

The Parser's Dilemma: Memory vs. Grammatical Constraints in Sentence Processing



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How does the parser deal with conflicting constraints from memory limitations and grammatical knowledge?

Memory Load and Grammatical Faithfulness in Sentence Processing

➤ Sentences often contain syntactic dependencies e.g., in (1a) *the cookies* (filler) is the object of *ate*, but is dislocated from its canonical position (gap) (cf. (1b)).

- Fillers cannot receive an interpretation until this *filler-gap dependency* is resolved [1].

(1) a. These are **the cookies** that you ate _____. b. You ate **the cookies**.

➤ To reduce memory load, the parser tries resolving dependencies as quickly as syntactically possible [2, 6].

- e.g., In (2), the parser initially entertains the hypothesis that *the book* is the object of *wrote*.

➤ Relative clauses act as grammatical islands, preventing gap formation, as in (3) [3, 4].

(2) We like **the book** that the author wrote **X** unceasingly about _____.

(3) We like **the book** that the author [**who wrote unceasingly**] praised _____.

Early Integration Over Grammatical Faithfulness?

➤ Memory overload can hinder comprehension, but the parser must respect syntactic knowledge.
➤ In the presence of multiple dependencies, there is some evidence that the parser violates the (normally robust) relative clause island constraint [5].

Current Research Questions:

➤ Under what conditions will the parser violate grammatical constraints in favor of resolving dependencies?

- How many and which types of dependencies will induce the parser to take a “short cut”?
- Are some constraints more violable than others during processing?

➤ (Future) Does type of memory load matter – could sentence-external load induce this effect?

- Are general-purpose memory limitations the issue, or is it a computational bottleneck?

