Prosodic Entrainment Influences Syntactic Phrase Generation

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Speech processing is subserved by cyclic electrophysiological activity, so-called neural oscillations. Oscillations within the delta band (i.e., < 4 Hz) are thought to synchronize or *entrain* to the rhythm of intonational phrase boundaries (IPBs; for review, see Meyer, 2018). By means of entrainment, oscillations inherit the rhythm of an acoustic stimulation to persist after stimulation offset (e.g., Kösem et al., 2018).

In addition to synchronizing to IPBs, oscillations were recently found to subserve the internal segmentation of speech into syntactic phrases independently of IPBs (Meyer et al., 2017). Our study aimed at further supporting the role of neural oscillations in the generation of syntactic phrases. Specifically, we tested whether prosodic entrainment can trigger the perception of an IPB in an upcoming visual sentence, leading to the termination of a syntactic phrase in spite of the absence of an IPB.

The online experiment was run on 80 participants via the *Gorilla* framework. Each trial started with one of two prosodic contours, repeated three times to induce entrainment. The contour was followed by word-by-word RSVP of a target sentence; presentation of the two sentence-final words was self-paced. Natural contours for entrainment were obtained by filtering the visual target sentences after synthesizing them with a deep-learning-based TTS. Target 2-clause sentences involved a coordination ambiguity such as *Jim saw Tom and John laughed.* (Hoeks et al., 2002). Target 1-clause sentences (e.g.*, Jim saw Tom and John.)* were used in addition. Of the two types of prosodic contours, the *slow* condition matched the duration of *Jim saw Tom and John*, aimed at driving participants up the garden path in 2-clause sentences. In contrast, the *fast* condition matched the duration of *Jim saw Tom*, aimed at avoiding the garden-path. For 1-clause sentences, correct syntactic structures were expected in case of *slow* entrainment, but incorrect ones in case of *fast* entrainment (Figure 1).

Syntactic phrase generation was inferred from reading times to the third noun and the sentence-final verb, as well as from reaction times to correctly answered comprehension questions. Statistical analysis was based on systematic comparison of mixed linear models. We hypothesized longer reaction times on comprehension questions following 2-clause sentences in the *slow* condition, as well as longer self-paced reading times at the sentence-final verb. Both would show a garden-path effect elicited by prosody entrainment.

Reading times (Figure 2) did not show the hypothesized garden-path effect at the verb. Instead, readers were found to selectively speed up on the third noun under *slow* entrainment for both 1– and 2-clause sentences. Reaction times to comprehension questions were generally slower for 1-clause sentences. This suggests that participants were surprised when sentences did not end with a verb, likely assuming the general option of a sentence-final verb from the experimental procedure. In addition, a cross-over interaction was obtained, with reaction times to 1-clause sentences increasing under *slow* entrainment and reaction times to 2-clause sentences increasing under *fast* entrainment.

We interpret this pattern as evidence that *slow* entrainment strengthened participants' temporal prediction of a 2-clause (i.e., long) sentence. This interpretation is corroborated by the speedup at the comprehension question for the 2-clause sentence (i.e., when the assumed prediction of a 2-clause sentence was correct) and the slowdown for the 1-clause sentence (i.e., when this prediction was incorrect). Importantly, this result argues against an alternative explanation in terms of prosodic priming, which would have predicted a garden-path effect both at the verb and in comprehension questions. Prosodic entrainment thus affects downstream syntactic phrase generation in a predictive fashion. Via oscillatory entrainment, IPBs may not only trigger the termination of syntactic phrases, but also enable listeners to predict the duration of the upcoming syntactic material.

