

Implicit causality revision is costly but delayed: Evidence from self-paced reading

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The incremental view of language processing assumes that speakers continuously use incoming linguistic information to update expectations about upcoming words. Thus, when predictions about syntactic and semantic structure of sentences is violated, readers take longer to process information [6]. Whether language processing is incremental at other levels of linguistic analysis remains a topic of considerable debate: at the level of discourse, the evidence for discourse revision being costly has been mixed [2]. In this project, we investigate whether revising causal event structure, a core processing unit of human cognition [1], requires processing effort.

Phenomenon. We focus on the phenomenon of implicit causality [4] and ask how readers handle incoming linguistic information that either matches or contradicts their expectations. Previous studies [5] suggested that encountering unexpected pronouns caused significant slowdowns in reading times in the region immediately following the pronoun. However, other studies found no such effects, and rather argued for clause-final integration costs [3, 7]. We attempt to replicate both of these effects within a single study by building Winograd-schema sentences [9] in German.

Methods. In an online experiment (preregistered), we exploit the gendered status of German nouns to create sentences with either unambiguous (1-a) or ambiguous pronouns (1-b) that either match (congruent) or contradict (incongruent) the implicit causality bias of the verbs.

- (1) a. The mother calmed the son down because *he/she* was *agitated/experienced*.
- b. The father calmed the son down because *he* was *agitated/experienced*.

Each participant ($n = 100$) evaluated 40 NP1, 40 NP2, and 40 neutral verbs (the latter were used as fillers) in a moving-window paradigm, reading sentences chunk-by-chunk. After each trial, they also answered comprehension questions. To estimate the number of participants, we performed Bayesian sample size estimation via simulation and Bayes Factor calculation based on nested model comparison [8]; we additionally calibrated informative priors based on the reanalysis of [5].

Results. We used Bayesian mixed-effects regression for log-normal data, running 20000 iterations, with 4000 for warm-up. For sentences with unambiguous pronouns, our analysis revealed no processing costs immediately on the area containing the pronoun. However, participants possibly took longer to read the segment following the pronoun (Median = 0.2, CrI [0, 0.5], $pd = 99\%$, 7.6% in ROPE; BF estimation with 30000 iterations unstable). On the region revealing the explicit cause (blue line in Figure 1), we observed a reliable interaction between verb bias and congruency ($M = 0.08$, CrI [0.02, 0.13], $pd = 99.6\%$, 0% in ROPE; BF > 1000 in favor of the model containing the interaction). For sentences with ambiguous pronouns, the results were qualitatively similar. We discuss two possible interpretations of the results. On the first interpretation, revising the causal structure of events causes delays in later regions for NP2 but not NP1 verbs. On the second interpretation, it is possible that anaphoric references to the most recent antecedent are processed faster. This would mean that congruent NP2 sentences and incongruent NP1 sentences show fastest processing, as our results suggest.

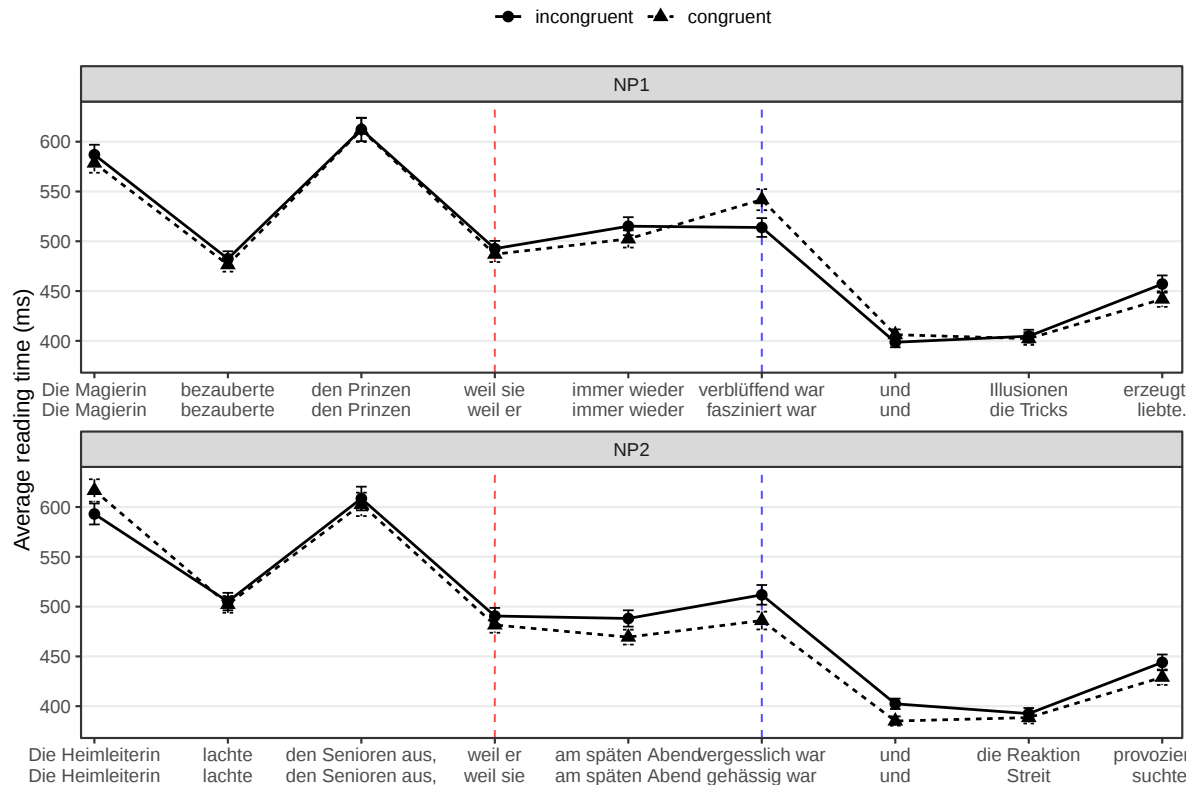


Figure 1: Average reading times for sentences with NP1 and NP2 verbs. Red line: the pronoun region, blue line: the disambiguating adjective region. The upper sentence in each panel shows a congruent pronoun, the lower sentence shows an incongruent pronoun. Translations are provided in (2).

- (2)
- [NP1, congr.] The Sorceress enchanted the prince because she time and again was amazing and created illusions.
 - [NP1, incongr.] The Sorceress enchanted the prince because he time and again was fascinated and loved the tricks.
 - [NP2, congr.] The nursing home director laughed at the elderly man because he had been forgetful late in the evening and prompted her reaction.
 - [NP2, incongr.] The nursing home director laughed at the elderly man because she was being spiteful late in the evening and looking for a fight.

References:

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