Cognition 136 (2015) 135–149

Contents lists available at ScienceDirect

Cognition

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

Effects of prediction and contextual support on lexical processing: Prediction takes precedence

Trevor Brothers, Tamara Y. Swaab, Matthew J. Traxler *

University of California, Davis, Department of Psychology and Center for Mind and Brain, United States

ARTICLE INFO

Article history:
Received 15 March 2014
Revised 16 October 2014
Accepted 31 October 2014

Keywords:
Prediction
N250
N400
Sentence processing
Event-related potentials

ABSTRACT

Readers may use contextual information to anticipate and pre-activate specific lexical items during reading. However, prior studies have not clearly dissociated the effects of accurate lexical prediction from other forms of contextual facilitation such as plausibility or semantic priming. In this study, we measured electrophysiological responses to predicted and unpredicted target words in passages providing varying levels of contextual support. This method was used to isolate the neural effects of prediction from other potential contextual influences on lexical processing. While both prediction and discourse context influenced ERP amplitudes within the time range of the N400, the effects of prediction occurred much more rapidly, preceding contextual facilitation by approximately 100 ms. In addition, a frontal, post-N400 positivity (PNP) was modulated by both prediction accuracy and the overall plausibility of the preceding passage. These results suggest a unique temporal primacy for prediction in facilitating lexical access. They also suggest that the frontal PNP may index the costs of revising discourse representations following an incorrect lexical prediction.

1. Introduction

Contemporary approaches to language processing emphasize forward looking, anticipatory processes (Altmann & Mirković, 2009; Elman, 1990; Kuperberg, 2013). Rather than viewing comprehenders as passive processors of incoming linguistic input, these approaches view comprehenders as active constructors of meaning. Part of this meaning construction activity entails using prior knowledge and experience to generate expectations about how a discourse will unfold in the near future. The outcome of the anticipatory process, its success or failure, is viewed as a major factor contributing to the processing load that "bottom-up" perceptual information imposes in a given context. Anticipatory, likelihood-driven processes are believed to contribute to lexical, syntactic, and discourse processing in a variety of theoretical frameworks (e.g., Gibson, Bergen, & Piantadosi, 2013; Hale, 2001; Jaeger & Snider, 2013; Levy, 2008). Despite this strong emphasis on prediction and anticipation, there is very little direct evidence that successful vs. unsuccessful prediction *per se* influences language processes as they unfold. Instead, the chain of inference is usually less direct. Contexts are constructed that make successful prediction easier or more difficult, and differences in processing difficulty across these contexts are then attributed to successful prediction. The current study takes a different approach that allows more direct assessment of the consequences of successful prediction on lexical access.

During natural language processing, words are typically embedded in a discourse which provides a broader context for interpreting meaning. Discourse context has been shown to facilitate lexical retrieval as well as memory for

* Corresponding author at: UC Davis, Department of Psychology, 1 Shields Avenue, Davis, CA 95616, United States. Tel.: +1 530 754 9468 (o); fax: +1 530 752 2087.
E-mail address: mjtraxler@ucdavis.edu (M.J. Traxler).

http://dx.doi.org/10.1016/j.cognition.2014.10.017
0010-0277/

congruent words (e.g., Bransford & Johnson, 1972). Most broadly, prior linguistic information can activate networks of related concepts or event schemas which can facilitate processing (Schank, 1975). In more highly constraining contexts, comprehenders can also make predictions about specific lexical items that are likely to appear in the upcoming discourse.[1] For example, when listening to the sentence "*I could tell he was mad by the tone of his* ..." the upcoming word '*voice*' will be processed more quickly (Schwanenflugel & Shoben, 1985; Traxler & Foss, 2000) and with higher perceptual accuracy (Jordan & Thomas, 2002; Miller, Heise, & Lichten, 1951) than if this word were presented in a less predictive context. A number of studies have shown that lexical prediction may influence comprehension processes before the critical word itself has even appeared. For example, words embedded in highly predictable contexts are skipped more frequently during natural reading (Rayner, Slattery, Drieghe, & Liversedge, 2011). While listening to continuous speech, participants will strategically fixate objects in a visual scene that are likely to be mentioned in the near future (Kamide, Altmann, & Haywood, 2003).

