<u>Capturing continuous effects of context during naturalistic story reading</u>

Shannon McKnight & Albert Kim (University of Colorado Boulder)
shannon.mcknight@colorado.edu

Many psycholinguistic studies have investigated how context processing is reflected in the brain's response to words. These studies often focus on single words in isolated sentences. Natural reading and listening, however, involves the interaction between a much larger body of contextual information and the current word. To understand how naturalistic context impacts the neural operations underlying word reading, we recorded EEG while 30 participants read nine short stories related to science topics (e.g., "Solar eclipse", "The life of a bee"), totaling ~3,000 words. Words appeared on the screen one by one at a self-paced rate (Ditman, Holcomb & Kuperberg, 2007). ERPs for each word, averaged across subjects, were drawn between 0-1000ms with a 200ms pre-stimulus baseline period, referenced to linked mastoid channels.

We quantified contextual fit by calculating a word's semantic distance to the words in a leftward context window. Contextual fit for each content word in the stories (~1500 content words) was defined as the cosine distance between the word's vector space representation (GloVe vector space: Pennington et al, 2014) and the sum of vectors of the 10 preceding content words. A larger cosine value indicated strong contextual fit for the word. We examined how ERP voltages were predicted by this measure of contextual fit along with 6 lexical features simultaneously: word length, visual complexity, consonant-vowel proportion, bigram frequency, word frequency, and sentence position. We fit a multiple-regression model predicting voltages at each 5ms time-point in the first 500ms post-word onset, at each of 62 scalp-located electrodes and corrected for false discovery rate (Groppe et al, 2012; Dufau et al, 2014). Word length significantly predicted ERP voltage between 70-120ms, followed by significant effects of visual complexity (150-300ms), sentence position (175-300ms), bigram frequency (225-250ms), and word frequency (200-400ms). Contextual fit predicted activity between 300-500ms, corresponding to the semantic access related N400 component. These relationships together confirm that word-recognition within our self-paced story reading paradigm elicits a cascade of neural responses reflecting increasingly sophisticated lexical representations (Fig 1).

We next examined how context interacted with effects of lexical features. We separated words into three bins of contextual fit (high, medium, and low) and then conducted the analysis described above with just lexical features as predictors. Effects of lexical features were strong when contextual fit was low (Fig 2), and effects nearly disappeared when contextual fit was high. We conclude from this pattern that stronger context leads to greater prediction of the upcoming word, reducing the impact of the word's lexical features on the brain's activity because those features have been "pre-activated". These pre-activations appear to be relayed from high-order semantic representations to visual processing areas, reflected in the impact of context on very early EEG activity related to physical features of a word such as length.

Finally, we investigated the amount of context used by comprehenders in recognizing each word. We examined the impact of contextual fit on 300-500ms EEG activity separately for context windows ranging in size from 5 to 20 preceding content words. For each window, we quantified the strength of context's impact by summing the t-values of all of the tests within the 300-500ms time-window. Contextual fit effects were maximal for windows of 10 content words, and decreased continuously as the window was made either smaller or larger. It seems that readers are strongly influenced by representations of context that can reach quite far back in the text—in the current situation, around 10 content words, which typically spans 2-3 sentences. But the impact of context diminishes as the context window extends beyond this maximal value, suggesting prioritization of recent information in impacts of context.

