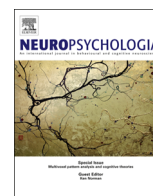




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Contents lists available at ScienceDirect

Neuropsychologia

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

Predictability, plausibility, and two late ERP positivities during written sentence comprehension



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ARTICLE INFO

Article history:

Received 2 May 2013

Received in revised form

11 June 2014

Accepted 12 June 2014

Available online 20 June 2014

Keywords:

Language

Sentence comprehension

Prediction

Plausibility

ERP

P600

N400

ABSTRACT

Van Petten and Luka's (2012, *International Journal of Psychophysiology*, 83(2), 176–190) literature survey of late positive ERP components elicited by more or less predictable words during sentence processing led them to propose two topographically and functionally distinct positivities: a parietal one associated with semantically incongruent words related to semantic reanalysis and a frontal one with unknown significance associated with congruent but lexically unpredicted words. With the goal of testing this hypothesis within a single set of experimental materials and participants, we report results from two ERP studies: Experiment 1, a post-hoc analysis of a dataset that varied on dimensions of both cloze probability (predictability) and plausibility, and Experiment 2, a follow-up study in which these factors were manipulated in a controlled fashion. In both studies, we observed distinct post-N400 positivities: a more anterior one to plausible, but not anomalous, low cloze probability sentence medial words, and a more posterior one to semantically anomalous sentence continuations. Taken together with an observed canonical cloze-modulated N400, these dual positivities indicate a dissociation between brain processes relating to written words' sentential predictability versus plausibility, clearly an important distinction for any viable neural or psycholinguistic model of written sentence processing.

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1. Introduction

In everyday language, we often hear or read sentences that continue in semantically unexpected ways. In the laboratory, electrophysiological brain responses can indicate whether such continuations, for instance, constitute novel but sensible continuations on the part of the comprehender (e.g., 'They let the canoe into the water and paddled with Frisbees...'; Chwilla, Kolk, & Vissers, 2007), clash with personal value systems ('I think euthanasia is... acceptable...' processed by a strict Christian, van Berkum, Holleman, Nieuwland, Otten, & Murre, 2009), or are interpreted as jokes (e.g., 'I let my accountant do my taxes because it saves time: last spring it saved me 10 years.'; Coulson & Kutas, 2001). Although from a comprehender's perspective these words may not be likely sentence continuations, they are certainly plausible. Sentence studies manipulating semantic expectancy, however, have more

frequently utilized incongruent (anomalous) completions than employing only plausible ones (see Van Petten & Luka, 2012). Although two words might share the same near-zero cloze probability rating (a common proxy measure for online predictability), they could fundamentally differ in their contextual plausibility: e.g., 'He pounded the nails with a book/summer.' Semantically anomalous continuations like *summer* have been a mainstay of psycholinguistic event related brain potential (ERP) research for decades (e.g., Kutas & Hillyard, 1980), with low contextual predictability and anomaly often conflated in studies that have focused on amplitude modulations of the N400—an ERP component related to ease of semantic access. Less frequently, however, studies have made use of more plausible continuations like those mentioned above. And rarely, it seems, have brain responses to plausible and anomalous low cloze probability continuations been directly contrasted within a single study to assess the contributions of these two factors to online sentence comprehension.

Two late ERP positivities may prove useful for addressing this issue. Based on a survey of the ERP sentence processing literature, Van Petten and colleagues (e.g., Thornhill & Van Petten, 2012; Van Petten & Luka, 2012) have hypothesized that there is a late frontal

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positive ERP component that is dissociable from an established posterior/parietal late positive component (LPC, sometimes referred to as the P600 or semantic P600). Namely, they suggest that the parietal post-N400 positivity (PNP) may be linked to reanalysis or repair following impaired interpretation due to syntactic or semantic incongruity. Although for many years the P600 was thought to be an ERP response exclusive to syntactic violations and ambiguities (dating back to Osterhout & Holcomb, 1992), a wave of studies in the past decade has been influential in revising this interpretation, with findings of P600s to anomalies that are more semantic in nature (for instance, to thematic role violations, animacy violations, and so-called semantic illusions, e.g., Hoeks, Stowe & Doedens, 2004; Kim & Osterhout, 2005; and Nieuwland & van Berkum, 2005, respectively; see Kuperberg, 2007 for a review).

