Updating predictions incrementally: Listeners are able to process new information following prediction errors

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Comprehenders can predict upcoming language based on global context [1-2] and use disconfirming evidence or informative cues to update their predictions rapidly [3-5]. However, a recent study found that prediction failure hinders local semantic processing, questioning the utility of prediction in language comprehension [6]. To further examine possible costs induced by prediction errors, we investigated whether listeners can use new information to update their noun prediction after encountering a prediction error. We built on the design of [3] to use an unexpected nominal classifier to signal a prediction error and manipulated the informativeness of the adjective that follows. Our results suggest that listeners can use an informative cue to update their prediction even when it immediately follows an early sign of prediction error.

Method: 50 participants listened to sentences like (1) (translated from Chinese; see Fig. 1) while their eye movements were tracked. The sentential context was strongly predictive of a particular noun (e.g., *tree*) but always ended with an unexpected target noun (e.g., *table*). The target noun was preceded by a nominal classifier (specific vs. general) and an adjective (informative vs. uninformative), resulting in a 2×2 design. While the general classifier was compatible with all nouns depicted in the visual display, the specific classifier was incompatible with the expected noun and thus signalled a prediction error. Meanwhile, it was compatible with other two objects displayed, the unexpected target and competitor (e.g., chair). While all nouns were compatible with the uninformative adjective, only the target noun was compatible with the informative adjective so it can in principle be used to predict the upcoming noun.

(1) The old house's courtyard is full of greenery, and in its centre, there is …

(a) Early sign of prediction error (specific classifier):

One **CL_{zhang}** {chess-playing / good-looking} table

(b) No early sign of prediction error (general classifier):

One **CL_{xie}** {chess-playing / good-looking} table

Results: We observed that, after encountering a specific (relative to a general) classifier, listeners were more likely to look toward the unexpected target and competitor. As the sentence continued, they increased looks to the unexpected target upon hearing an informative (relative to an uninformative) adjective no matter whether it follows a specific or a general classifier (Fig. 2). We used a generalised additive mixed model to test the effects from 200 ms after the classifier onset to 200ms after the average noun onset (Fig. 3). The results showed a significant main effect of classifier ($p < .001$) and adjective ($p < .001$) but no interaction ($p = 0.86$). We then did a bootstrapping analysis [7] to directly compare the onset of divergence between the informative and uninformative adjective conditions, following a specific vs. general classifier (Fig. 4). The difference in the divergence points was only 15 ms (95% CI = [-80, 120]), suggesting that listeners were equally quick to use the informative adjective to update their noun prediction no matter whether they had just encountered a prediction error or not.

Discussion: We found listeners can use an adjective to update their noun predictions even when they had just encountered an unexpected classifier, indicating that comprehenders can rapidly use new information to update their predictions even right after encountering an early sign of prediction error. In a new EEG study (in progress), we will test whether comprehenders can still update their prediction after encountering a prediction error in the absence of any visual display of candidate objects.

老家的院子里种了很多绿色植物，院子中央有…
The old house's courtyard is full of greenery,
and in its centre, there is …

(a) Early sign of prediction error (specific classifier):

一　张　{下棋的 / 好看的}　桌子
One　**CL$_{zhang}$**　{chess-playing / good-looking}　table

(b) No early sign of prediction error (general classifier):

