Journal of Memory and Language 93 (2017) 203–216

Contents lists available at ScienceDirect

Journal of Memory and Language

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

Goals and strategies influence lexical prediction during sentence comprehension

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ARTICLE INFO

Article history:
Received 21 October 2015
revision received 8 October 2016
Available online 9 November 2016

Keywords:
Prediction
Anticipation
Automaticity
N400
Post-N400 positivity
Self-paced reading

ABSTRACT

Predictive processing is a critical component of language comprehension, but exactly how and why comprehenders generate lexical predictions remains to be determined. Here, we present two experiments suggesting that lexical prediction is influenced by top-down comprehension strategies, and that lexical predictions are not always generated automatically as a function of the preceding context. In Experiment 1 ($N = 24$), participants read predictable and unpredictable sentence-final words while EEG was recorded from the scalp. When comparing two different sets of task instructions, the neural effects of cloze probability were enhanced when predictive processing was emphasized. In Experiment 2 ($N = 252$), participants read predictable and unpredictable sentence continuations in a self-paced reading task, and the overall validity of predictive cues was manipulated across groups using a separate set of filler sentences. There was a linear relationship between the benefits of a constraining sentence context and the global validity of predictive cues. Critically, no reading time benefits were observed as *prediction validity* approached zero. These results provide important constraints for theories of anticipatory language processing, while calling into question prior assumptions about the automaticity of lexical prediction.

Introduction

In the past decade there has been a shift in our understanding of how readers construct meaning during online comprehension. While it has long been appreciated that context can affect the comprehension of individual words, recent studies suggest that language comprehenders can also use contextual constraints to actively predict upcoming words in a discourse (Altmann & Mirković, 2009; Brothers, Swaab, & Traxler, 2015; Huettig, 2015; Kutas, DeLong, & Smith, 2011). Whether it is a listener making anticipatory eye-movements to a predicted object in a scene (Altmann & Kamide, 1999), a reader skipping over a predictable word in a passage of text (Rayner, Slattery, Drieghe, & Liversedge, 2011), or an eager interlocutor finishing a friend's sentence (Howes, Healey, Purver, & Eshghi, 2012), anticipation appears to be a fundamental mechanism in both language comprehension and human cognition more generally (Clark, 2013).

One important method for assessing the neural timecourse of predictive processing is the event-related potential (ERP) technique. In previous ERP studies, the N400 component has been shown to be sensitive to the difficulty of processing meaningful stimuli, including words, pictures, and linguistic gestures. In addition to a number of low-level, lexical variables (Kutas & Federmeier, 2011; Van Petten, 2014), one of the primary factors that influences N400 amplitude during reading is the predictability of a word in context. Predictability in these studies is often operationalized as *cloze probability*, or the likelihood that a

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http://dx.doi.org/10.1016/j.jml.2016.10.002
0749-596X/

participant will provide a particular word in an offline, sentence-completion task (Taylor, 1953). Previous studies have shown a strong linear relationship between cloze and N400 amplitude (DeLong, Urbach, & Kutas, 2005; Kutas & Hillyard, 1984). It has been theorized that this N400 predictability effect is driven by pre-activation of semantic and lexical features, which ultimately results in facilitated neural processing of the predicted word (Kutas & Federmeier, 2000; Swaab, Ledoux, Camblin, & Boudewyn, 2012).

Another ERP component which is known to be sensitive to contextual probability is the post-N400 positivity (Delong, Urbach, Groppe, & Kutas, 2011; Van Petten & Luka, 2012). Unexpected sentence continuations, in addition to showing larger N400 amplitudes, also produce an enhanced late positivity over frontal electrode sites. It has been hypothesized that this component reflects the costs of encountering a disconfirmed lexical prediction (Federmeier, Wlotko, De Ochoa-Dewald, & Kutas, 2007; Thornhill & Van Petten, 2012), or the costs of revising the preceding discourse context in light of new, unanticipated information (Brothers et al., 2015).