Electrophysiological studies of language processing have shown that a word's cloze probability, which is defined as the proportion of participants producing this word during an offline sentence completion task, correlates with the amplitude of the N400 component during reading comprehension (Kutas & Hillyard, 1984). Modulation of the amplitude of the N400 has been linked both to the facilitation of lexical integration processes (van Berkum, Hagoort, & Brown, 1999), as well as lexical access and semantic memory retrieval (Kutas & Federmeier, 2000). More recently, it has been suggested that amplitude of this component is attenuated when features of a word have been pre-activated by the preceding context (for a review see Swaab, Ledoux, Camblin, & Boudewyn, 2012).

In constraining contexts, the generation of specific lexical predictions could influence multiple levels of word processing via the pre-activation of phonological, morphological or semantic properties of the predicted word. Evidence for pre-activation comes from a variety of electrophysiological studies using sentence or discourse contexts. In these paradigms a critical *probe* word is introduced that is either congruent or incongruent with the upcoming, anticipated lexical item. For example, DeLong, Urbach, and Kutas (2005) found it was easier for readers to process the function word '*an*' while anticipating a phonologically congruent continuation like '*airplane*' as opposed to a phonologically incongruent one like '*kite*'. Other studies using this technique have found evidence for the pre-activation of animacy and semantic category information, as well as grammatical features like gender (Szewczyk & Schriefers, 2013; Boudewyn, et al., submitted; van Berkum, Brown, Zwitserlood, Kooijman, & Hagoort, 2005; Wicha, Moreno, & Kutas, 2004).

While accurate predictions appear to facilitate lexical access and integration, there is also evidence for costs when a lexical prediction is disconfirmed. Behaviorally, these costs can result in longer reaction times for unexpected words appearing in highly constraining contexts (Schwanenflugel & Shoben, 1985). In the electrophysiological literature, it has been hypothesized that the costs of incorrect prediction are reflected in a late, post-N400 positivity (PNP). This positivity, which appears over frontal and left hemisphere electrode sites, is larger for unpredictable words in context (Delong, Urbach, Groppe, & Kutas, 2011), and this relationship appears to be modulated by sentence constraint (Federmeier, Wlotko, De Ochoa-Dewald, & Kutas, 2007; but see Thornhill & Van Petten, 2012 for conflicting results). Additionally, this frontal component appears to be distinct from other, posterior positivities which occur in response to anomalous or ungrammatical sentence continuations (DeLong, Quante, Kutas, & plausibility, in press). While little is known about the exact mechanisms underlying this frontal positivity, it has been hypothesized to reflect either the detection or resolution of disconfirmed predictions (see Van Petten & Luka, 2012 for a review).

While these studies provide some evidence for both costs and benefits of predictive processing, there is a methodological limitation across this set of published studies which remains unresolved. Specifically, prior studies have not provided direct evidence on a trial-by-trial basis whether participants actually predicted the target stimulus. As a result, these studies have been unable to fully dissociate the effects of *specific* lexical pre-activation, from other sources of contextual support (e.g. semantic association or discourse plausibility). While some of the previously mentioned studies have side-stepped this issue by looking for the consequences of prediction earlier in the sentence, these studies have been unable to evaluate the effects of lexical pre-activation on the predicted words themselves. To address this issue, the current experiment used a paradigm that isolates the effects of lexical prediction from other sources of contextual facilitation.

In the experiment reported here, participants read moderately constraining (50% cloze) two-sentence passages, while trying to actively predict the final word of each. After each passage was complete, participants responded by button press whether their prediction was correct. By separately averaging ERP trials for predicted and unpredicted targets, we isolated processing differences at the final critical word that were uniquely driven by prediction accuracy.[2] In addition to these 50% cloze passages (whose final words should appear equally often as predicted and unpredicted targets) we also constructed passages that rendered these same critical words highly unpredictable (<1% cloze). This control condition allowed us to also compare *unpredicted* target words in low-cloze contexts to *unpredicted* targets in more supportive, medium-cloze contexts. Any differential ERP activity between these two conditions should index the

[1] Following Van Petten and Luka (2012), we define *prediction* as a reader or listener's expectation "that a particular word (lexical item) will appear in the near future" (p. 179). Unlike more general forms of semantic anticipation, lexical prediction entails the pre-activation of word-specific features, such as phonological information or grammatical gender.

[2] For a similar technique used to isolate the effects of memory encoding on subsequent recall (the difference due to memory, or DM effect) see Sanquist, Rohrbaugh, Syndulko, and Lindsley (1980) and Paller, Kutas, and Mayes (1987).