In contrast, the more anterior late positivity (sometimes noted beginning between 400 and 600 ms) may relate to violations of lexical predictions involving semantically congruent (plausible) substitutions, this being a consistent factor across a majority of the limited number of studies in which it has been observed. Although many of the reports of this frontal positivity have been quite recent (see below for some representative studies), it has been an incidental finding in the sentence comprehension literature dating back nearly 20 years. Kutas (1993) noted a larger left frontal post-N400 positivity (500–900 ms) to congruent low cloze relative to high cloze probability endings in highly constraining ($\geq 75\%$) sentence frames, suggesting at the time that the ERP component might index inhibition of predicted words. Coulson and Van Petten (2007), using visual hemifield presentation, also noted a 600–900 ms left hemisphere-biased late frontal positivity elicited by congruent low cloze, relative to high cloze probability, continuations. Moreno, Federmeier, and Kutas (2002) observed in Spanish–English bilinguals that relative to expected sentence completions, both lexical switches (English synonyms of expected endings) and code switches (English-to-Spanish translations of expected endings) elicited late frontal positivities (650–850 ms), especially in highly constraining idioms, but also in constraining non-idiomatic sentences. Federmeier, Wlotko, De Ochoa-Dewald, and Kutas (2007), as well, observed an increased late frontal positivity (500–900 ms) to congruent low cloze continuations of high but not low constraint sentences. In our own work, (DeLong, Urbach, Groppe, & Kutas, 2011; DeLong, Groppe, Urbach, & Kutas, 2012) we have similarly observed frontal positivities temporally overlapping and continuing beyond more succinct posterior N400 effects to congruent low relative to high cloze probability continuations in predictive sentences, both in younger as well as older (age 60+ years) adults.

A precise functional correlate of this frontal positivity has yet to be isolated, but a number of the aforementioned studies have proposed that this brain response may reflect a consequence to neurally pre-activating, but not receiving, highly expected (i.e., high cloze probability) continuations. For instance, Federmeier et al. (2007) linked the effect to a cost for the prediction “mismatch”, and DeLong et al. (2011, 2012) suggest it may be a “misprediction” response.

However, elicitation of the proposed frontal positivity seems to require *both*: 1) a constraining context, operationalized in terms of either highly convergent cross-participant offline cloze probability norming responses, or possibly through somewhat more divergent responses (e.g., 30% or greater agreement) but supplied with relatively short response times by individual participants in speeded cloze norming tasks¹, and 2) a low cloze probability but semantically plausible sentence continuation. A strong test of this hypothesis, and an aim of the current study, is to contrast the ERPs

to (1) relatively expected (high cloze) plausible sentence continuations with those to (2) unexpected (low cloze) *plausible* and (3) unexpected (low cloze) *anomalous* continuations in constraining sentence contexts. If, within a single group of readers, there turn out to be ERP differences between the effects of (1) vs. (2) compared to (1) vs. (3), then this would indicate a clear dissociation between the brain's processing of predictability and plausibility, and would prove valuable for assessing the independence of the frontal and posterior positivities and their putative sensitivities to plausible versus implausible unexpected continuations, respectively.

To our knowledge no single study has analyzed late positivities to these specific conditions in predictive contexts. Although Kutas, Lindamood, and Hillyard (1984) included these experimental conditions, they only reported N400 findings. Geyer, Holcomb, Kuperberg, and Pearlmutter (2006) modulated plausibility of sentence continuations, comparing plausible, implausible and anomalous words, but noted only a posterior P600 to anomalous words but no frontal positivities; however, it is unclear the extent to which their contexts were contextually constraining, what the critical word cloze probabilities were, what the proportion of “strange” versus “normal” sentences was, and the role that a plausibility judgment task may have played in eliciting late positivities they observed. Similarly, Van de Meerendonk, Kolk, Vissers, and Chwilla (2010) examined sentences with plausible, mildly implausible and strongly implausible continuations, again observing only a posterior P600 to the strongly implausible words, but controlled for neither sentential constraint nor critical word cloze probability, thus making it difficult to assess whether or not our proposed criteria for eliciting the frontal positivity were met. If the frontal positivity is a response to only semantically *plausible* (i.e., sensible) low cloze probability continuations of constraining contexts, and the posterior PNP is modulated by an item's *implausibility*, this would ultimately limit the candidate functional processes of these ERPs and would indicate that different mechanisms come into play during sentence comprehension for items varying along these dimensions.

In an attempt to dissociate these two effects within a single group of participants and within a single stimulus set, we report results from two separate studies. In Experiment 1 we investigate the sensitivities of the frontal and posterior positivities in an ERP study that afforded a post-hoc analysis of sentence stimuli sorted on their offline plausibilities. Experiment 2 has the same experimental goals, but investigates these questions in an experiment specifically designed to test for a positivity dissociation through manipulations of cloze probability and plausibility.

2. Experiment 1

DeLong, Urbach, and Kutas (2005) argued for sentential-based prediction based on cloze probability-graded modulations of N400 mean amplitude to more and less expected prenominal indefinite articles (*a/an*). Post-hoc analyses of those data (DeLong et al., 2011) revealed a prolonged, late frontal positivity to unexpected nouns (e.g., to *lisp* in ‘*It was difficult to understand the visiting professor because he spoke with a lisp...*’ for which ‘*an accent*’ is the most expected continuation). Initially, we hypothesized that this positivity might reflect the violation of a contextual expectancy for a part of speech, namely, adjectives (e.g., *thick*, *heavy*, or *Russian*) that might have been neurally triggered by the unexpected article (e.g., *a*), but which never appeared. Such a strategy could presumably allow the brain's parser to salvage the most contextually expected noun (e.g., *accent*), especially when it is difficult to activate an alternative online. However, once an unexpected noun (e.g., *lisp*) appears instead of an anticipated adjective, additional

¹ See Thornhill and Van Petten (2012) for a discussion of the relevance of “weak” and “divergent” expectations for determining levels of sentence constraint.

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