Lossy Context Surprisal Predicts Task Differences in Relative Clause Processing

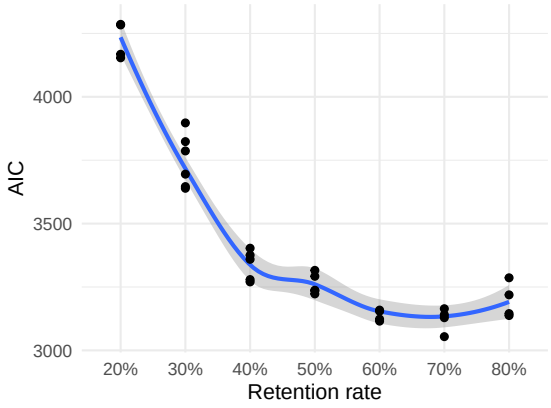
A fundamental goal of computational psycholinguistics is to predict and explain syntactic processing difficulty as manifested in reading times. English comprehenders take longer to read object relative clauses (ORCs), such as “The director that the dancer admired,” compared to equal-length subject relative clauses (SRCs), such as “The director that admired the dancer.” When do readers slow down, and why?

Expectation-based accounts (e.g. surprisal theory; Levy, 2008) predict that readers will slow down at the ORC noun phrase “the dancer.” SRCs are more frequent than ORCs (Roland et al., 2007); therefore, on seeing “The director that,” readers will expect a subject relative verb to follow. Vani et al. (2021) found that participants in a Maze task (Forster et al., 2009) showed the predicted slowdown at the ORC determiner “the.”

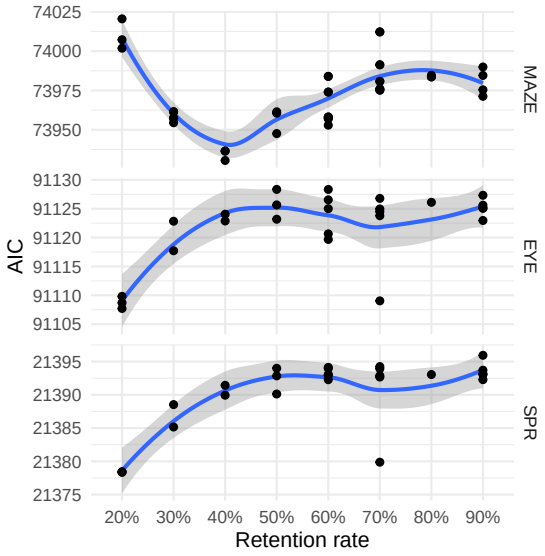
By contrast, memory-based accounts (e.g. Dependency Locality Theory; Gibson et al., 2000) predict that the ORC slowdown should instead appear at the verb “admired,” as readers integrate the dependency to the distant object “director.” This behavioral pattern has been reported in eye-tracking studies (Staub, 2010; Roland et al., 2021).

We argue that these discrepant empirical findings can be explained as task effects: the Maze task imposes higher memory demands, so readers systematically retain more of the preceding sentence context in Maze experiments compared to eye-tracking while reading. We support this account with computational evidence from the Resource-Rational Lossy Context Surprisal model (LCS; Hahn et al., 2022), which conceptually unifies expectation- and memory-based accounts.

We find that manipulating the LCS retention rate captures task-dependent differences observed in reading times (RTs) across experiments. Filler item RTs from the Maze task are best fit with a relatively high retention rate (e.g. 60%; Figure 1a), while lower retention (20%) better predicts eye-tracking RTs (Figure 1b). Using these task-dependent retention rates, LCS correctly predicts critical RT patterns observed for English relative clauses. In particular, low-retention (20%) LCS follows memory-based theories and predicts higher RTs for object relative verbs — an effect found in eye-tracking but not Maze studies (Figure 2). These results can explain the apparently contradictory behavioral evidence supporting both memory- and expectation-driven accounts: relative clause processing is likely modulated by the memory demands of the task, and we can model this phenomenon using Lossy Context Surprisal.



(a) Linear mixed-effects model fit for LCS to Maze RT data on filler items (Vani et al., 2021). Points are individual LCS model instances, line shows GAM smooth, x-axis shows retention rate, y-axis shows goodness of fit in AIC. Retention rate 60–70% achieves the best fit on average.



(b) Linear mixed-effects model fit for LCS to Maze (Hahn et al., 2022), eye-tracking (ET), and self-paced reading (SPR) data for filler items from Vasishth et al. (2010). Points are individual LCS model instances, line shows GAM smooth, x-axis shows retention rate, y-axis shows goodness of fit in AIC — lower is better. Maze data are better approximated by LCS with a higher retention rate (40%) compared to ET and SPR data (20%).

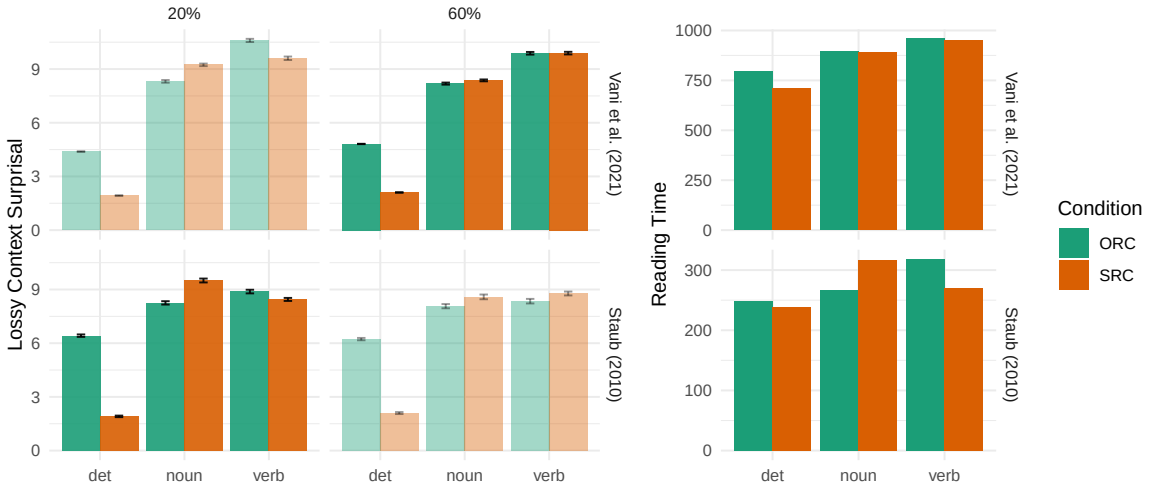


Figure 2. LCS predictions (left; error bars show standard error across model instances and items) and reading time data (right) for stimuli from Staub (2010, ET gaze duration, Experiment 1) and Vani et al. (2021, Maze, Experiment 1; cf. their Figs. 3 and 4). At the higher retention rate (60%), LCS predicts only the determiner slowdown observed in Maze data (top row). At the lower retention rate (20%), LCS also predicts the ORC verb slowdown observed in ET data (bottom row).

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