Predicting ellipsis usage with a game-theoretic model informed by production data

Game-theoretic approaches have been increasingly applied in pragmatics. So far most of the evidence supporting them comes from controlled experiments (since Frank and Goodman, 2012) and even though the results should scale up to more complex real life situations, it has not been shown that they do. I explore this with a case study on the usage of elliptical utterances known as fragments (Morgan, 1973). Given an appropriate context (1), the speaker can choose between a sentence (1a) and a fragment (1b) to communicate a message. I hypothesize that this choice depends on a trade-off between the lower production cost of the shorter fragment and the risk of misunderstanding: Fragments are ambiguous, so the listener might infer (1c) instead of (1a).

Model I model the choice between fragments and sentences as a signaling game (Franke, 2009; Frank and Goodman, 2012). 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 for the speaker. The $m \in M$ can differ in prior probability $Pr(M)$ and the listener will assign the most likely m_{max} to a fragment u_{frag}, so the speaker will produce u_{frag} only 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 production data elicited by Lemke (2021). The model predictions generated were evaluated with a series of 4 pseudo-interactive gamified utterance selection experiments (60 subject each, recruited on Prolific) (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. Cost is implemented by a system of virtual coins, sentences (100) are more expensive than fragments (30) and successful communication rewarded with a payoff (120).The three experimental conditions differ in the message that the speaker is asked to communicate: (i) the *most likely* message given the ambiguous fragment, (ii) a *less likely* one, (iii) the message corresponding to the *unambiguous* fragment. My account predicts a gradual increase of fragment ratio as a function of the fragment's $p(m|u)$.

Exp. 1 used the costs described above. The data (See Fig. 3) analysis with logistic mixed effects regressions (Bates et al., 2015) shows that fragment ratio increases with fragment $p(m|u)$ ($|z| = 5.16, p < .05$). This does not hold when considering the ambiguous conditions only ($|z| = .03, p > .9$), so it could result from avoiding ambiguity instead of reasoning about $p(m|u)$.

Exp. 2 tested whether subjects take into account utterance cost by adjusting them to (130/40/100) and the starting balance (300 instead of 500), which should increase the advantage of fragments. A joint analysis with exp. 1 confirms a higher fragment ratio in exp. 2 ($|z| = 2.49, p < 0.05$).

Exp. 3 investigated whether the trend in exp. 1 and 2 results from ambiguity avoidance by replacing the low $p(m|u)$ condition by an unambiguous one. This removed all ambiguity from the experiment. The joint analyis with exp. 2 shows that subjects produced more fragments in exp. 3 ($|z| = 4.14, p < 0.001$), but there is still a $p(m|u)$ main effect ($|z| = 8.92, p < 0.001$).

Exp. 4 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 ($|z| = 5.82, p < 0.001$).

Discussion All experiments support the game-theoretic prediction that fragments are more often used when the risk of misunderstanding is low. Exp. 3 shows the effect cannot be explained by ambiguity avoidance alone and exp. 4 replicates it even within the ambiguous conditions. Exp. 1 and 2 also indicate that speakers consider utterance cost. This extends the evidence for game-theoretic reasoning from tightly controlled experiments to more diverse and realistic situations.

(1) Passenger approaches conductor at the train station and points at a 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.