一　些　{下棋的 / 好看的}　桌子
One　**CL$_{xie}$**　{chess-playing / good-looking}　table

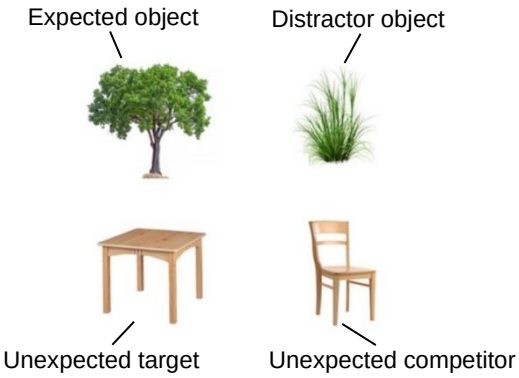

Figure 1. Sample material and visual display

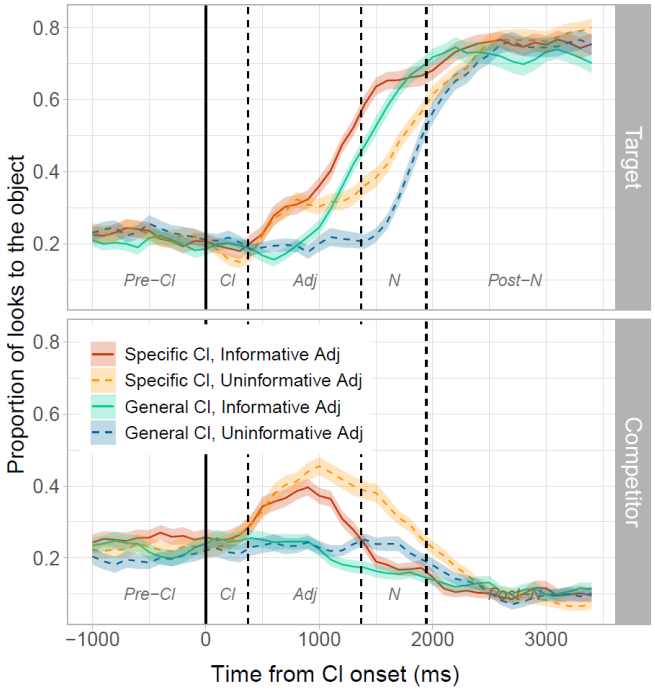

Figure 2. Proportions of looks to unexpected target and competitor object, time-locked to the classifier onset (0 ms), across four conditions. Standard errors were shown in semi-transparent shades.

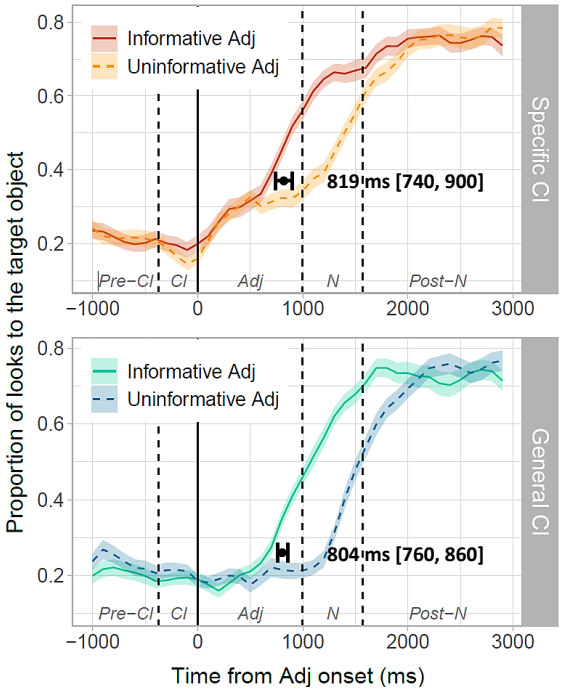

Figure 4. Proportion of fixations to the unexpected target object, time-locked to the adjective onset (0 ms). Points indicate the bootstrap means of the onset of divergence. Error bars represent 95% percentile confidence interval.

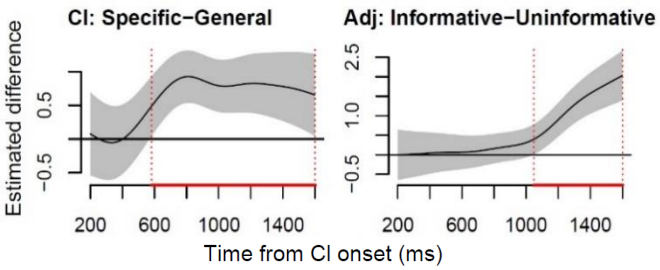

Figure 3. Estimated difference smooth of classifier and adjective (fixations on the target object). Red dotted lines and the red portion of the x-axis denote the significant time window of the difference smooth. Shaded areas denote confidence interval.

Reference:

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