Experiments: Self-Paced Reading and Eye-Tracking

Items Overview

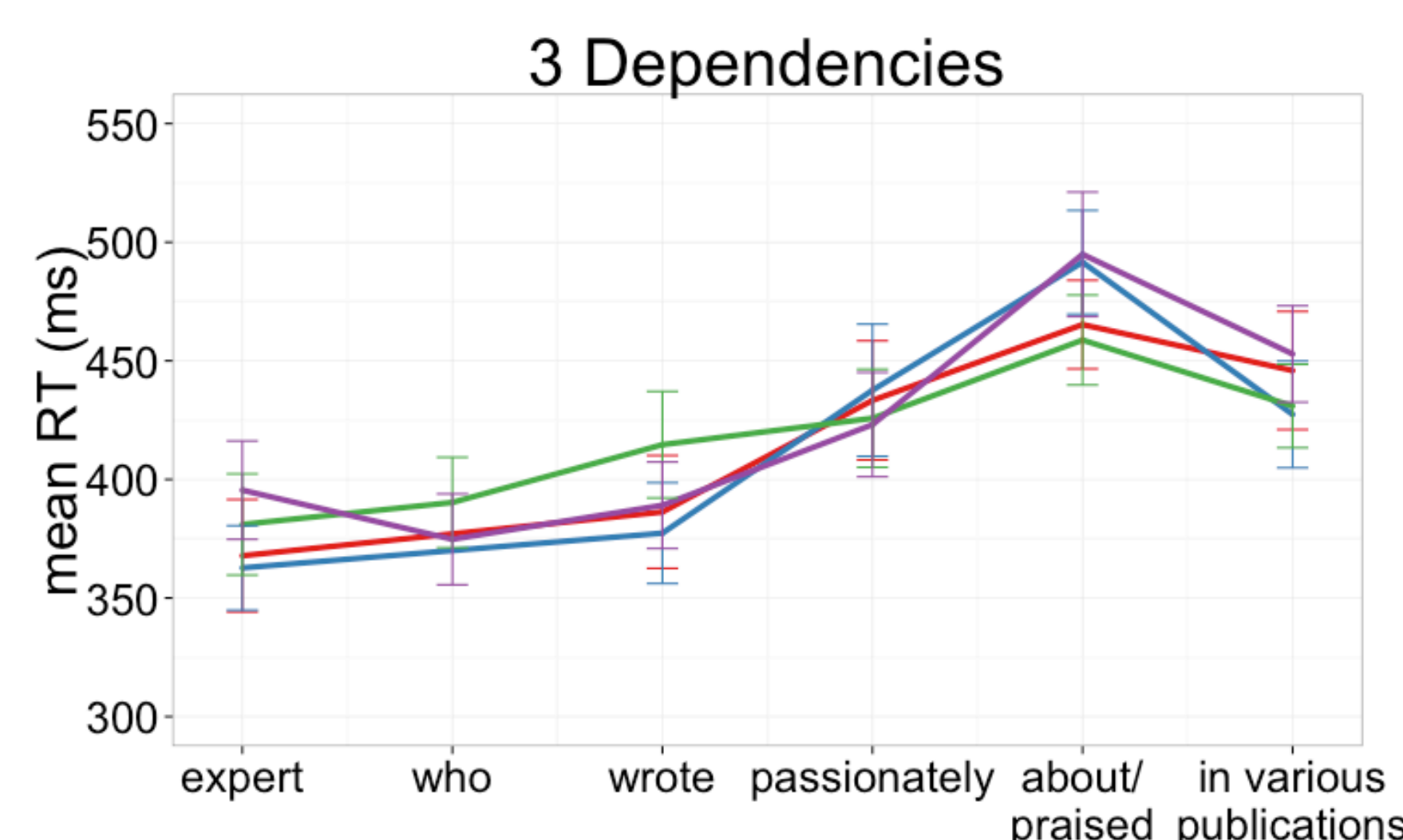
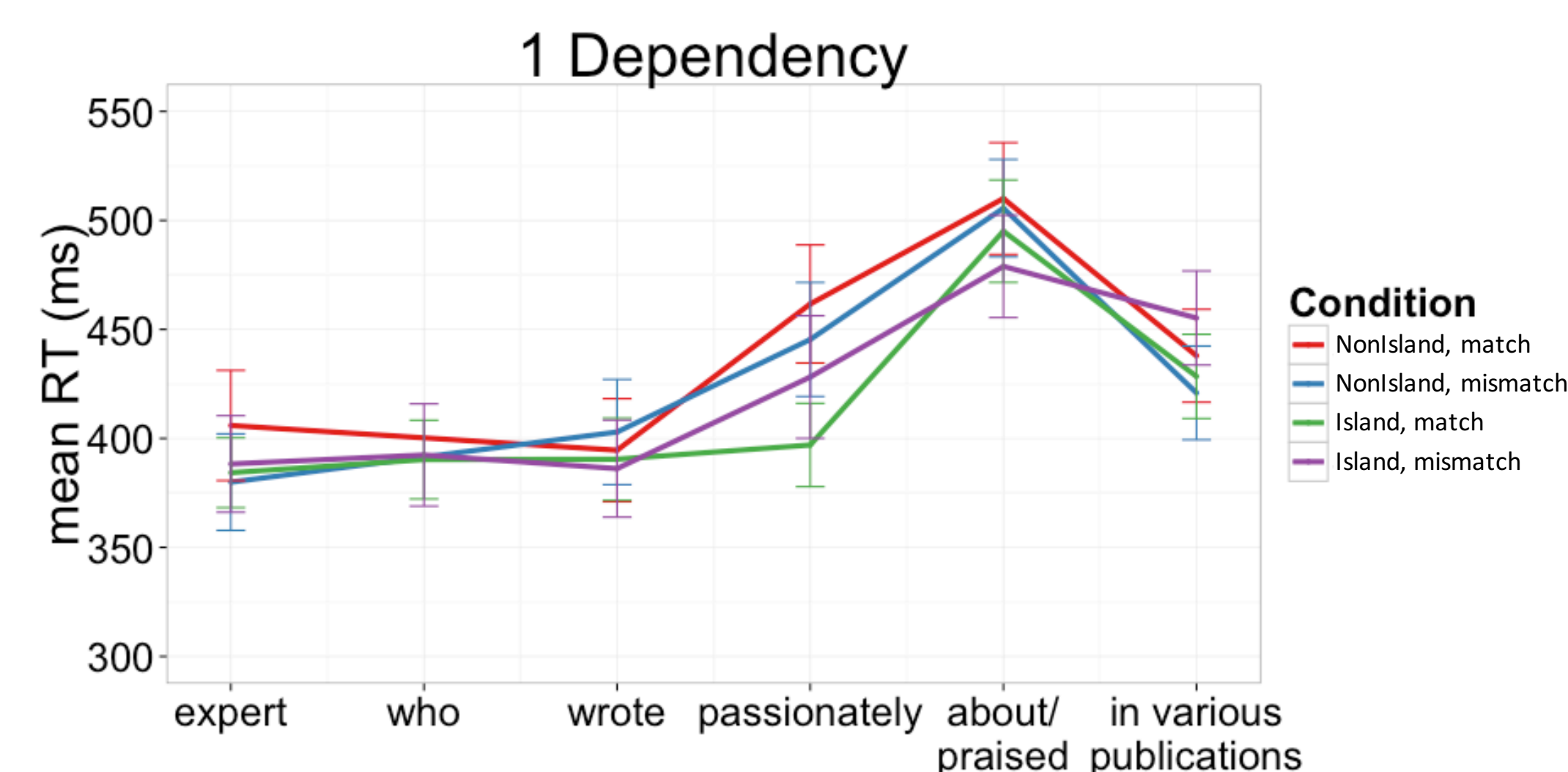
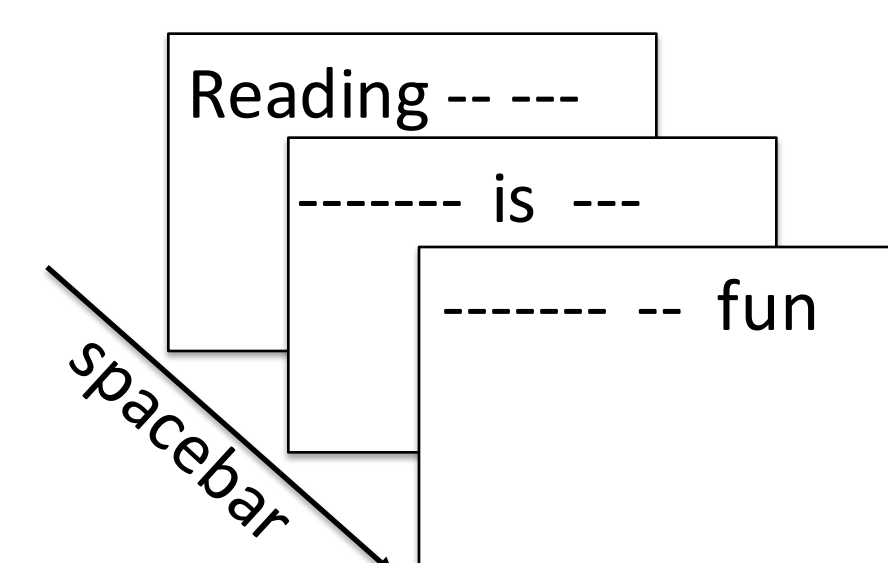
➤ 3 factors: 2 (dependency) x 2 (islandhood) x 2 (plausibility) = 8 conditions
➤ 3 dep: (i) **main clause**, (ii) **antecedent**, and (iii) **wh-gap** predictions
➤ Semantic fit between filler and verb normed on Amazon MechTurk using 7-point scale (n=24, plausible z-score: .506; implausible z-score: -1.07)

