



When prediction is fulfilled: Insight from emotion processing



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ARTICLE INFO

Article history:

Received 23 July 2015

Received in revised form

1 December 2015

Accepted 13 March 2016

Available online 14 March 2016

Keywords:

Prediction

Emotion

Language

ERP

P200

N400

LPC

ABSTRACT

Research on prediction in language processing has focused predominantly on the function of predictive context and less on the potential contribution of the predicted word. The present study investigated how meaning that is not immediately prominent in the contents of predictions but is part of the predicted words influences sentence processing. We used emotional meaning to address this question. Participants read emotional and neutral words embedded in highly predictive and non-predictive sentential contexts, with the two sentential contexts rated similarly for their emotional ratings. Event Related Potential (ERP) effects of prediction and emotion both started at ~200 ms. Confirmed predictions elicited larger P200s than violated predictions when the target words were non-emotional (neutral), but such an effect was absent when the target words were emotional. Likewise, emotional words elicited larger P200s than neutral words when the target words were non-predictive, but such effect were absent when the contexts were predictive. We conjecture that the prediction and emotion effects at ~200 ms may share similar neural process(es). We suggest that such process(es) could be affective, where confirmed predictions and word emotion give rise to 'aha' or rewarding feelings, and/or cognitive, where both prediction and word emotion quickly engage attention.

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1. Introduction

The extent to which stimuli and the context in which the stimuli occur contribute to processing is of key interest to cognitive sciences. Here we investigated the interaction between words and their preceding context during sentence processing. Numerous studies have examined sentence context driven prediction: Information retrieved from the sentential context can pre-activate aspects of upcoming words prior to their occurrence (e.g., Huettig, 2015, for recent review). Many linguistic features of a predicted target word are activated this way, including semantic/conceptual (Kutas and Federmeier, 2000; Federmeier et al., 2002), conceptual-perceptual (Rommers et al., 2013), morpho-syntactic (Van Berkum et al., 2005; Wicha et al., 2003, 2004), phonological (DeLong et al., 2005), and orthographic features (Kim and Lai, 2012; Federmeier and Laszlo, 2009). In contrast, less research has been done with regard to how meaning cued by the target word interacts with context to impact sentence processing.

The current study used Event Related Potentials (ERPs) to investigate the time course of the contributions of word meaning

not immediately prominent or predictable given the sentential context. To this end we used emotionally loaded words, based on the assumption that if any aspect of word meaning were to be activated fast, the emotional aspect would be a good candidate (Zajonc, 2000, but see Storbeck et al., 2006). Emotional words and neutral words were embedded in highly predictive sentential contexts. Critically, the emotional content difference in the contexts between the emotional and neutral conditions was minimized such that the emotional difference became clear only after the emotional and neutral target words appeared.¹ This design allowed us to test the contribution of the emotional meaning in the predicted word.

Most ERP studies have associated prediction of language meaning with the N400 component. The N400 is a negative deflection occurring in the 300–500 ms time range post word onset. N400 effects have been found for words that are semantically incongruent with its prior sentential context, relative to those that are congruent (Kutas and Federmeier, 2011). Such effects have

¹ It is possible that some emotion associated with the main purport of the prediction (i.e. the target word) can be activated prior to the onset of the predicted word. We dealt with this first by matching the mean emotional ratings of the pre-target contexts between emotional and neutral conditions, and second by focusing on the effects (i.e., subtracting the experimental condition from its control) rather than a given condition in isolation.

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been argued to support prediction, as readers obviously cannot predict any semantically incongruent word prior to the onset of those words. However, the very same effect can also be argued to support post-lexical integration. In this case, readers need not form predictions proactively – they could be waiting for the target word before activating the word meaning and integrating the activated word meaning with its context post-lexically. Recent studies demonstrated that, integration or not, the N400 effect is affected by prediction (Van Berkum et al., 2005; DeLong et al., 2005; Kutas et al., 2011). DeLong et al. (2005) examined contextually constraining sentences (e.g. *The day was breezy so the boy went outside to fly a ...*) followed by a predicted / semantically congruent word (*kite*) and an unpredicted / less semantically congruent word (*airplane*). Not surprisingly, classic N400 effects were found for the unpredicted / incongruent relative to the predicted / congruent words, supporting both prediction and integration accounts. Critically, N400 effects were found for the indefinite article before the unpredicted words relative to the one before the predicted words (a), supporting the prediction account. This suggests that the readers had the predicted word in mind along with its indefinite article before the onset of the target word. A recent study has localized the effects to 350–450 ms (Lau et al., 2014), which very likely represents a time course difference between the N400 effect elicited by semantic violation and the N400 effect elicited by prediction violation.

