The interplay of memory and expectation in Hungarian relative clause processing

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Hungarian subject-extracted (SRC) and object-extracted (ORC) relative clauses both have flexible word order, which allows us to tease apart Memory-based and Expectation-based accounts of relative clause (RC) complexity and processing. In Hungarian, the more frequent SRC and ORC structures have longer filler-gap dependencies, meaning that the predictions of Memory and Expectation diverge. In two self-paced reading experiments, we find that both accounts capture RC processing, but under different conditions. In the absence of context, Expectation prevails; however, in RC-biasing contexts, Memory is supported.

Background. An important case study in the processing of syntactic complexity is the asymmetry we observe between the English SRC (1a) and ORC (1b): ORC is harder to process than SRC.

(1) a. The engineer [$_{RC}$ who _ annoyed the analyst] wrote a report about the project. (SRC)
b. The engineer [$_{RC}$ who the analyst annoyed _] wrote a report about the project. (ORC)

There are two competing classes of accounts. Memory-based accounts generally predict a locality preference – shorter filler-gap dependencies are preferred (Gibson, 1998; Lewis & Vasishth, 2005). Expectation-based accounts attribute greater processing cost to less expected/frequent structures (e.g. surprisal, Hale, 2001; Levy, 2008). Importantly, in English the predictions of both accounts converge, since English SRCs instantiate a shorter filler-gap dependency than ORCs, and they are also more frequent.

Experiment 1: extraction site × locality. Hungarian is particularly suitable for teasing apart these two accounts, because extraction site and locality (i.e. the length of the relevant filler-verb dependency) can be varied independently. SRCs (2) can occur either in a VO (local) or OV (non-local) configuration, while ORCs (3) can occur in VS (local) or SV (non-local). Cf. English SRCs that are VO and ORCs that are SV.

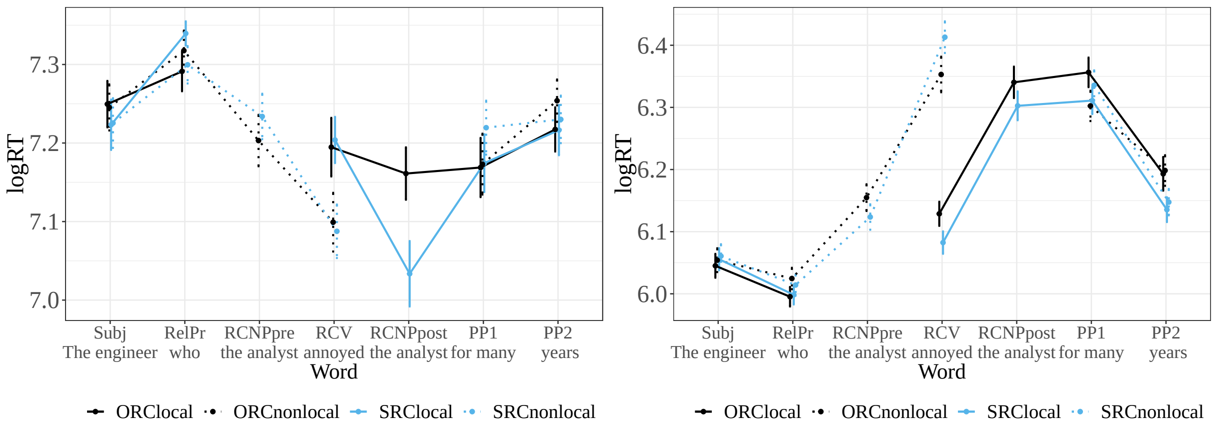
(2) A mérnök, aki {idegesítette az elemzőt} / {az elemzőt idegesítette},...
the engineer.NOM who.NOM {annoyed the analyst.ACC} / {the analyst.ACC annoyed}...
Both: 'The engineer who annoyed the analyst... (wrote a report about the project).'

(3) A mérnök, akit {idegesített az elemző} / {az elemző idegesített},...
the engineer.NOM who.ACC {annoyed the analyst.NOM} / {the analyst.NOM annoyed}...
Both: 'The engineer who the analyst annoyed... (wrote a report about the project).'

81 native Hungarian speakers took part in a self-paced reading experiment testing such sentences (2×2 design, item N=32). A comprehension question followed each sentence. To avoid a confound with event plausibility, nouns (e.g. *engineer*, *analyst*) were counterbalanced to occur both in head NP and RC NP positions.