Predictions

➤ Positing gaps only where grammatically licensed → Interaction between islandhood and plausibility: slower at and after verb in non-island plausibility mismatch conditions (b & f) compared to match conditions.
➤ Violating the island constraint in favor of early resolution → Interaction between all 3 factors: slower at and after verb in non-island plausibility mismatches (b & f) and in 3 dependency island mismatch (h).

Experiment 1: Self-Paced Reading (n=40)

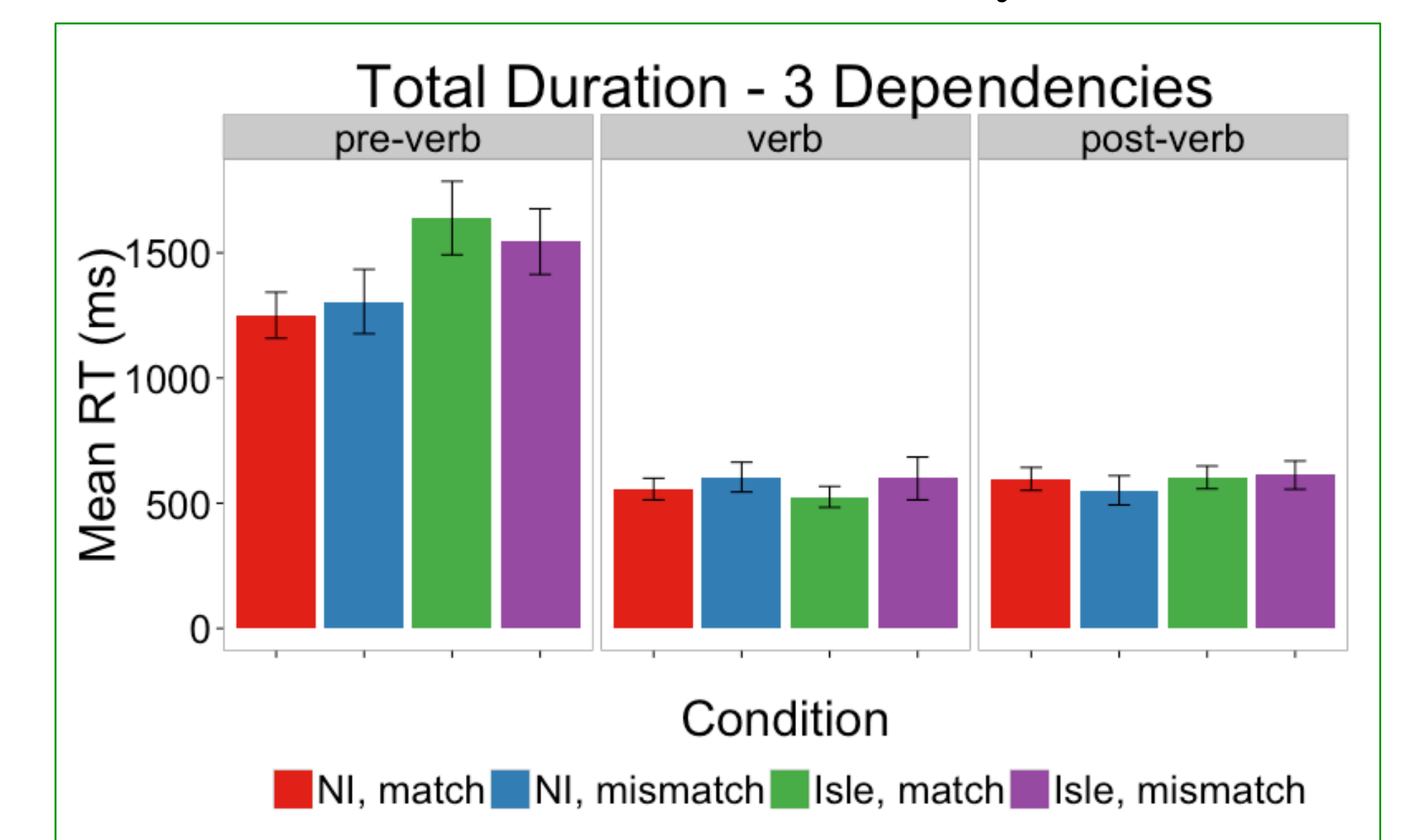
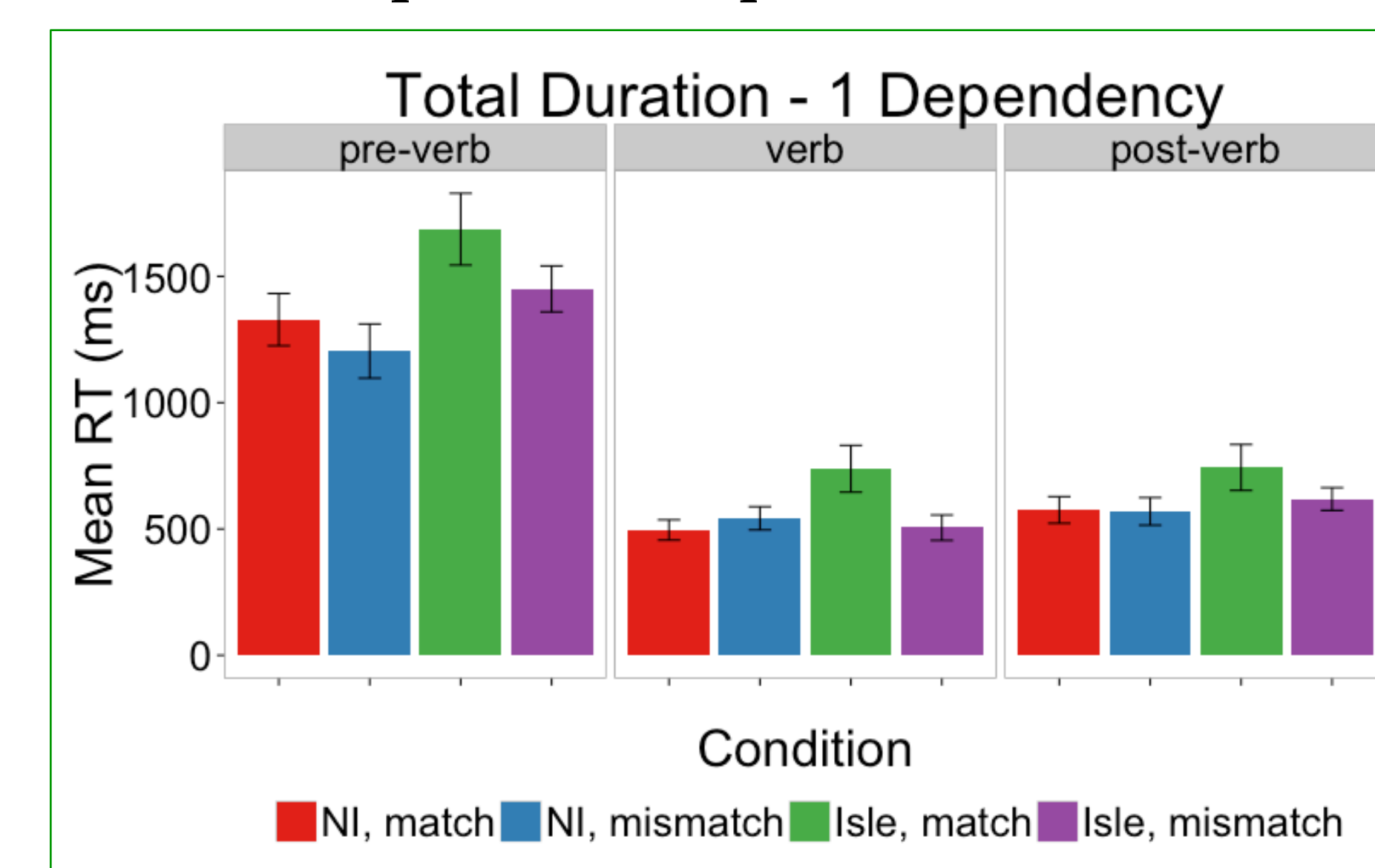
➤ Participants read sentences word-by-word, pressing spacebar to move on.
➤ Time spent on word is taken as indicator of processing difficulty or surprisal.
➤ Yes/No comprehension question after each sentence (incorrect excluded)