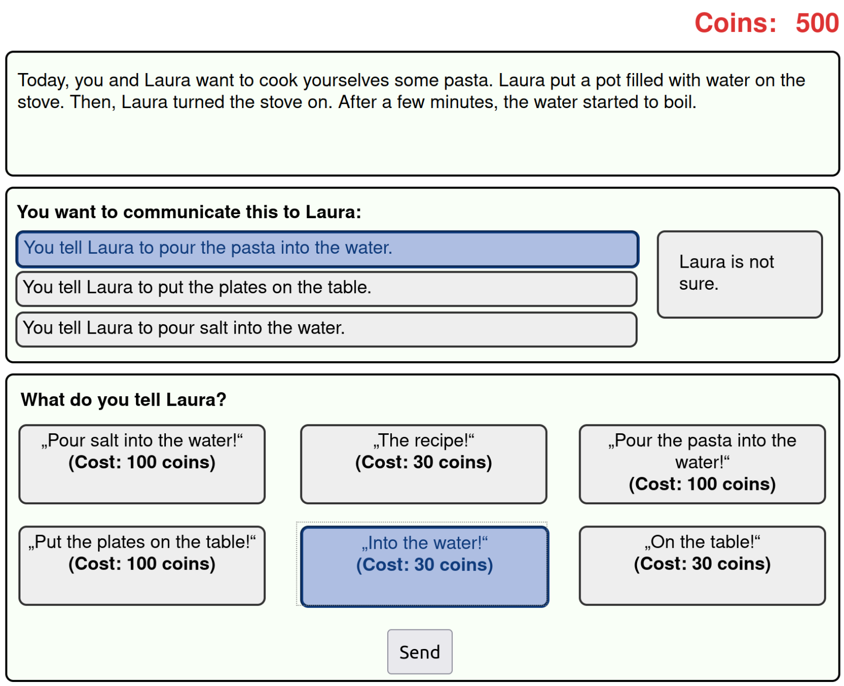
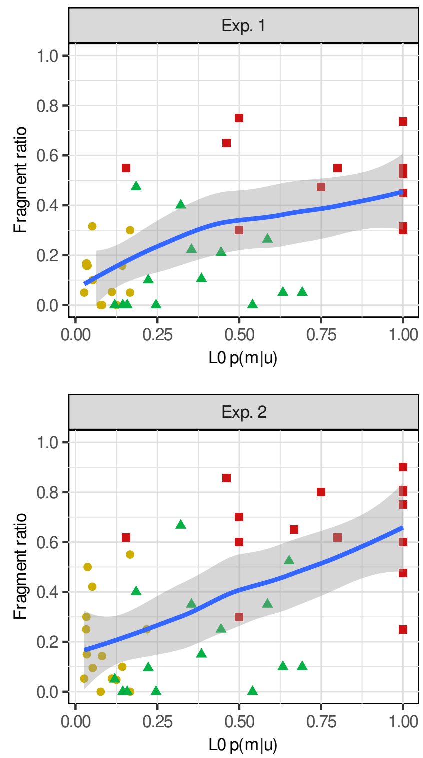


Figure 2 Screenshot of the experiment, which was conducted in German, translated to English for convenience.



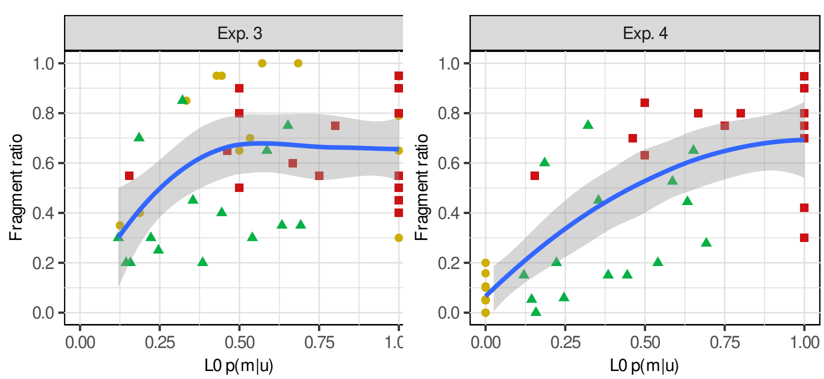


Figure 3 Ratio of fragments (errors excluded) by item and condition across the four experiments. The low $p(m|u)$ condition is diplayed in yellow ●, the high $p(m|u)$ condition in green ▲ and the unambiguous condition in red ■.

Selected references • Frank, M.. & Goodman, N. (2012). Predicting pragmatic reasoning in language games. Science 336(6084). 998–998. • Lemke, R. (2021). Experimental Investigations on the Syntax and Usage of Fragments. Language Science Press. • Morgan, J. (1973). Sentence fragments and the notion 'sentence'. In Kachru, B. et al., editors, Issues in Linguistics. Papers in Honor of Henry and Renée Kahane, 719–751. University of Illinois Press.