Why do we elide? Testing a game-theoretic model of fragment usage

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Background: Theoretical accounts of fragments and other ellipses have mostly focused on their syntax, but to a lesser extent, on how speakers ultimately choose between a sentence (1a) and the corresponding fragment (1b). Previous work found processing difficulty effects (e.g. Arregui et al., 2006; Lemke, 2021), however, speakers might avoid ellipsis not only if it is hard to process, but also if the listener is likely to (effortlessly) retrieve an unintended meaning (1c). I hypothesize that speakers trade-off this risk of misunderstanding and the lower production cost of fragments. The trade-off is modeled as a signaling game informed by crowd-sourced production data, and its predictions evaluated with pseudo-interactive production experiments.
Model: Following the approach to implicature by Franke (2009), the speaker sends an utterance $u \in U$ to communicate their message $m \in M$ and the listener has to infer which m the speaker had in mind (See Fig. 1). Shorter utterances have a lower cost c. The $m \in M$ differ in prior probability Pr(M) and the listener assigns the most likely m_{max} to a fragment u_{frag}. The speaker chooses u_{frag} if the lower c outweighs the risk of u_{frag} not being interpreted as m_{max}.
Experiments: Empirically plausible approximations to M, U, Pr(m) and $[[u]]_m$ were obtained from crowd-sourced production data from Lemke (2021) and the model predictions evaluated with 3 web-based experiments (60 subjects each) (See Fig. 2). The participant takes the speaker role, while the listener role is simulated according to model predictions. In each trial (n = 15), the participant reads a context story, 3 messages that could be communicated and 6 utterances. 3 of the utterances are sentences corresponding to the messages. Among the 3 fragments, one is ambiguous between two of the sentences, one unambiguously refers to the third sentence. An explicit cost structure is implemented by a system of virtual coins: sentences (130) are more expensive than fragments (40) and successful communication rewarded with a payoff (100).The 3 experimental conditions differ in the message that the speaker is asked to communicate: (i) the *most likely* (high p(m|u)) message given the ambiguous fragment, (ii) a *less likely* one (low p(m|u)), (iii) the message corresponding to the *unambiguous* fragment. My account predicts a gradual increase of fragment ratio as a function of the fragment's p(m|u).
Results: The data for **Exp. 1** (See Fig. 3) were analyzed with LMMs (Bates et al., 2015), confirming that fragment ratio increases with fragment p(m|u) ($\chi^2 = 16.01, p < 0.001$). However, this does not hold within the subset of ambiguous conditions ($\chi^2 = 16.01, p > 0.5$), so the effect could result from subjects avoiding any ambiguity instead of more fine-grained game-theoretic reasoning. **Exp. 2** addressed this by replacing the low p(m|u) condition by an unambiguous one, making the high p(m|u) and unambiguous conditions fully unambiguous. A comparison to exp. 1 evidences a higher fragment ratio ($|z| = 4.14, p < 0.001$), but there is also a p(m|u) main effect across both studies ($|z| = 8.92, p < 0.001$). **Exp. 3** used a new low p(m|u) condition (not based on the production data), which addresses the possibility that the messages produced by subjects were not unlikely enough. Unlike in exp. 1 and 2, the p(m|u) effect was also significant for the ambiguous conditions only ($|z| = 5.82, p < 0.001$), which provides evidence for game-theoretic reasoning. **Exp. 4** aimed at replicating this with a free production task, where subjects entered their answer into a text field (each word cost 20 coins). This provides a more natural task and allows for other utterance reduction strategies than fragments (e.g. article and object drop). The study found no effect of p(m|u) on fragment ratio, but utterances communicating predictable messages were longer (in words) ($|z| = 2.57, p < 0.05$).
Discussion The utterance selection studies (exp 1–3) confirm the prediction that fragments are used to communicate predictable meanings, which supports the game-theoretic account: Exp. 2 shows the effect cannot be explained by ambiguity avoidance and exp. 3 replicates it even within the ambiguous conditions. This indicates that, at least for fragments, the usage of ellipsis is not only constrained by syntactic and processing constraints but also by pragmatic considerations. Exp. 4 suggests that subjects do not only use fragments, but also other means of reducing utterance length to communicate efficiently.

(1) Passenger approaches conductor at the train station next to a waiting train.

