

Prediction and integration of discourse-level meaning are functionally related

The relation of prediction and language processing have recently received increasing attention in psycholinguistics [1, 2], with prediction being investigated in semantics and discourse level pragmatics [3]. To date, predictive processing has mainly been investigated indirectly, with critical measures being taken *after* the critical language input had been presented. Especially in EEG studies, ERPs observed after the critical input have been compared between more vs. less predictable conditions [4]. If these post-word differences between conditions are effects of prediction, i.e., of processes executed *before* the presentation of the critical linguistic material, then (i) the effects of these processes should already be observable while predictions are generated, and (ii) the effects before and after the critical words should be found to be related.

In the present study we investigate the processes of discourse level prediction and their relation to language input processing. We visually presented short discourses in German including conditional sentences containing either the conditional connective *if* or *only if*. Within the presented discourses, the conditional sentences with these different connectives allowed for more or less predictable discourse continuations. Consider the following example:

- Sentence 1: *Leon besuchte seine Eltern und dachte sich:*
(Leon visited his parents and thought:)
- Sentence 2: **Wenn / Nur wenn** die Blumensträuse hübsch sind, bringe ich einen mit.
(**If / Only if** the bouquets are pretty, I will take some with me.)
- Sentence 3: *Wie sich zeigte, waren die Blumensträuse nicht hübsch.*
(As became apparent, the bouquets were not pretty.)
- Sentence 4: *Von denen brachte er **einen / keinen** mit und ging weiter.*
(Of those he took **one / none** and went on.)

S1 set the scenario context. The conditional sentence S2 contained either *if* or *only if*. After S3, which, in critical trials, negated the antecedent of the conditional in S2, *only if* discourses allowed for a strong prediction of a negated conditional consequent in S4, while bare *if* discourses did not allow for a strongly constrained prediction [5, 6]. S4 finally either negated the consequent of the conditional in S2, containing the critical quantifier *none*, or confirmed it, containing the quantifier *one*. We thus tested a 2 × 2 design, with two levels of conditional and two levels of discourse continuation, disclosed at and by the critical quantifier.

In Exp. 1 we gained first indirect evidence for the differences in predictability of the discourse conclusion presented in S4 in a self-paced reading study presenting 108 discourses like the exemplified one to 29 participants. We found negated quantifiers to be read significantly faster in discourses with *only if* conditionals than in discourses with bare *if* conditionals (**Fig. 1**).

In order to gain more direct evidence for the effects being due to predictive processing, the target processes need to be observed in situ, i.e. before the critical discourse continuation is presented [7, 8]. Measuring participants' EEG signal, and changing the presentation procedure to even-paced visual presentation, we tested 144 items in 38 subjects in Exp. 2. Analyzing subjects' brain responses across trials before the critical quantifier, we observed a significantly increased Prediction Potential (PP) [9], a slowly building negative brain wave before the critical input, in *only if* scenarios as compared to bare *if* scenarios, indicating that subjects built stronger expectations about the upcoming discourse continuation in *only if* scenarios as compared to *if* scenarios (**Fig. 2A**). This finding supports previous linguistic analyses on the semantics of the two conditional connectives. Additionally, in response to the presentation of the critical quantifier, negative quantifiers (*none*) led to significantly decreased P300 responses in *only if* scenarios as compared to *if* scenarios (**Fig. 2B**). These results match the previous effect observed in reading times in Exp. 1, giving reason to assume that discourse continuations containing negative quantifiers were easier to be integrated into the discourse representation after they were made predictable in *only if* scenarios as compared to bare *if* scenarios.

Notably, in the constraining discourse contexts containing *only if*, where strong PPs were observed, the size of the word-induced P300 component in response to both expected and unexpected discourse continuations was found to be predictable by the size of the PP before the critical word (**Fig. 3**). The greater the PP before the onset of the critical word, the greater the word-induced P300 component in response to unexpected, positive quantifiers, but the smaller the P300 in response to expected, negative quantifiers. In other words, the stronger the expectations generated by participants in the constraining context condition (*only if*), the greater the word-induced processing effort for the integration of the new information in cases where the input was unexpected (*one*), and the smaller the processing effort for word-induced discourse updating when the input matched the expectations (*none*).