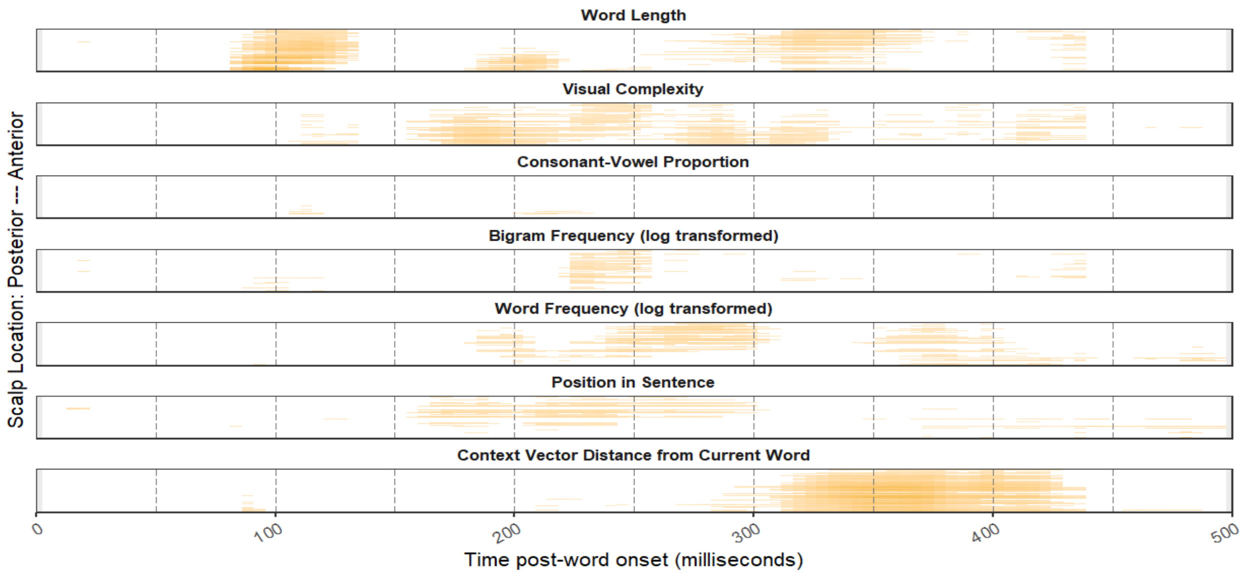

Figure 1: Effects of lexical features on ERP activity averaged across subjects, over time and at every electrode. Color indicates a significant statistical test after FDR correction for multiple comparisons; blue indicates negative slope and red indicates positive slope. Visual features (word length and visual complexity) affect the ERP first, followed by higher order features such as word and bigram frequency. Contextual support shows strongest effects within an N400 time window broadly across the scalp.

Figure 2: Effects of lexical features separately for words with low, mid, and high contextual fit. Color indicates significant tests after FDR correction for multiple comparisons; blue indicates negative slopes, red indicates positive slopes. As contextual fit increases, lexical features are less predictive of ERP responses to words, indicated by the lack of color in panel 3 compared to panel 1.

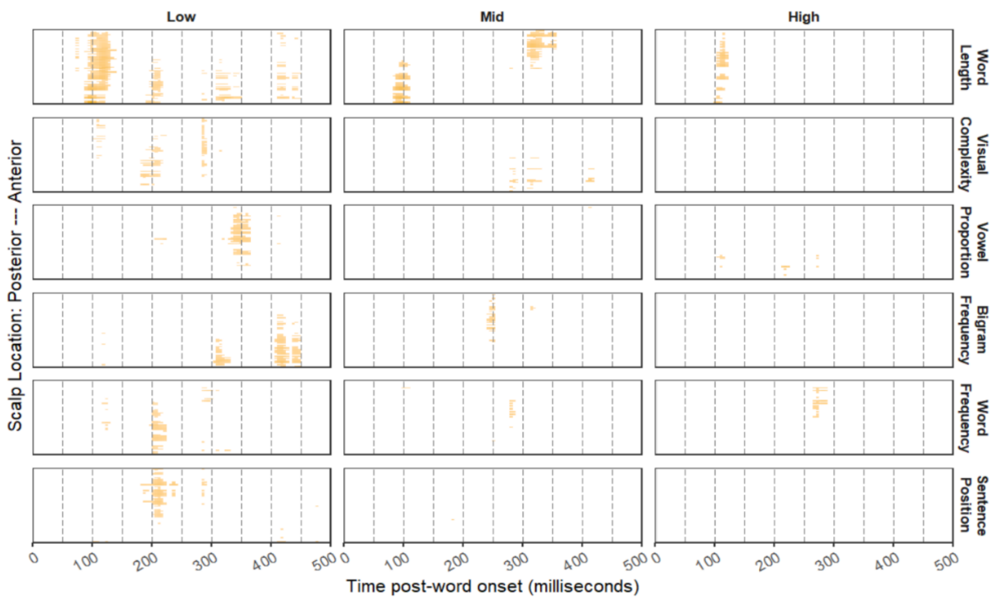

Figure 3: Statistical strength of effects of contextual fit effects, at various context window sizes. Each point reflects the summed t-values for all tests between 300-500ms post-word onset. Context window size varies between 5-20 previous content words included in a summed word vector compared to the current word. The effects were maximal for a 10 word context window, and decreased for smaller or larger windows.