Changing the narrative: ERP markers of building and updating situation models during deep naturalistic comprehension

Background. Decades of research using ERPs have focused on how prior contexts can facilitate the process of accessing the meaning of each incoming word. This facilitation is reflected by a reduction in the amplitude of the N400 component, which emerges between 300–500 ms following word onset. Facilitation of this kind occurs for a range of contexts including related prime-target pairs, locally predictable sentences, and longer discourse contexts. Indeed, during naturalistic language comprehension, the N400 is evoked by every content word with an amplitude that closely tracks its lexical predictability. The present ERP study focuses on a set of processes that go beyond accessing the meanings of individual words and integrating them into their linguistic context. Specifically, we focus on the process of incrementally updating a *situation model*—a higher-level mental representation that connects linguistically-inferred events with broader, schema-relevant knowledge stored in long-term memory.[1] There is emerging evidence that a set of late frontally distributed positivities (LFPs) observed between 500–1000 ms are linked to successful updates of this higher-level situation model.[2] For example, in contrast to the N400, LFPs are *only* produced when comprehenders have established a situation model, and new, incoming information prompts them to update it.[3] This typically occurs when an unexpected but plausible word disconfirms strong contextual expectations (e.g., "He got her a pearl necklace for her *collection*.").[4] However, if comprehenders have ample time and they are actively engaged in retrieving new schema-relevant information (e.g., during self-paced reading), then LFPs can also be evoked by unexpected words in low constraint contexts.[5-7] To date, the LFP has only been studied in controlled experimental paradigms that match "critical words" across expected and unexpected conditions. Here, we ask whether LFPs, like N400s, are produced on every content word during deep naturalistic reading comprehension.

Design. (*Self-paced reading, N = 22*) English-speaking adults read short, engaging vignettes (3–5 sentences) while ERPs were recorded. We encouraged deep comprehension by asking questions after each passage (e.g., yes/no questions, multiple choice). We calculated predictability values for each content word using an online cloze task with different participants (M = 15.8%, SD = 24.4%, *range* = 0–100%). Constraint of the prior context was operationalized as the probability of the most common continuation at that point in the passage (M = 39.1%, SD = 20.9%, *range* = 5–100%).

Analysis and Results. A set of linear mixed effects models regressed mean N400 (300–500 ms, centroparietal electrodes) and LFP (500–1000 ms, frontal electrodes) amplitudes from each content word onto *z*-scored, continuous measures of *lexical predictability*, *contextual constraint*, and various lexical control features. Our results replicate the N400's sensitivity to lexical predictability in naturalistic contexts with reduced N400s to more predictable words (b = 0.48, t = 5.85, p < .001). Critically, we found that LFPs were also evoked by all content words in our short passages, and they were more positive when words were more unexpected (b = –0.3, t = –4.31, p < .001; see Figures 1–2). We found no additional effect of contextual constraint on either the N400 or LFP.

Discussion. We found clear evidence that an extended, frontally distributed neural response between 500–1000 ms on each content word is a key component of natural, deep reading comprehension. We also show that this effect is graded by lexical predictability. This may be because lexical predictability covaries with (and acted as a proxy in our study for) the amount of new, schema-level information that comprehenders retrieved to successfully update their situation models. To directly test this hypothesis, and to dissociate the sensitivities of the N400 and LFP, we plan to develop novel ways to quantify the amount of information that words contribute to our higher-level interpretations. Finally, we note that this study was explicitly designed to motivate readers to comprehend deeply. Thus, in future work, we will manipulate comprehension instructions and presentation methods to test whether reducing participants' motivation to engage in deep comprehension limits LFPs to words that disconfirm prior, high-level predictions, as has been shown in previous studies.

