Constraints on Word Exchanges During Noisy-Channel Inference

Markus Bader (University Frankfurt) & Michael Meng (Merseburg University)

bader@em.uni-frankfurt.de

According to the Noisy Channel Model of Gibson et al. (2013), communication can succeed even when the input is corrupted because comprehenders rationally infer the speaker's intended meaning based on the a-priori probability of the literal interpretation and the probability that the input has been corrupted by noise. A major point of debate concerns what kind of corruptions comprehenders take into account. Whereas there is consensus that insertions and deletions are considered a possible source of noise, the status of word exchanges is less clear (Poppels and Levy, 2016).

To test whether and under which conditions word exchanges can be observed, we ran four online experiments on processing three types of simple German sentences: subject-before-object sentences (SO), object-before-subject sentences (OS), and passive sentences (see (1)). SO, OS and passive sentences provide an interesting test case because implausible sentences can be "repaired" by exchanging function words or by exchanging nouns (see (2) for SO). As in Gibson et al. (2013), sentences were presented in full along with a yes-no question to probe interpretation. Exp. 1 (N=48) tested plausible and implausible SO and OS sentences and varied whether a word exchange would cross a main verb or an auxiliary. Exp. 2 (N=74) included plausible and implausible passive sentences in addition to SO and OS sentences. Exp. 3 (N=78) tested implausible SO, OS and passive sentences and varied the proportion of implausible sentences in the total stimulus set (high: 50% vs. low: 15%). Exp. 4 (N=36) tested implausible SO, OS and passive sentences but required explicit corrections of implausible sentences in addition to answering yes-no questions.

Results are shown in Figure 1. The results were analysed using Baysian mixed-effect modeling. We consistently found that implausible SO and passive sentences elicit few non-literal interpretations whereas the rate of non-literal interpretations is high for implausible OS sentences. This holds regardless of whether word exchanges have to cross a main verb or an auxiliary (Exp. 1) and, as predicted by the Noisy Channel Model, is more pronounced if the overall proportion of implausible sentences is low (Exp. 3). Thus, exchanges of function words of the same syntactic category are considered, but not noun exchanges. Moreover, word exchanges are considered only when resulting in a more likely syntactic structure, supporting the idea that comprehenders' noise model is structure-sensitive (Poppels and Levy, 2016). This prevents function word exchanges to be applied to SO and passive sentences. Finally, Exp. 4 showed that comprehenders use noun exchanges to a much higher extent when asked to provide explicit corrections, in line with Ryskin et al. (2018). This suggests that constraints on word exchanges depend on whether or not sentences are corrected consciously.
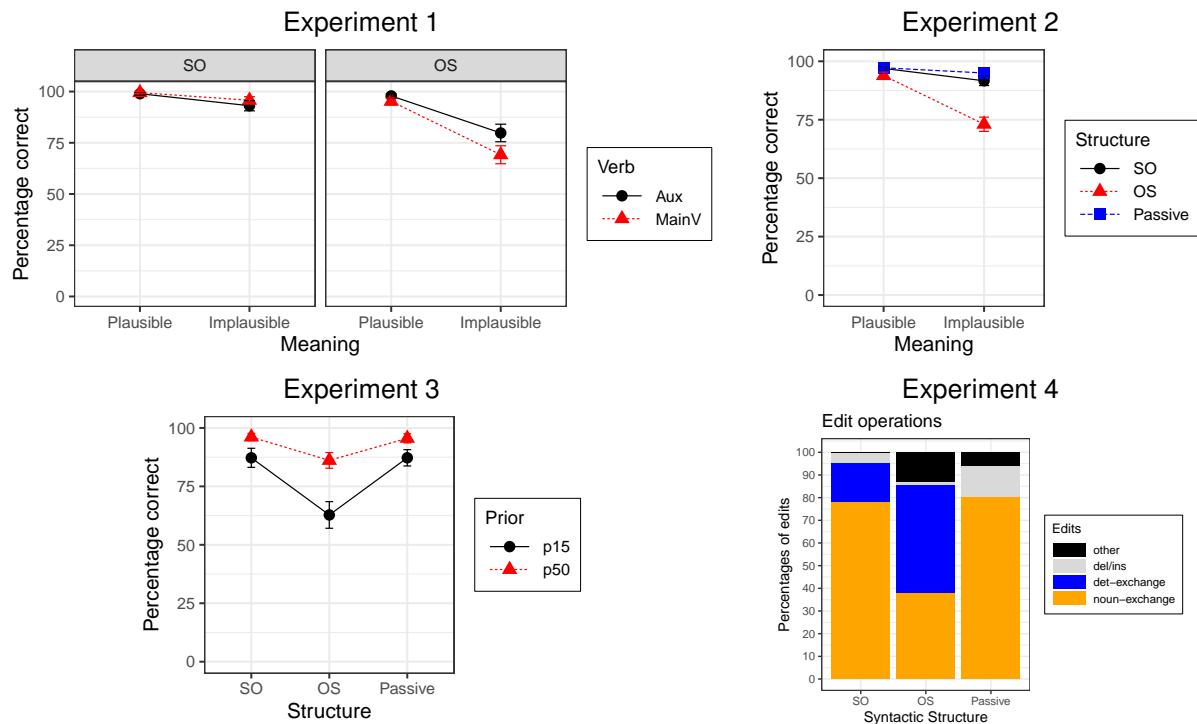
Figure 1: Percentages of correct answers in Exp. 1–3 and distribution of edit operations in Exp. 4.

(1)   Implausible versions of the experimental sentences (plausible versions are obtained by exchanging nouns)

     a.   [SO:] Der   Knochen hat den   Hund gegessen.
             the$_{NOM}$ bone   has the$_{ACC}$ dog   eaten

     b.   [OS:] Den   Hund hat der   Knochen gegessen.
             the$_{ACC}$ dog   has the$_{NOM}$ bone   eaten

     c.   [Passive:] Der   Hund wurde vom   Knochen gegessen.
             the.NOM dog   was   by-the bone   eaten

(2)   [Presented – SO:] Der   Knochen hat den   Hund gegessen.
                    the$_{NOM}$ bone   has the$_{ACC}$ dog   eaten

     a.   [Noun exchange – SO:] Der   **Hund** hat den   **Knochen** gegessen.
                    the$_{NOM}$ dog   has the$_{ACC}$ bone   eaten

     b.   [Det exchange – OS:] **Den**   Knochen hat **der**   Hund gegessen.
                  the$_{ACC}$ bone   has the$_{NOM}$ dog   eaten

References

Gibson, E., Bergen, L., and Piantadosi, S. T. (2013). Rational integration of noisy evidence and prior semantic expectations in sentence interpretation. *Proceedings of the National Academy of Sciences*, 110(20):8051–8056.

Poppels, T. and Levy, R. P. (2016). Structure-sensitive noise inference: Comprehenders expect exchange errors. In Papafragou, A., Grodner, D., Mirman, D., and Trueswell, J. C., editors, *Proceedingsof the 38th Annual Meeting of the Cognitive Science Society*, pages 378–383, Austin, TX. Cognitive Science Society.

Ryskin, R., Futrell, R., Kiran, S., and Gibson, E. (2018). Comprehenders model the nature of noise in the environment. *Cognition*, 181:141–150.