Predictions. Under the Memory account, word orders supporting **local/shorter filler-verb dependencies would be less costly** (VO, VS) than non-local ones (OV, SV), irrespective of SRC vs. ORC status. To check the predictions of the Expectation account, we carried out corpus searches in the Hungarian National Corpus (Oravecz et al., 2014). For both SRC and ORC, non-local structures (SRC count: 466, ORC: 50) are more frequent than local ones (SRC: 44, ORC: 26). Thus Expectation makes the opposite predictions to Memory: **non-local structures should be easier** to process. This is consistent with the idea that because RCs represent a syntactically constrained context, additional pre-verbal material (in non-local sentences) helps sharpen expectations about the location/identity of the (predicted) verb. Expectation accounts also predict a general advantage for SRCs, since they are overall more frequent than ORCs. Levy et al. (2013), using a similar manipulation in Russian, found a clear reading time advantage for local sentences at the RC Verb. However, in Russian, local structures are also the more frequent ones, whereas in Hungarian they are not. Thus Hungarian better teases apart the predictions of the two competing accounts.

Results and Discussion. Analyses on log-transformed reading times (RTs) revealed that for both SRC and ORC, the RC Verb (*annoyed* in (2, 3), RCV region in Figure (a)) had significantly shorter RTs in the non-local than in the local configurations ($p<.01$). That is, **non-local OV/SV sentences were easier** to process than local VO/VS ones, irrespective of SRC/ORC status (cf. Levy et al., 2013). This provides evidence for Expectation, but not Memory-based accounts. Surprisingly, there was no effect on the rel. pronoun (RelPr, $p=.49$), where case marking disambiguates SRC vs. ORC – even though SRCs are overall more frequent. However, RTs in general were very high on the rel. pronoun, which may be indicative of an RC parse being surprising in general – an idea which is supported by corpus data (0.12%/0.014% probability of tran-



(a) Experiment 1: no context

(b) Experiment 2: biasing context

sitioning to *who*/*whom* after the head NP). To further test this, we introduce RC-biasing contexts in Exp. 2.

Experiment 2: context manipulation. Prior research (i.a. Gibson and Wu, 2013) has shown that context can play a role in RC processing, by e.g. helping to avoid ambiguity with a main clause interpretation. In this experiment, we embedded sentences such as (2, 3) under contexts that promoted a (restrictive) RC interpretation, such as: "Mary is working together with two engineers on a project. She received a report on Sunday, but didn't know which engineer wrote it. She asked her secretary. Her secretary replied:". 67 native speakers of Hungarian participated in the experiment, which was identical to Exp. 1 (four conditions, extraction site $\times$ locality) except for the addition of the context manipulation.

Results and Discussion. In general, context seems to have reduced overall RT on the rel. pronoun, suggesting that our context manipulation successfully led participants to predict an RC parse (compare Figures (a) and (b) at the RelPr region). However, the predicted SRC-ORC difference still does not arise (p=0.76). Additionally (see RCV region in Figure (b)), for both SRC and ORC, the RC Verb had significantly shorter RTs in the local than in the non-local configurations ($p<.001$). That is, **local sentences were easier** to process than non-local ones, irrespective of SRC/ORC status. This is the opposite of the empirical findings of Exp. 1, and thus supports the prediction of Memory, rather than Expectation-based accounts.

Conclusion. Across two self-paced reading experiments, we capitalised on the word order flexibility of Hungarian to investigate competing models of RC processing. While English SRCs always instantiate a more local/shorter filler-gap dependency than ORCs, in Hungarian both SRCs and ORCs can occur in local or non-local configurations. Importantly, the local structures favoured by Memory are the less frequent ones in Hungarian, meaning that the predictions of Expectation diverge – making Hungarian particularly suitable for teasing apart the two accounts. We found a locality effect when participants are already biased towards RC structures: shorter filler-gap dependencies were easier to process (Exp. 2). Otherwise, complexity was dominated by incremental probabilistic update, and the more frequent structures were the ones easier to process (Exp. 1). Thus our results indicate that online probabilistic update and online dependency building are two independent mechanisms, and they dominate to different extents under different circumstances. Specifically, when comprehenders are unsure about the overall structure of the sentence they are hearing, they rely more on probabilistic expectations based on their prior linguistic experience. In the presence of sufficient contextual cues, however, when comprehenders know what general parse they should be expecting, processing is no longer dominated by probabilistic predictions, and that is why a strong memory effect is revealed. In sum, Expectation and Memory are both relevant factors in RC processing, but dominate under different conditions. Another possibility is that the calculated corpus probabilities do not hold in the presence of explicit biasing context – which could suggest different predictions for Expectation for Exp. 2. We are exploring this possibility in a follow-up sentence completion study, where we aim to collect more fine-grained probability estimates under context.

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