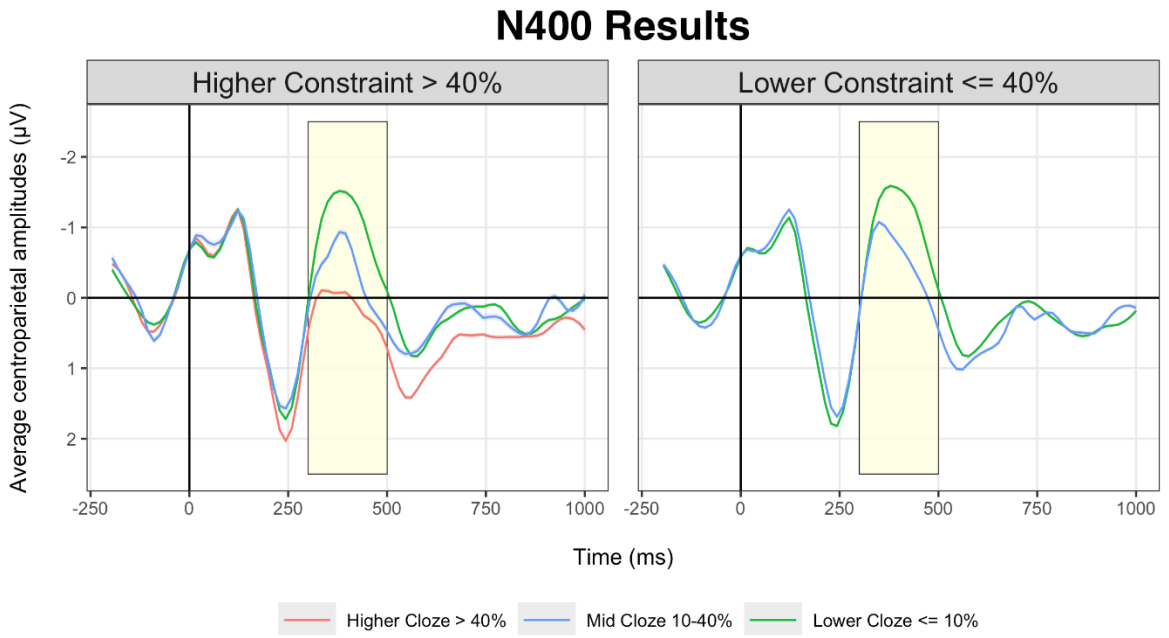

Figure 1. Evoked activity averaged across content word onset at centroparietal electrodes (Cz, C3/4, CPz, CP1/2, Pz, P3/4). For presentation purposes, we broke up the plots by prior constraint (High Constraint > 40%, left; Low Constraint <= 40%, right) and for the ERP waveforms we created three groups based on a words cloze value: High Cloze (red, >40%), Mid Cloze (blue, 10-40%), and Low Cloze (green, <=10%).

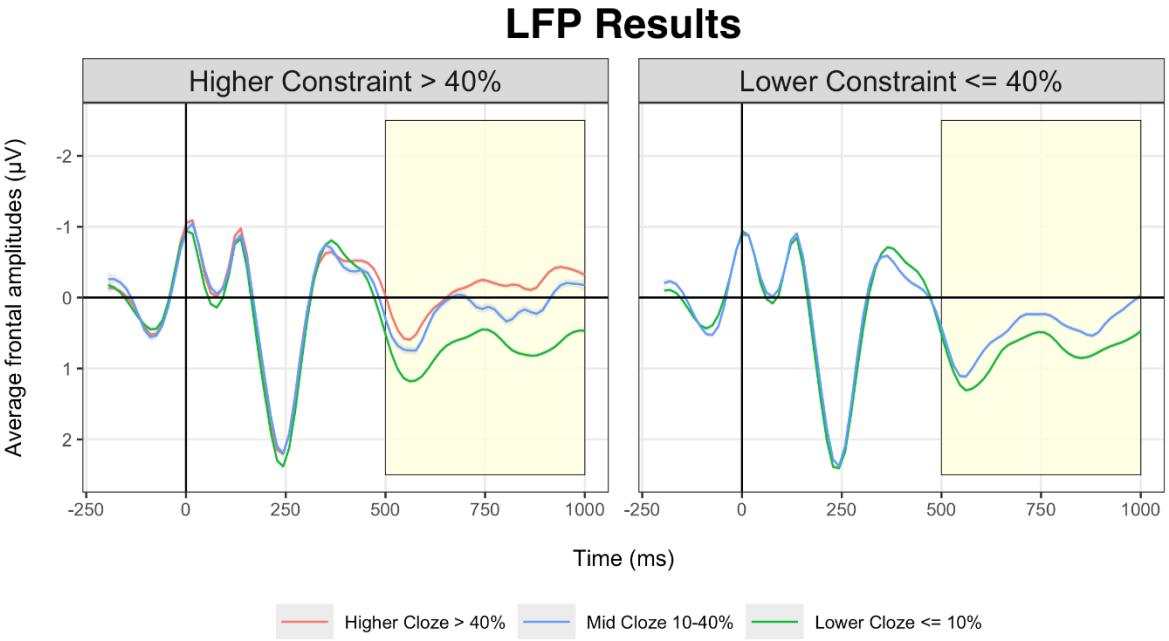

Figure 2. Evoked activity averaged across content word onset at frontal electrodes (AF3/4, FPz, FP1/2, Fz, F3/4). For presentation purposes, we broke up the plots by prior constraint (High Constraint > 40%, left; Low Constraint <= 40%, right) and for the ERP waveforms we created three groups based on a words cloze value: High Cloze (red, >40%), Mid Cloze (blue, 10-40%), and Low Cloze (green, <=10%).

References: [1] Zwaan & Radvansky (1998). *Psychological bulletin*. [2] Kuperberg, Brothers, & Wlotko (2020). *JCN.* [3] Brothers, Wlotko, Warnke & Kupernerg (2020). *Neurobiology of Language*. [4] Federmeier, Wlotko, De Ocho-Dewald & Kutas (2007). *Brain research.* [5] Chow, Lau, Wang & Phillips (2018). *LCN.* [6] Freunberger & Roehm, 2016. *LCN*. [7] Thornhill & Van Petten (2012). *International Journal of Psychophysiology.*