

## Testing a dual-process model of predictive language processing

Jan Engelen (Tilburg Center for Cognition and Communication, Tilburg University)

Marleen Velthuis (Tilburg School of Humanities and Digital Sciences, Tilburg University)

Jelmer Pieterse (Tilburg School of Humanities and Digital Sciences, Tilburg University)

J.A.A.Engelen@tilburguniversity.edu

There is extensive evidence that language comprehension involves prediction at various levels of representation (e.g., Kuperberg & Jaeger, 2015). Recently, a dual-mechanism account has been proposed that distinguishes between prediction-by-production and prediction-by-association (Pickering & Gambi, 2019). Prediction-by-production refers to the predictive activation of semantic, syntactic, and phonological representations by covertly simulating the speaker's utterance, deriving the speaker's intention, and then running that intention through one's own production system. Using this mechanism allows for sophisticated predictions, but it is also resource-intensive and time-consuming. Prediction-by-production, then, is presumably an optional process which is most likely to succeed when speech is presented at a relatively slow rate (Huettig & Guerra, 2019) and when the listener is not under a heavy cognitive load (Ito et al., 2018). By contrast, prediction-by-association refers to the automatic spreading of activation from representations activated by the linguistic input to semantically and phonologically related representations. This mechanism, which does not allow for sophisticated predictions, is assumed to work quickly and virtually resource-free.

While many experimental studies have yielded data that are consistent with one of the two mechanisms (e.g., Kukona et al., 2011), or data that could be explained by both mechanisms equally well (e.g., Altmann & Kamide, 1999; see analysis in Pickering & Gambi, 2019), we know of no work that has tested the contributions of both mechanisms within a single task, within the same participants, and with the same stimuli. Such work would provide strong evidence for the dual-mechanism account. In this study, we aim to fill this gap by testing the contributions of the two prediction mechanisms in two visual-world eye-tracking experiments.

In Experiment 1, participants ( $N = 26$ ) were presented with 36 spoken Dutch sentences of the form "The [Noun-1] is looking at/for [the<sub>common</sub>/the<sub>neuter</sub>] depicted [Noun-2]", while they viewed an array of line drawings containing Noun-2 and three unrelated distractors. Figure 1 shows a sample experimental display. In half of the sentences, there was a strong semantic association between Noun-1 and Noun-2 (e.g., hunter-deer), whereas in the other half of the sentences Noun-1 was equally weakly related to Noun-2 and the three distractor objects. When present, this semantic cue should activate the prediction-by-association mechanism and trigger anticipatory looks toward the target object. In addition, all sentences contained a gender-marked determiner (either "de" or "het") that was congruent with the target object but not with the distractor objects (see Huettig & Janse, 2016). For listeners to derive a prediction from this syntactic cue, they cannot rely on semantic or associative priming and need to use their production system. During half of the trials, participants were hindered in using their production system by having them perform a concurrent verbal memory task (i.e., remembering a string of five random digits). The hypothesis that follows from the dual-process model is that under concurrent verbal memory load, anticipatory looks based on the syntactic cue will be reduced, while anticipatory looks based on the semantic cue will not be affected.

The preliminary results (full statistical analyses are currently being conducted, see <https://aspredicted.org/sy9v9.pdf>) are shown in Figure 2. The left panel shows the target fixation proportions around the onset of Noun-1. When Noun-1 was semantically related to the target, there was an increase in target fixations after 500 ms relative to when Noun-1 was semantically unrelated. The memory task appears to delay, but not reduce these anticipatory fixations. The right panel shows the target fixations (for trials with a semantically unrelated Noun-1 only) around the onset of the determiner. There was no increase in target fixations in this time window, suggesting that listeners did not utilize this cue for making anticipatory eye movements, regardless of memory load (cf. Huettig & Guerra, 2019; Huettig & Janse, 2016).

Data collection for Experiment 2 ( $N = 30$ ), involving the superimposition of babble noise as an alternative means to induce processing difficulty, has been temporarily suspended because of difficulty in recruiting participants due to Covid-19 related restrictions.

