Contextual Facilitation in Language Comprehension: Insights from a Unified Predictive Coding Framework

Samer Nour Eddine[1], Trevor Brothers[3], Lin Wang[1,2], Gina Kuperberg[1,2]; [1]Tufts University, [2]Massachusetts General Hospital, [3]North Carolina Agricultural and Technical State University

A central question in psycholinguistics is how form is mapped onto meaning during incremental language comprehension. Critically, when provided with constraining contextual information, this mapping process is often facilitated, resulting in both faster behavioral responses and reductions in evoked neural activity. However, the underlying sources of these neural and behavioral facilitation effects and their relationship to each other remains an open question. In previous modeling work, we simulated various contextual effects on the N400 using predictive coding principles. In the predictive coding framework, each hierarchical level of the cortex contains two kinds of units:1) state units, whose activity encodes beliefs about the state of the world, and 2) error units, which update these beliefs by signaling inconsistencies in representations between cortical levels . By passing predictions and prediction error between layers, these state and error units can extract high-level structure from low-level sensory information. Importantly, the summed activity of lexical and semantic error units in this model captured key properties of the N400 response, including its sensitivity to a wide range of contextual factors. Here, we shift our focus to the activity in the state units, and show that the same model accurately captures behavioral facilitation effects from the same set of contextual manipulations, including word repetition, semantic priming, lexical predictability, anticipatory semantic overlap and the null effect of constraint. Our model encodes three hierarchical levels of linguistic representation: orthographic, lexical, and semantic, each with its own state units. Over time, the model converges to the correct lexical state that can accurately explain the bottom-up orthographic input. We operationalize behavioral response times as the duration (number of iterations) it takes for the activity of the most active lexical state unit to surpass a predefined threshold. To simulate word-pair priming, we presented word-pairs that were either repetitions (LIME–LIME), semantic associates (SOUR–LIME) or unrelated (BANK–LIME). To simulate lexical predictability, anticipatory semantic overlap and the null effect of constraint, the higher-level state units associated with each word were clamped to activations proportional to their predictability (cloze), before presenting any bottom-up input. Across three simulations, the bottom-up input was either identical to this top-down prediction, was semantically related, or was unrelated. Results: Similar to human readers, responses were faster for repeated and primed words. We also observed a graded reduction in response times as a function of word predictability, with no additional effect of constraint. Finally, responses were faster when the unpredicted input was semantically related to the modal prediction. Discussion: Predictive coding offers a biologically-motivated and parsimonious account of both neural and behavioral patterns in language comprehension. Our model shows that the same contextual manipulations that attenuate error unit activity (the N400) also cause lexical state units to converge more rapidly, resulting in faster behavioral responses. Importantly, because these two outcomes are tied to distinct sub-components of the model, this model predicts that some contextual manipulations (e.g. form priming) may lead to dissociations between behavior and the N400. Exploring these dissociations empirically in future work would constitute a strong test of the model.