Pragmatic predictions from the visual world modulate neural semantic activity

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Listeners continuously infer and predict speakers' intended meaning based not only on what is said but also on relevant world knowledge, including information from the visual world. For example, when a description of an object within a visual display begins with an adjective like *tall*, listeners generally infer that the adjective provides information necessary to uniquely denote the intended referent [1]. If the visual display contains two objects that match the adjectival description – one that contrasts with another object along the relevant dimension (e.g. a tall and short pitcher) and one that does not (e.g. a tall ladder) – listeners generally predict that the former will be the target object [2].

The aim of the present study is to characterize the neural effects of these visually-derived pragmatic inferences. Participants (n=24) heard a female speaker say, "The target is the (adjective) (noun)" (e.g., *tall pitcher*) while viewing a four-picture display and focusing their gaze on the center of the display grid. Event-related potentials (ERPs) were time-locked to the onset of the final critical word (e.g. *pitcher*). After each sentence, a location probe was presented, in which two grid cells were shaded, and participants pressed a button to indicate whether or not the target picture had been presented in one these shaded cells. In 120 experimental trials (interleaved with 80 fillers), the contents of the visual display were manipulated across three counterbalanced conditions. In trials with pragmatically expected nouns, the target picture appeared along with a picture of the same type of object with a contrasting attribute (e.g., a tall and short pitcher); the display also contained a picture of a different type of object with the same attribute (e.g., a tall ladder), and another distractor [3, left]. In trials with pragmatically unexpected nouns, the critical word disconfirmed pragmatic expectations: the target picture was the only of its type in the display, and the display instead contained two other pictures of the same type forming a contrast set with respect to the adjectival attribute (e.g. a tall and short ladder) [3, center]. In trials with pragmatically intermediate nouns, both the target picture and a distractor appeared along with a contrasting version (e.g. a tall and short pitcher and a tall and short ladder) [3, right]. In half of the critical trials, the adjective was relative (e.g. *tall*, *long*); in the other half, it was absolute (e.g. *green*, *wooden*).

Pragmatically unexpected critical nouns evoked a larger N400 (between 300-500ms) at central and centro-parietal sites than pragmatically expected critical nouns (p<.05), with pragmatically intermediate nouns eliciting effects numerically in between the two [4]. Visually-based pragmatic predictions thus facilitated semantic processing of incoming words. These effects were also observed earlier, within the N250 time window (between 200-300ms; p<.01), suggesting that pragmatic predictions also facilitated processing of incoming words by way of phonological form predictions.

At frontal sites, between 400-600ms, pragmatically unexpected critical words evoked a significantly larger negativity than both other conditions (p<.05) [5]. This anterior negativity effect has been linked to the demands of suppressing high-probability competing alternatives (e.g. [6,7]). Here we suggest that the observed anterior negativity reflects the demands of suppressing the strong pragmatic prediction of an alternative adjective-noun structure (e.g. *tall ladder*) and enhancing activity of the lower-probability target adjective-noun combination (e.g. *tall pitcher*) upon hearing the noun. In addition, between 800-1200ms, pragmatically unexpected critical words evoked a larger posterior positivity than both other conditions (p<.05) [8], which may reflect structural reanalysis (i.e. a late P600 effect) on trials in which participants had committed strongly to an (incorrect) prediction [9].

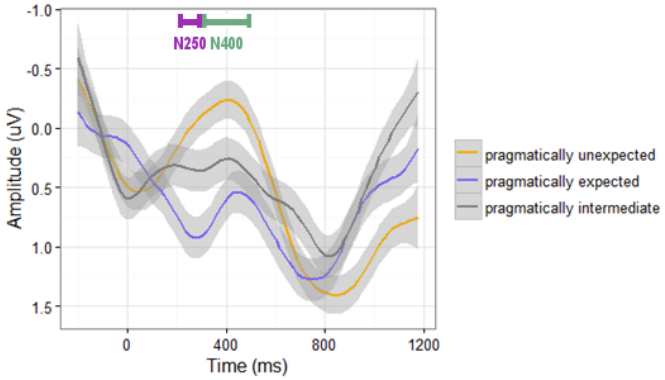
These findings show that pragmatic information from contextually salient sets of contrasting items in visual context can modulate neural activity related to semantic prediction, and can lead to prolonged neural processing when such predictions are disconfirmed.

[1] Grice HP (1975). in *Syntax and Semantics: Speech Acts*, Vol. 3, eds. P Cole, JL Morgan, New York, NY: Seminar Press, 225-42.

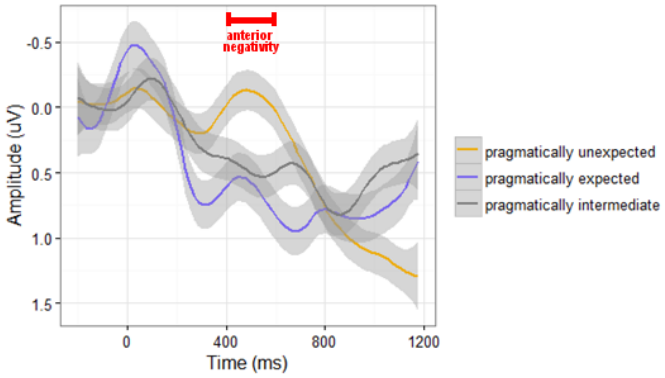
[2] Sedivy JC, Tanenhaus MK, Chambers CG, Carlson GN (1999). *Cognition, 71(2),* 109-47.

[3] Example displays for the stimulus "The target is the tall pitcher", corresponding to the pragmatically expected (left), unexpected (center), and intermediate (right) conditions.

[4] ERP waveforms across central and centro-parietal sites (Cz, C3, C4, Pz, CP1, CP2). Time windows for analyses are shown at top of plot (N250: 200-300ms, purple; N400: 300-500ms, teal).



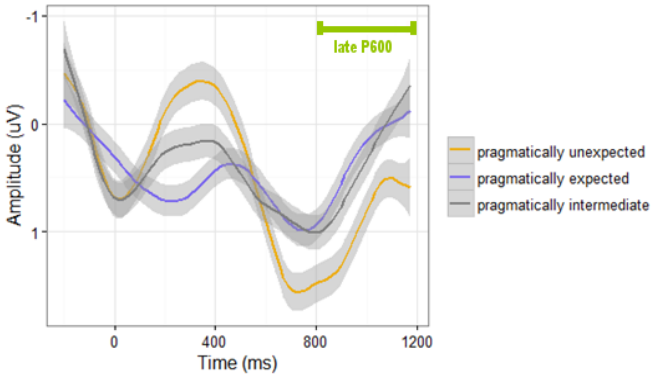
[5] ERP waveforms across prefrontal and frontal sites (FPz, FP1, FP2, Fz, FC1, FC2). Time window for anterior negativity analyses is shown at top of plot (400-600, red).



[6] Baggio G, Choma T, van Lambalgen M, Hagoort P. (2010). *Journal of Cognitive Neuroscience, 22,* 2131-40.

[7] Wittenberg E, Paczynski M, Wiese H, Jackendoff R, Kuperberg G. (2014). *Journal of Memory and Language, 73,* 31-42.

[8] ERP waveforms across parietal and occipital sites (Pz, CP1, CP2, Oz, O1, O2). Time window for late posterior positivity analyses is shown at top of plot (800-1200, green).



[9] Xiang M, Kuperberg GR (2015). *Language, Cognition, and Neuroscience, 30 (6),* 648-72.