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Predicting form and meaning: Evidence from brain potentials



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ABSTRACT

We used ERPs to investigate the pre-activation of form and meaning in language comprehension. Participants read high-cloze sentence contexts (e.g., “*The student is going to the library to borrow a . . .*”), followed by a word that was predictable (*book*), form-related (*hook*) or semantically related (*page*) to the predictable word, or unrelated (*sofa*). At a 500 ms SOA (Experiment 1), semantically related words, but not form-related words, elicited a reduced N400 compared to unrelated words. At a 700 ms SOA (Experiment 2), semantically related words and form-related words elicited reduced N400 effects, but the effect for form-related words occurred in very high-cloze sentences only. At both SOAs, form-related words elicited an enhanced, post-N400 posterior positivity (Late Positive Component effect). The N400 effects suggest that readers can pre-activate meaning and form information for highly predictable words, but form pre-activation is more limited than meaning pre-activation. The post-N400 LPC effect suggests that participants detected the form similarity between expected and encountered input. Pre-activation of word forms crucially depends upon the time that readers have to make predictions, in line with production-based accounts of linguistic prediction.

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Introduction

People regularly use contextual information and world knowledge to predict aspects of language that are likely to be mentioned as a sentence or discourse unfolds (e.g., Altmann & Kamide, 1999; Federmeier, 2007; Huettig, 2015; Kutas, DeLong, & Smith, 2011). Prediction is often hypothesized to occur via a so-called *pre-activation* mechanism, whereby some aspects of word meaning, grammar or form are activated before the onset of the predicted word (e.g., DeLong, Urbach, & Kutas, 2005; Federmeier & Kutas, 1999; Laszlo & Federmeier, 2009; Otten, Nieuwland, & Van Berkum, 2007; Van Berkum, Brown, Zwitserlood, Kooijman, & Hagoort, 2005). But how these types of linguistic information are pre-activated is still

unclear. The production-based prediction account proposes prediction via a comprehender’s production system (Pickering & Garrod, 2007, 2013). Under this account, pre-activation of form does not occur in the absence of pre-activation of meaning, because the language production system first accesses meaning, and then maps the meaning information onto form information. In this paper, we report two event-related brain potential (ERP) experiments that investigate pre-activation of meaning and form of predictable words during language comprehension to explore the relationship between meaning and form pre-activation. We investigate pre-activation, as indexed by N400 ERP modulations (Kutas & Federmeier, 2011), at a word presentation rate that is standard in reading ERP studies (Experiment 1; 500 ms per word) and at a slower presentation rate (Experiment 2; 700 ms per word) which allows more time to generate online predictions. Below, we first discuss the production-based prediction theory, and then outline existing evidence for the pre-activation of meaning and of form before introducing the current study.

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Production-based prediction accounts

Pickering and Garrod (2007, 2013) proposed that people use the language production system when predicting upcoming words during comprehension. According to this account, when people comprehend sentences, they covertly imitate those sentences and implement their production systems to predict upcoming words. Lexical prediction is thought to involve pre-activation of linguistic information (e.g., word form, meaning) of predictable words. Linguistic information associated with predictable words is pre-activated using the same mechanisms that are used to produce words.

A most parsimonious possibility is that comprehenders make direct use of the mechanisms involved in language production – a version of prediction-by-production that we call *prediction-with-implementation*. Although language production models (e.g., Dell & O’Seaghdha, 1992; Levelt, Roelofs, & Meyer, 1999) differ in many important respects, they agree on the view that people produce a word by first activating its semantic information and then proceeding through stages that lead to activation of its phonological or orthographic information (its word form). These stages take several hundred milliseconds according to most estimates (see Indefrey & Levelt, 2004). According to prediction-with-implementation, comprehenders also pre-activate semantic information before form information, following roughly the same time-course. It is of course possible for the comprehender to actually complete the speaker’s utterance, simply by continuing the process of production until the stage of articulation – this is exactly what happens in a cloze test.