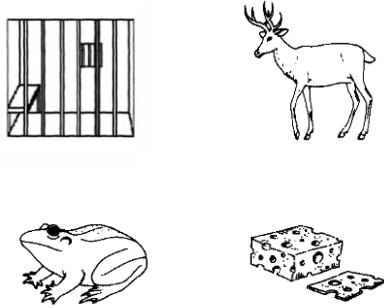


Figure 1. Sample display. After a 4000 ms preview, participants heard either “The hunter is looking for the depicted deer” or “The man is looking for the depicted deer”. “Deer” (“hert” in Dutch) is a neuter gender noun, preceded by the article “het”, whereas the other items are common gender nouns, preceded by the article “de”.

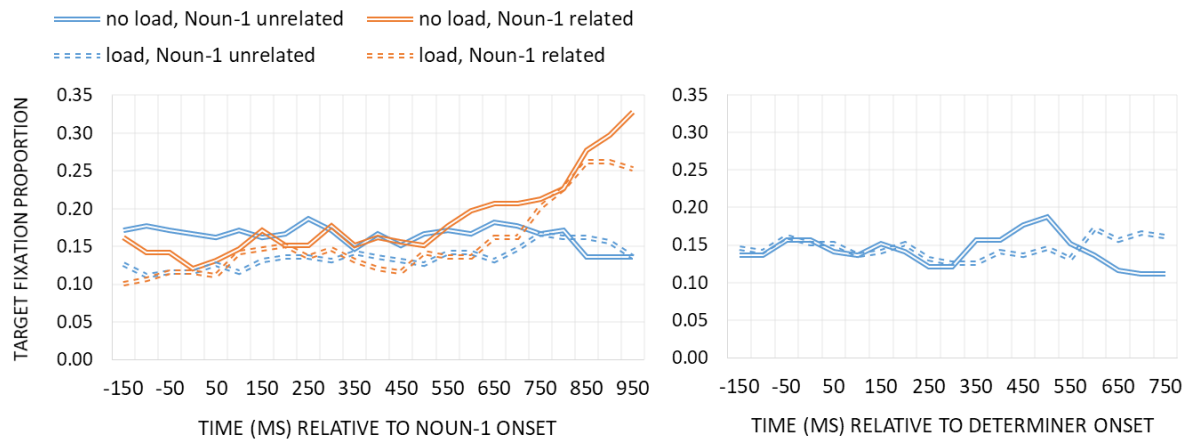


Figure 2. Fixation proportions across experimental conditions for 50 ms time bins around Noun-1 onset (left panel) and pre-Noun-2 determiner onset (right panel).

## References

- Altmann, G. T., & Kamide, Y. (1999). Incremental interpretation at verbs: Restricting the domain of subsequent reference. *Cognition*, 73(3), 247-264.
- Huettig, F., & Guerra, E. (2019). Effects of speech rate, preview time of visual context, and participant instructions reveal strong limits on prediction in language processing. *Brain Research*, 1706, 196-208.
- Huettig, F., & Janse, E. (2016). Individual differences in working memory and processing speed predict anticipatory spoken language processing in the visual world. *Language, Cognition and Neuroscience*, 31(1), 80-93.
- Ito, A., Corley, M., & Pickering, M. J. (2018). A cognitive load delays predictive eye movements similarly during L1 and L2 comprehension. *Bilingualism: Language and Cognition*, 21(2), 251-264.
- Kukona, A., Fang, S.-Y., Aicher, K. A., Chen, H., & Magnuson, J. S. (2011). The time course of anticipatory constraint integration. *Cognition*, 119(1), 23-42.
- Kuperberg, G. R., & Jaeger, T. F. (2016). What do we mean by prediction in language comprehension?. *Language, Cognition and Neuroscience*, 31(1), 32-59.
- Pickering, M. J., & Gambi, C. (2018). Predicting while comprehending language: A theory and review. *Psychological Bulletin*, 144(10), 1002.