This is the first work observing the Prediction Potential for predictions on the discourse level, i.e., triggered by predictions across sentences. We find that the observed Prediction Potential and the word-induced P300 are functionally related. The correlations of prediction effort or commitment before the discourse continuation, as indicated by the Prediction Potential, and the processing effort for integration of the presented discourse continuation, as indicated by the P300, are taken as evidence for a direct link between pre-activation of expected discourse continuations and reduced (or increased) costs of input processing. Our results thus demonstrate that the mental processes of discourse understanding are functionally interconnected with processes of discourse prediction.

Figure 1. Reading times in Experiment 1.

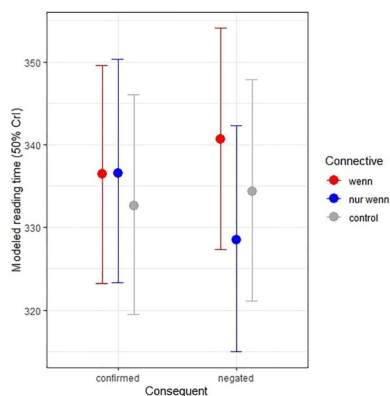


Figure 2. Prediction Potentials (panel A) and word-induced ERPs (panel B) in Experiment 2.

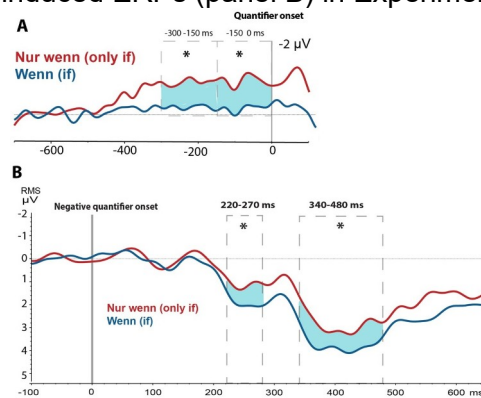
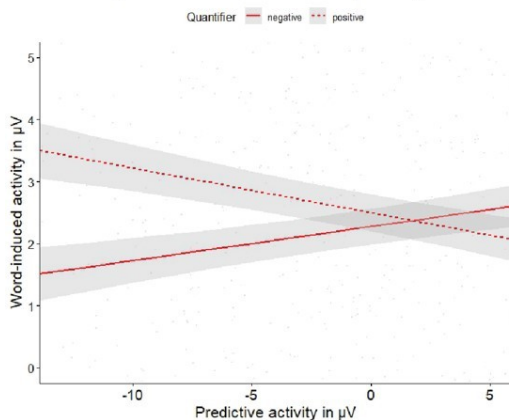


Figure 3. Correlations of Prediction Potential and P300 in *only if* trials in Experiment 2.

Correlation of predictive (-150 - 0 ms) and word-induced (220 - 480 ms) brain activity in *only if* trials



References

- [1] Pickering, M. J., & Garrod, S. (2013). An integrated theory of language production and comprehension. *Beh Brain Sci*.
- [2] Heilbron, M., Armeni, K., Schoffelen, J.-M., Hagoort, P., & de Lange, F. P. (2022). A hierarchy of linguistic predictions during natural language comprehension. *PNAS*.
- [3] Nieuwland, M. S., & Van Berkum, J. J. A. (2006). When Peanuts Fall in Love. *J Cogn Neurosci*.
- [4] Kutas, M., & Federmeier, K. D. (2011). Thirty Years and Counting. *Ann Rev Psych*.
- [5] Herburger, E. (2015). Only if: If only we understood it. *Sinn und Bedeutung*.
- [6] Herburger, E. (2019). Bare conditionals in the red. *Ling Phil*.
- [7] Altmann, G. T. M., & Kamide, Y. (1999). Incremental interpretation at verbs. *Cognition*.
- [8] Pulvermüller, F., & Gisoni, L. (2020). Semantic Prediction in Brain and Mind. *TICS*.
- [9] Gisoni, L., Miller, T. M., & Pulvermüller, F. (2017). Neural Correlates of Semantic Prediction and Resolution in Sentence Processing. *J Neurosci*.