Unexpected information triggers rapid prediction updating: Evidence from eye movements

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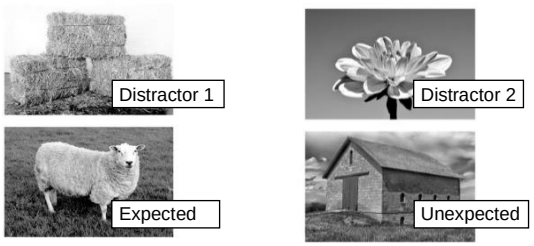
Comprehenders can use rich contextual information to predict upcoming language in real time [1-3], and recent studies have shown that they can also use unexpected information to update their predictions very quickly [4, 5]. A recent study examined listeners' sensitivity to cues that are inconsistent with their predictions and found that Mandarin Chinese listeners were able to rapidly redirect their eye gaze towards a previously unexpected object upon hearing a prediction-inconsistent nominal classifier [5]. In the present study, we extended these findings to English using measure words (MW; e.g., "pile" in "a pile of books"). Unlike classifiers in Mandarin Chinese, MWs are not obligatory for nouns in English, and therefore, allow us to test whether comprehenders can quickly revise their predictions even when the relevant cue is not routinely present in the language. Our results extend earlier findings [5] and suggest that English listeners can rapidly use an unexpected MW to revise their noun predictions.

Method: Adopting the same experimental design as [5], we fully crossed the predictability of noun (expected vs. unexpected; measured by cloze probability) and measure word type (specific vs. general) in 24 items. Specific MWs delimit objects with certain features (e.g., *a cup of*, *a herd of*), whereas general MWs are compatible with a much wider range of objects (e.g., *a bunch of*, *a number of*) [6]. Participants (n=60) were presented with pictures of four objects on the screen in each trial (expected and unexpected objects along with two distractors; Fig.1), and we tracked their eye movements as they listened to sentences like (1).

(1) In the barn at the back of the field, the shepherd was keeping a ……
(a) herd/roomful of recently stolen sheep. *(Expected noun – Specific/General MW)*
(b) pile/roomful of recently stolen hay. *(Unexpected noun – Specific/General MW)*

Results: Mixed-effects logistic regressions showed that participants were more likely to look at the expected object than the unexpected object in the pre-MW and MW window (pre-MW: $p < 0.001$; MW: $p < 0.001$), showing a clear effect of noun predictability. In the post-MW adjective window, an additional significant effect of MW type was found (predictability: $\beta = 0.795$, $p = 0.001$; MW type: $\beta = 0.707$, $p < 0.001$), which shows that listeners were more likely to look towards the target after hearing a specific (than a general) MW regardless of whether the target was initially expected or not. We then focused on the two unexpected conditions and did a bootstrapping analysis [7] to identify the time point at which the proportion of looks to the target diverged upon hearing a specific vs. general MW. The mean onset of divergence in the bootstrap distribution is 608 ms after MW onset (95% CI = [520, 700], Fig. 3). Given that noun onset was on average 1199 ms after MW onset, these results showed that listeners were able to revise their predictions upon encountering a prediction-inconsistent MW before they heard the noun. To investigate whether English speakers were slower than Chinese speakers when using the unexpected cues, we reanalysed the original data from [5] and found that the mean onset of divergence is 542 ms (95% CI = [480, 600], Fig. 3). Although the mean onset of divergence is numerically earlier among the Chinese speakers than the English speakers, the difference between groups was not significant when compared to a bootstrapped null distribution by randomly shuffling the group labels ($p = 0.106$). This is consistent with the pattern we find in participants' first switch times from non-target to target upon hearing a specific classifier/MW. Chinese speakers switched their fixations a bit earlier than English speakers, but the difference was not significant ($t(58) = -0.94$, $p = 0.353$; Fig. 4).

Conclusion: Results are consistent with the effect first reported in Mandarin Chinese [5], providing further evidence that comprehenders can rapidly update their predictions in response to unexpected incoming information.