However, full implementation of the production system for prediction requires time and resources. When these are lacking, only a part of the production system may be used for prediction. As activation of form information follows activation of semantic information in the language production system, a partly engaged production system might lead to pre-activation of semantic information but not of form information. This means that a comprehender might pre-activate meaning without pre-activating form under conditions of difficulty, but would not pre-activate form without pre-activating meaning.¹

However, we note that a pattern wherein meaning pre-activation is more likely to occur than form pre-activation could also be compatible with an alternative account involving cascaded pre-activation. Cascaded pre-activation

has not previously been hypothesized to underlie prediction, but cascaded activation is a common mechanism in theories of spoken word recognition (Marslen-Wilson, 1987; Norris, 1994) and in theories of language production (Caramazza, 1997; Dell, 1986). Pre-activation of meaning may cascade into pre-activation of word form, whether or not predictions are generated by the production system. The ramifications of this account will be further discussed in the General Discussion.

Predicting meaning

Classic findings from Kutas and colleagues have shown that anomalous words lead to increased N400 ERPs in comparison to plausible words in the same sentence contexts (Kutas & Hillyard, 1980) and that this N400 effect is reduced for words that are semantically related to the plausible word (Federmeier & Kutas, 1999; Kutas & Hillyard, 1984). Federmeier and Kutas (1999) had participants read discourse contexts that led them to expect a particular target word (e.g., “They wanted to make the hotel look more like a tropical resort. So along the driveway, they planted rows of . . .”) and then presented them with that predictable word (*palms*), a related implausible word within the same semantic category as the target word (*pinus*), or an implausible word from a different semantic category (*tulips*). As in Kutas and Hillyard (1984), participants’ N400 responses were reduced for implausible within-category words (*pinus*) compared to between-category words (*tulips*). This reduction was greater in *high-cloze* contexts, which were created based on a sentence completion pre-test in which participants produced the expected completion (*palms*) 90% of the time, than in *medium-cloze* contexts, in which participants produced the expected completion 59% of the time (see Thornhill & Van Petten, 2012, for similar findings).

Although implausible within-category words (*pinus*) elicited a greater N400 reduction in high-cloze sentences than in medium-cloze sentences, they were rated as less plausible in high- than in medium-cloze sentences. Crucially then, because the N400 reduction did not pattern with the plausibility pre-test data, Federmeier and Kutas (1999) could rule out an integration account in which the observed N400 reductions reflected within-category words being more plausible sentence continuations (and therefore easier to integrate) than between-category words. They concluded that, prior to the onsets of the target words, participants had activated semantic features of the expected sentence continuations. This in turn implied activation of some of the within-category words’ semantic features, resulting in facilitation of the within-category words relative to those which didn’t share a semantic category, as indexed by N400 reduction.

Federmeier and Kutas’ (1999) findings are indeed consistent with an account of prediction that operates via pre-activation of semantic category features. However, a remaining inconsistency comes from the fact that a pre-activation account also strongly suggests that high-cloze target words themselves should show a reduced N400 effect compared to medium-cloze target words. But, surprisingly, Federmeier and Kutas (1999) did not find this basic effect of cloze probability.

¹ Pickering and Garrod (2013) in fact proposed a different type of production-based prediction that they called *prediction-by-simulation*. To summarize briefly, there is good evidence that people predict their own utterances using so-called forward models, based on associations between their intention (e.g., to talk about a kite) and aspects of the word they would use to describe that intention (e.g., the phoneme /k/). These forward models are ready before the utterance itself (thus allowing self-monitoring), and there is no reason that predictions of meaning need be ready before predictions of form. They can then use such forward models to predict during comprehension, again before the speaker produces the utterance. This form of prediction makes no claim that prediction should depend on time or resources, and in particular does not assume that prediction of form is less likely to occur than prediction of meaning. However, Pickering and Garrod’s model is compatible with the occurrence of both prediction-by-simulation and prediction-with-implementation.

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