Unifying memory retrieval and prediction in sentence comprehension: a cue-based computational model

Elise Oltrogge[a], João Veríssimo[b], Umesh Patil[c] and Sol Lago[a]
[a]Goethe University Frankfurt, [b]University of Lisbon, [c]t2k GmbH

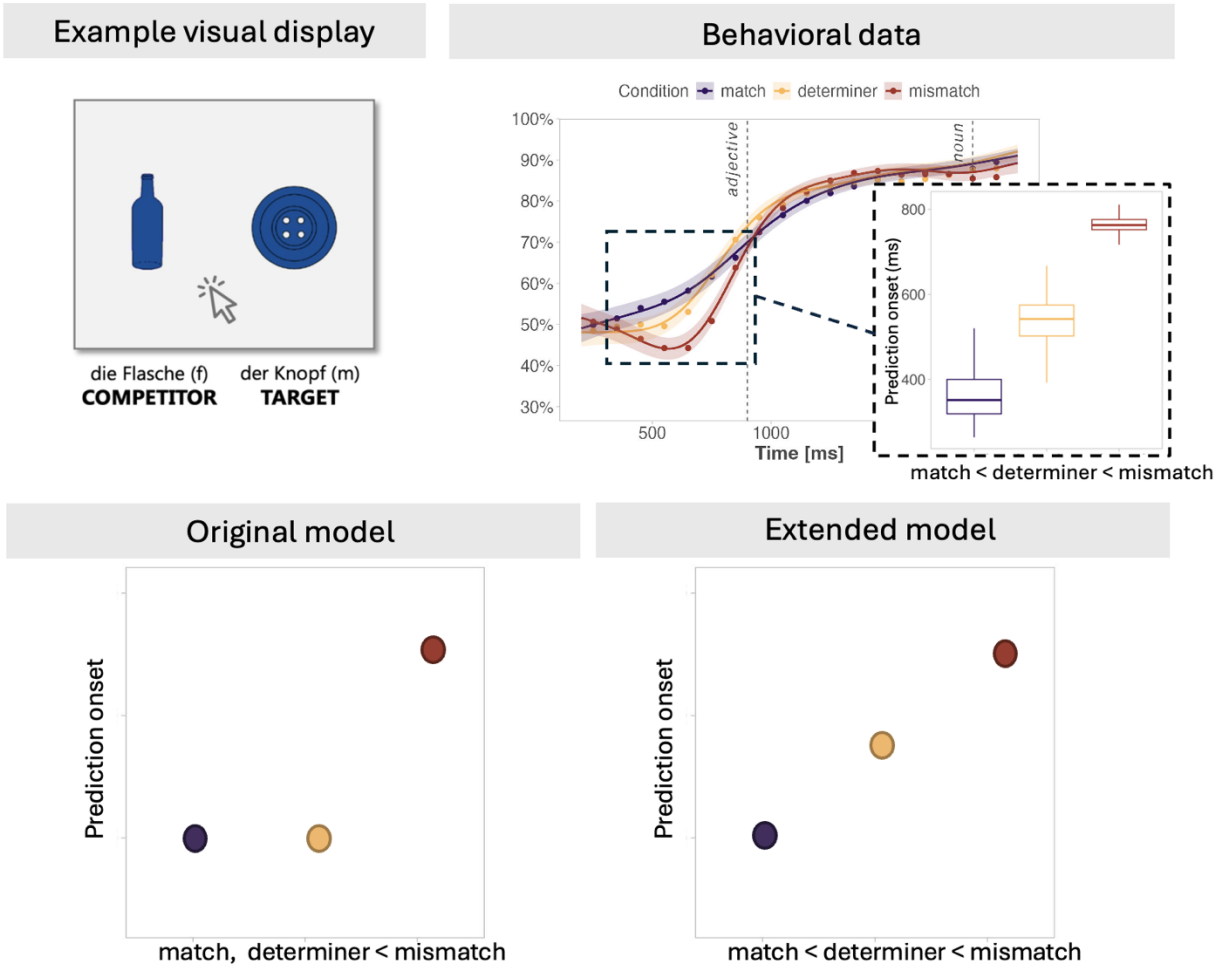
Recent accounts propose that prediction can be conceptualized as a type of memory retrieval, such that both processes rely on a cue-based architecture with a shared memory store [1,2]. A computational model of this proposal [2] explains the comprehension of German possessive pronouns, which encode antecedent gender and have a suffix agreeing with the possessee, triggering both retrieval and prediction processes (Fig. 1). In this model, predictions share a memory store with other cognitive processes, such as antecedent retrieval, and must be retrieved during predictive processing. However, this model was built for pre-existing data and remains untested on novel cases. We applied it to a new construction replacing the possessive pronoun with an indefinite determiner like "a". This preserved prediction—as German determiners agree in gender with a following noun—while removing antecedent retrieval—as indefinite determiners, unlike pronouns, do not presuppose but rather introduce a new discourse referent. We evaluated the model predictions by running a visual world eye-tracking experiment. The results replicated previous findings with possessive pronouns [3] but did not match the model predictions for determiners. Thus, we extended the model to introduce a process to capture the creation of new discourse referents. This extension aligns better with the human data and provides an exciting way to integrate discourse representations into cue-based retrieval models of sentence processing.

Methods. In the visual world experiment, 97 native German participants viewed displays with two objects while hearing instructions in three experimental conditions. In the first two conditions, the instruction contained a possessive pronoun whose antecedent matched or mismatched in gender with the target noun (Fig. 1). In the third condition, the pronoun was replaced with an indefinite determiner. In all conditions, the suffix of the pronoun/determiner agreed in gender with the target noun, allowing for its prediction. The onset of the predictive effect (i.e., the emergence of a target-over-competitor looking preference after the pronoun/determiner onset) was diagnosed in each condition using a GAMM-based method [4]. The cue-based retrieval model used to generate predictions was taken from [2].

Results and discussion. The computational model from [2] predicted a 2-way split: an earlier prediction onset in the match condition vs. the mismatch and determiner conditions (Fig. 2). By contrast, the prediction effect in the human data showed a 3-way split: an early onset in the match condition, followed by the indefinite determiner condition, and finally the mismatch condition. To explain the delay in the determiner condition our extended model assumed an additional processing step at the determiner. This was motivated by findings that indefinite determiners elicit a processing cost, either due to the additional cognitive resources involved in creating a new discourse referent [5] or to the implementation of a verification procedure involved in computing an anti-uniqueness presupposition [6]. The extended model predicted a 3-way split like the one shown by the human data: match>determiner>mismatch. Overall, the combined experimental and computational results show that the cue-based retrieval framework provides a useful way to formalize the cognitive computations underlying prediction and their interaction with retrieval.

Figure 1. Example item set in the three experimental conditions tested in the visual world experiment (96 items, 32 trials p/condition p/participant).

Figure 2. Top panel: sample visual display and results of the visual world experiment, with estimated prediction onsets by condition. Vertical bars show the median and the boxplots the first and third quartile of the prediction onsets. Bottom panel: predictions of the original computational model from [3] and of our extended model.



References. [1] Chow et al. (2016) *Lang. Cogn. Neurosci.* [2] Patil & Lago (2021) *Proceedings of the 19th International Conference on Cognitive Modeling* [3] Stone et al. (2021) *Lang. Learn*. [4] Veríssimo & Lago (2023) *AMLaP 2023* [5] Kirsten et al. (2014) *Lang. Cogn. Neurosci.* [6] Bade & Schwarz (2019) *Proceedings of the Annual Meeting of the Cognitive Science Society*