Despite recent progress, there are still many unknown variables that may influence how and when lexical predictions are generated. One critical, unanswered question is whether specific lexical predictions are activated *automatically* as a function of the preceding context, or whether predictions are generated *strategically* to facilitate upcoming text processing (for a discussion, see Huettig, 2015). According to an *automatic-activation* account of prediction, as readers process a semantically rich sentence context (*the web was spun by*...) they will rapidly activate a set of associated concepts (*spider*). Given a sufficiently constraining context, activation will accumulate for a specific lexical item, resulting in pre-activation even to the level of phonological or orthographic features. This would all occur automatically and unconsciously, simply as a function of the pre-existing links that a reader has formed in lexical-semantic memory.

Alternatively, generating specific lexical predictions at the form level may require additional processing mechanisms beyond simple spreading activation. It may be the case that true *prediction* requires the selection of some word candidates at the expense of others. Like other forms of lexical selection (cohort competition, lexical ambiguity resolution), this process would likely unfold gradually over time, requiring a resource-demanding inhibition of competing alternatives. While some forms of semantic priming are relatively resource-free, *anticipatory* priming effects may require additional attention and cognitive resources. Some support for this hypothesis comes from a dual-task study by Heyman, Van Rensbergen, Storms, Hutchison, and De Deyne (2015). In this experiment, participants showed selective impairments in anticipatory semantic priming when they were placed under high levels of concurrent working-memory load. Moreover, it appears that readers with better cognitive control abilities show larger anticipatory priming effects during both lexical decision and naming tasks (Hutchison, 2007; Hutchison, Heap, Neely, & Thomas, 2014).

If the generation of lexical predictions is *metabolically costly*, as suggested by Kuperberg and Jaeger (2016), then an efficient comprehender may suppress anticipatory mechanisms when they are no longer beneficial or relevant to the task at hand. Similarly, in an environment where predictive cues are particularly important (e.g. understanding a friend at a noisy party), comprehenders may increase the amount of resources devoted to top-down, anticipatory processing (Huettig, 2015; Lupyan & Clark, 2015).

Currently, the main source of evidence for strategic modulations of this type comes from single-word semantic priming tasks (den Heyer, Briand, & Dannenbring, 1983; Holcomb, 1988; Lau, Holcomb, & Kuperberg, 2013). For example, semantic priming effects in a lexical decision task are enhanced when the proportion of related prime-target pairs (doctor-NURSE) in the experiment is high, and reduced when the relatedness proportion is low (see Neely, 1991 for a discussion). While these studies are informative, it is still unclear if strategic mechanisms of this type can influence lexical prediction during language comprehension more generally.

In the present experiments we investigated whether top-down goals and strategies can influence lexical anticipation mechanisms during sentence and discourse processing. In Experiment 1 we used two neural indices of lexical prediction (the N400 and post-N400 positivity) to determine whether anticipatory effects at the discourse-level can be influenced by top-down comprehension strategies. In Experiment 2, we directly manipulated the environmental validity of predictive cues, to determine whether readers could strategically modulate their degree of anticipatory processing during a self-paced reading task.

One of the primary tests for establishing the automaticity of a cognitive mechanism is to determine whether it is *controllable* or *goal dependent* (Moors & De Houwer, 2006). To this end, we first recorded ERPs under two reading conditions: a standard *Comprehension* task in which participants answered true-false comprehension questions, and a separate *Prediction* task in which participants were instructed to actively anticipate the final word of each sentence. Using this task manipulation, we tested whether the standard ERP effects of cloze probability are generated automatically as a function of the preceding context, or if these effects could be altered as a function of readers' comprehension goals. If lexical predictions are subject to top-down control, we would expect an enhancement of both the benefits (N400) as well as the costs (PNP) of constraining contexts when a predictive reading strategy is emphasized.

Experiment 1

Materials and method

Participants

Twenty-four undergraduates (16 females) from the University of California, Davis participated in Experiment 1. The mean age of this group was 20.3 years (range 18–26, std = 2.3), and all were native English speakers with