(1) In the barn at the back of the field, the shepherd was keeping a ……
(a) herd/roomful of recently stolen sheep. *(Expected – Specific/General)*
(b) pile/roomful of recently stolen hay. *(Unexpected – Specific/General)*

Figure 1. Sample material

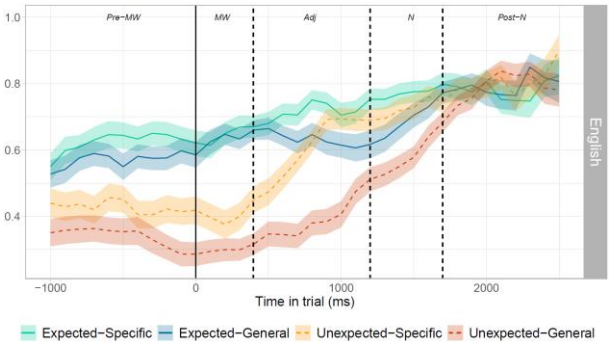


Figure 2. Proportion of looks to the target object time-locked to the onset of the MW (L1 English)

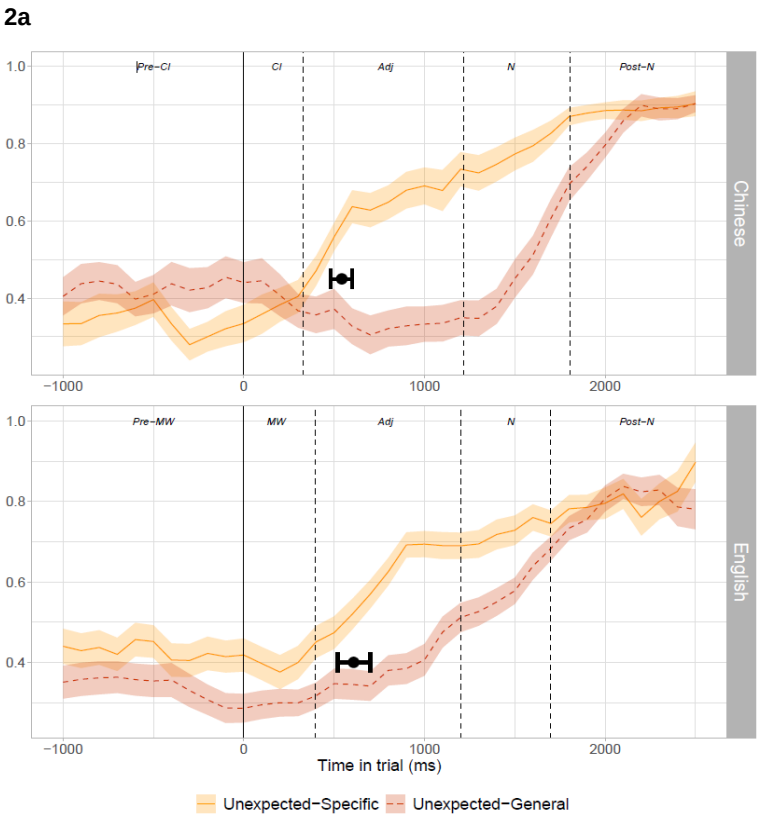


Figure 3. (a) Average proportion of looks to the target in unexpected conditions (time-locked to CI/MW onset). (b) Bootstrap distribution of divergence points, where black points with error bars represent mean divergence points and 95% CIs. Dotted vertical lines represent the divergence points in the original data.

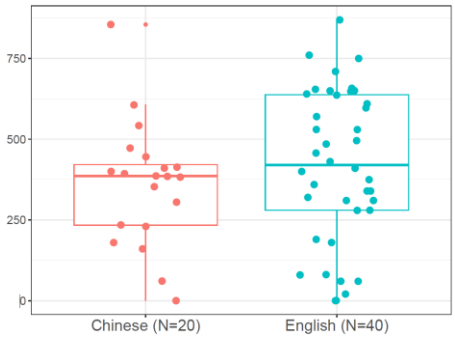


Figure 4. First switch times from non-target to target in the Unexpected N - Specific CI/MW condition. Only included participants who fixated on the non-target 100 ms before CI/MW onset.

Reference. [1] Kamide, 2008. *Language and Linguistics Compass*. [2] Kutas et al., 2011. *Predictions in the brain: Using our past to generate a future* [3] Pickering & Gambi, 2018. *Psychological Bulletin*. [4] Szewczyk & Wodniecka, 2020. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. [5] Chow & Chen, 2020. *Language, Cognition and Neuroscience*. [6] Klein et al., 2012. *Oxford Studies in Theoretical Linguistics.* [7] Stone et al., 2021. *Bilingualism: Language and Cognition*.