Several language prediction studies have also reported modulations of the Late Positive Component (LPC). Low-predictive words elicited more positive LPCs than high-predictive ones (Van Petten and Luka, 2012; DeLong et al., 2014). The LPCs in these studies have a less distinct time frame, and tend to occur at ~600 ms. The scalp distributions of the prediction LPC effects can be posterior or anterior, depending on the plausibility of the target words given their contexts (DeLong et al., 2014). When the target word is not plausible (i.e., anomalous), the LPC effect for low-predictive relative to predictive continuations typically shows a posterior distribution. When the target word is plausible, the LPC effect shows an anterior distribution. Note that the posterior LPC effect is the effect that has been mostly reported in general language literature, associated with discourse-level repair and re-interpretation of semantically ill-constructed language (Kuperberg, 2007; Brouwer et al., 2012). The anterior LPC effect has been implicated in the frontal inhibition network suppressing competing plausible meanings (DeLong et al., 2014).

Early cortical responses to emotional words relative to neutral words have been reported in many single word studies (Citron, 2012). The early effects range from as early as 80–120 ms (Hofmann et al., 2009a) to 200–300 ms (Kissler et al., 2007; Kanske and Kotz, 2007; Herbert et al., 2008). It has been suggested that these early effects reflect the allocation of attentional resources to the arousing dimension of the emotional words (Schacht and Sommer, 2009; Schupp et al., 2004). Late ERP effects for emotional words, such as Late Positive Potentials (LPP), are even more commonly reported (Kanske and Kotz, 2007; Schacht and Sommer, 2009; Hinojosa et al., 2010). However, the directionality of the late emotion effects varies from study to study, and is likely to be driven by tasks (Fischler and Bradley, 2006). These late effects in single word studies have been argued to reflect the valence dimension or/and the arousal dimension (Bayer et al., 2012; Recio et al., 2014).

A number of studies have examined the processing of emotional words when the words are embedded in emotionally neutral sentences that are non-predictive but sensible. Scott et al. (2012) focused on two factors of bottom-up word processing: word frequency and word valence. A word frequency by valence interaction was found in the 135–180 ms range. Specifically, people fixated on emotional words shorter than they did on neutral

words, but only in the low-frequency conditions, not in the high-frequency conditions. The authors suggested that the emotional content increases automatic vigilance but decreases sensitization, both of which play an important role in the processing of word frequency. Holt et al. (2009) examined emotional words embedded in passages such as “*Colin decided to walk to the market. On the way he saw a snake/diamond/button on the ground*”. Similar to Scott et al. (2012), the passages were emotionally neutral, non-predictive, and sensible. N400 effects were found for the emotional words (*snake/diamond*) relative to the neutral words (*button*). The authors suggested that the emotional features of the emotional words lead to deeper semantic analysis. Notably, their reported N400 effect ranged from 325 to 425 ms, different from the typical N400 time frame of ~300–500 ms. While Holt et al. (2009) used an early N400 time window to minimize its overlap with the LPC emotion effect following N400, it is possible that this negativity effect is related to the posterior negativity effects from 150 to 300 ms reported in emotional word and non-linguistic stimuli (Herbert et al., 2008; Kissler et al., 2007).

Delaney-Busch and Kuperberg (2013) examined emotional and neutral words embedded in emotional and neutral contexts. In the neutral context conditions (e.g., *Lucy was a female engineer. Her creations were big bridges/murals every time.*), the semantically incongruent words (*murals*) elicited more negative N400s than the congruent words (*bridges*), replicating the vast N400 literature. In the emotional context conditions (e.g., *Lucy was an awful/great engineer. Her creations were big failures/successes every time*), emotion was manipulated via a positive word (*great*) and a negative word (*awful*). The N400 congruity effect was attenuated for emotional words, which subsequently yielded an LPC emotion effect regardless of congruity. The authors argued that the emotional contexts may have acted as a task which oriented the readers’ attention toward the emotional properties of the incoming words, prioritizing emotional meaning and bypassing conceptual-semantic meaning. The authors suggested that this LPC effect may reflect the evaluation of the then focused emotional meaning.

In short, prediction accumulated in the pre-target context, when not met by the target word, elicited N400 and posterior LPC effects, which have been theorized to index semantic retrieval and semantic reanalysis, respectively. Second, the emotional content of words, when contrasted with neutral words, gave rise to early effects at ~200–300 ms and late positivity effects, which have been suggested to reflect emotional arousal and emotional valence. Third, while N400 effects for emotion in single word studies are actually quite uncommon (Kissler et al., 2006), emotional words embedded in neutral and non-predictive (but sensible) sentences have been reported to elicit larger negativity effects than neutral words in the 325–425 ms time frame. The negativity effects have been suggested to reflect deeper semantic processing for emotional than for neutral words in sentences. Finally, emotional words in emotional contexts/tasks, when mismatched with context emotionally, elicited a LPC effect, which has been suggested to index affective evaluation.

The present study examined emotional and neutral words in predictive and non-predictive (anomalous) sentences, to assess the contribution of emotional word meaning and contextually driven prediction of meaning during sentence processing. Based on the reviewed literature, we expected that the ERP effects associated with the contribution of emotional word meaning should emerge as an early effect before ~300 ms and as a late positivity after ~500 ms. The ERP effects associated with the contextually driven prediction should emerge as a negativity in the 300–500 ms time frame and as a late positivity effect after ~500 ms. Of particular interest was when the prediction effect and the emotion effect interact.

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