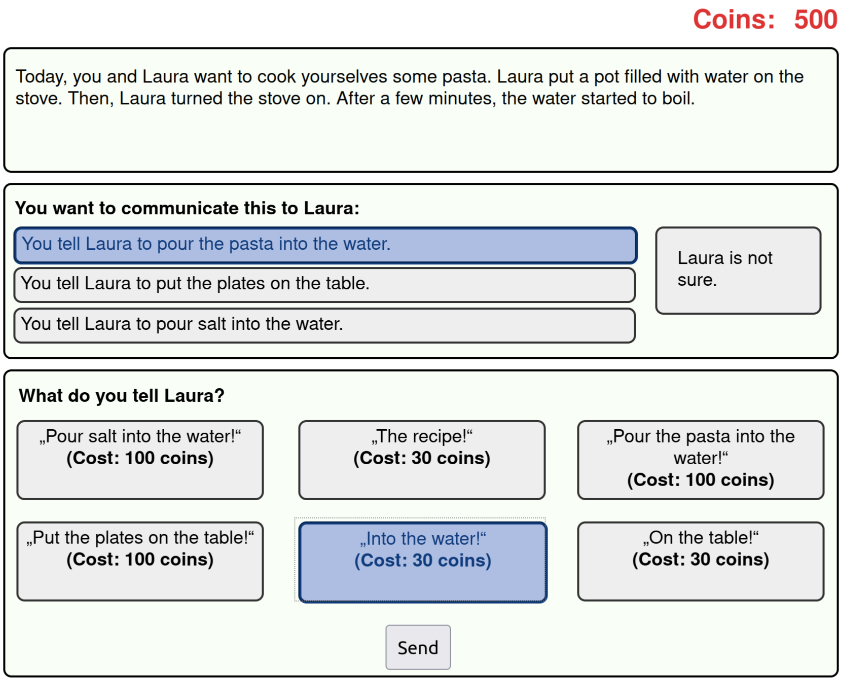
a. Does this one go to Paris? (Sentence)

b. To Paris? (Fragment)

c. Have you ever been to Paris? (Alternative interpretation)

$$L_0(m,u) = \frac{Pr(m) \times [[u]]_m}{\sum_{m'} Pr(m') \times [[u]]_{m'}} \quad (1) \qquad EU_{S1}(u,m) = L_0(m,u) \times payoff - cost \quad (2)$$

Figure 1: The listener reweighs Pr(M) among the messages from which the fragment could have been derived by grammatical omission ($[[u]]_m = 1$). The speaker maximizes their Expected Utility, which depends on the listener behavior, the payoff, and the utterance cost. Since cost and payoff are kept constant within each experiment, I use p(m|u) as a predictor in my analyses.



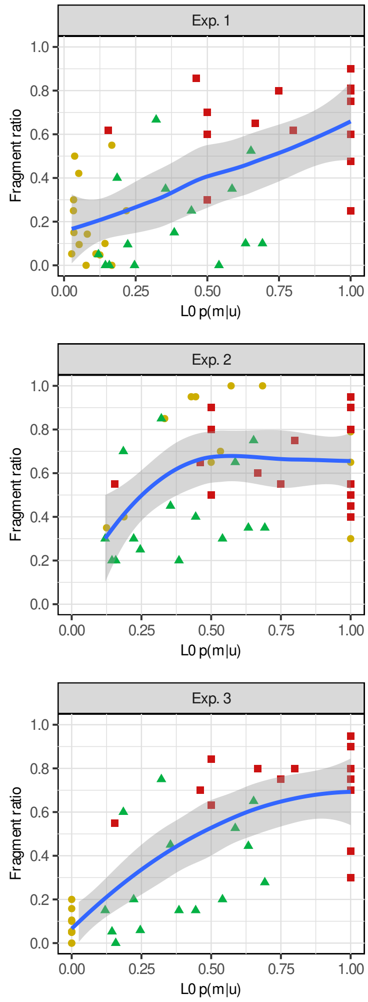


Figure 2: (top) Screenshot of the experiment, which was conducted in German, translated to English for convenience.

Figure 3: (right) Ratio of fragments (errors excluded) by item and condition across the three utterance selection experiments. The low p(m|u) condition is displayed in yellow ●, the high p(m|u) condition in green ▲ and the unambiguous condition in red ■.

References • Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. Journal of Statistical Software, 67 (1), 148. • Frank, M. C., & Goodman, N. D. (2012). Predicting pragmatic reasoning in language games. Science, 336(6084), 998998. • Franke, M. (2009). Signal to act: Game theory in pragmatics (Doctoral dissertation). Uni- versiteit van Amsterdam. • Lemke, R. (2021). Experimental investigations on the syntax and usage of fragments. Language Science Press.