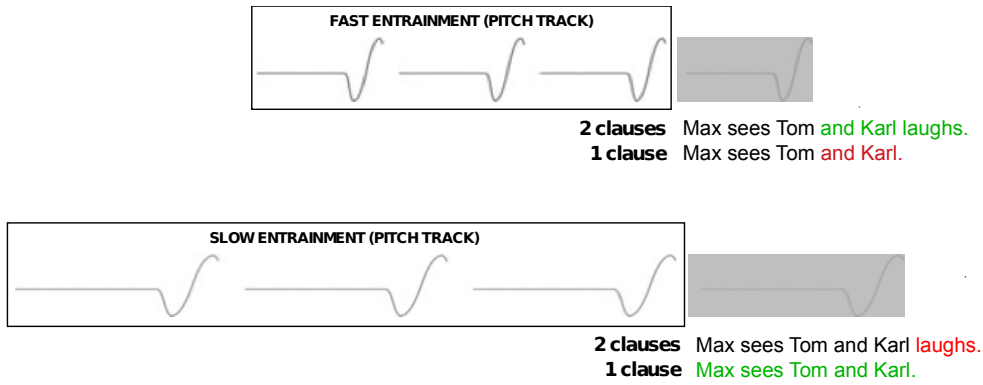

Figure 1. Experimental paradigm. Prosodic contour repeated 3 times to induce entrainment, followed by time-matched RSVP presentation of the sentence. Short contour (fast entrainment) induces correct chunking of 2-clause sentence, but incorrect in case of 1 clause. Long contour, on the contrary, induces correct chunking of 1-clause sentence, but incorrect in case of 2 clauses.

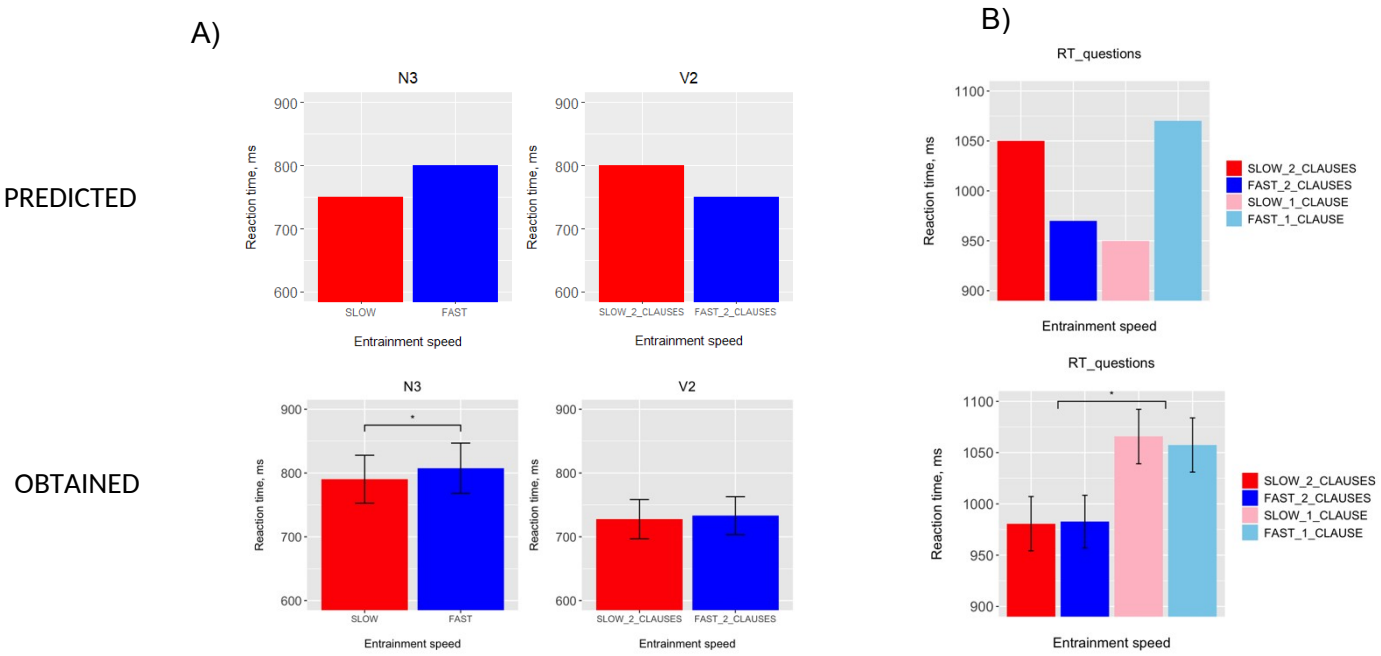

Figure 2. Predicted and obtained results. A) Self-paced reading. Speed-up for the 3rd noun (N3) in the slow condition, possibly due to increased expectedness. B) Comprehension questions. 1-clause sentences are generally harder to process and are even harder under slow entrainment, while 2-clause sentences are harder under fast entrainment.

References:

- Kösem, A., Bosker, H. R., Takashima, A., Meyer, A., Jensen, O., & Hagoort, P. (2018). Neural Entrainment Determines the Words We Hear. *Current Biology, 28* (18), 28672875.e3. https://doi.org/10.1016/j.cub.2018.07.023
- Meyer, L. (2018). The neural oscillations of speech processing and language comprehension: state of the art and emerging mechanisms. European *Journal of Neuroscience, 48* (7), 26092621. https://doi.org/10.1111/ejn.13748