., 2008; Stroud & Phillips, 2012). Sanford et al.’ (2011) findings appear to support the lexical view: in the borderline anomalies, the critical word that would be considered “pre-activated” in light of its good lexical semantic fit to the global context induced an anomaly but no increased N400 effect. Similar conclusions follow from research on so-called “semantic reversal anomalies”. In these sentences, exemplified by *For breakfast, the eggs would only eat toast and jam* (Kuperberg, Sitnikova, Caplan, & Holcomb, 2003) and *The hearty meals were devouring the kids* (Kim & Osterhout, 2005), the thematic roles and their arguments are misaligned (i.e. *eggs* and *hearty meals* are highly plausible Theme arguments of *eat* and *devour*, respectively, but implausible Agents). Like borderline anomalies, semantic reversal anomalies have been shown to engender late positivity but not N400 effects in English (e.g. Kuperberg et al., 2003; Kim & Osterhout, 2005) and Dutch (e.g. Kolk, Chwilla, van Herten, & Oor, 2003; Hoeks, Stowe, & Doedens, 2004). This result, which sparked a great deal of discussion (for recent reviews, see Bornkessel-Schlesewsky & Schlesewsky, 2008; van de Meerendonk, Kolk, Chwilla, & Vissers, 2009), appears to follow straightforwardly from the lexical preactivation account of the N400: as in the borderline anomalies, the critical word is lexically associated with the sentence context, but is anomalous within the sentence *per se*. The absence of an increased N400 effect for these sentences seems to suggest that lexical preactivation, rather than semantic integration or composition, is the critical factor determining N400 amplitude.

Interestingly, cross-linguistic variation in ERP responses to semantic reversal anomalies represents an additional complicating factor in characterising the N400. In contrast to English and Dutch, German, Turkish and Chinese do show N400 effects for reversal anomalies (Bornkessel-Schlesewsky et al., 2011; Schlesewsky & Bornkessel-Schlesewsky, 2009). In German, this N400 forms part of a biphasic response, incorporating an N400 followed by a late positivity.<sup>1</sup> Bornkessel-Schlesewsky et al. (2011) argue that the presence or absence of the N400 for reversal anomalies is determined by the extent to which sentence interpretation relies on word order (termed “sequence dependence” in Bornkessel-Schlesewsky et al., 2011). In English and Dutch, word order is by far the most important cue for sentence interpretation (Bates, Devescovi, & Wulfeck, 2001; MacWhinney, Bates, & Kliegl, 1984), while a variety of cues must be taken into account in German, Turkish and Chinese (including, for example, case marking and animacy).<sup>2</sup> These cross-linguistic results present a challenge for the lexical preactivation view of the N400, since all the sentences examined in each of these languages contained strongly associated nouns and verbs. From the cross-linguistic results, it appears that the N400 is sensitive to the differential weighting of information sources across languages. Moreover, this suggests that semantic inconsistencies are processed differently in languages that rely primarily on one information source during sentence comprehension (such as English) compared to languages which rely on more than one (such as German). Therefore, it may be the case that these “single source” languages (i.e. languages with one dominant cue) are more susceptible to a temporary “blindness” to semantic

<sup>1</sup> The presence or absence of the late positivity for reversal anomalies is also subject to cross-linguistic variation, though along a different dimension to the N400. However, since it is the presence or absence of the N400 that is central to the present paper, we refer the interested reader to Bornkessel-Schlesewsky et al. (2011) for details on the variation of the positivity.

<sup>2</sup> This proposal was further supported by an experiment on Icelandic, in which Bornkessel-Schlesewsky et al. (2011) examined reversal anomalies with different verb classes, one of which called for strongly sequence-dependent interpretation, while the other did not. Strikingly, results revealed an English-type response (a monophasic late positivity with no N400) for the sequence-dependent verbs, but a German-type response for the other verb class (a biphasic N400 – late positivity pattern).

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