➤ Participants are at 90.1% accuracy on comprehension questions (se = .85)
➤ No interaction between all three factors at verb ($\beta=-16.8$, $p=.62$) or adverb ($\beta=-43.4$, $p=.28$)
➤ No interaction between islandhood and plausibility at verb ($\beta=-13.4$, $p=.42$) or adverb ($\beta=21.3$, $p=.29$)

Experiment 2: Eye-Tracking (n=32)

➤ Eye movements recorded each millisecond allowing more natural sentence presentation & finer RT detail
➤ 2AFC comprehension question after each sentence (incorrect excluded from further analysis).



➤ Earlier measures (first fixation duration, first pass time) showed no 2-way or 3-way interaction.
➤ Regression Path Duration showed a marginally significant interaction between islandhood and plausibility at the pre-verb region ($\beta=-98.47$, $p=.064$), however this is not the direction that was predicted.
➤ Total duration yielded a significant interaction between three factors in verb region ($\beta=-244$, $p=.018$), again not in the predicted direction.

Discussion: Making Sense of our Failure to Replicate

Summary of Findings

➤ Mixed effects modeling in both experiments failed to find evidence of interaction effects, even in one dependency non-island sentences, where such effects have often been found [e.g., 6].
➤ The interaction effects found in the eye-tracking experiment were unpredicted and resulted from surprisingly high reading times in the 1 dependency island match condition.

Potential Explanations

➤ Subjects could answer comprehension questions accurately without attending to plausibility.
➤ Not enough three dependency sentences (16) to encourage strong predictions about the first two dependencies (cf. Atkinson and Omaki, who used 32 three dependency sentences).

References:

- [1] Gibson 1998, *Cognition*.
- [2] Traxler and Pickering 1996, *JML*.
- [3] Chomsky 1986, *Barriers*.
- [4] Ross 1967, Published Dissertation.
- [5] Atkinson and Omaki 2014, *AMLaP poster*.
- [6] Omaki et al. 2015, *Frontiers in Psych*.

Acknowledgements:

- 1) Provost's Undergraduate Research Award
- 2) Emily Atkinson, Zoe Ovans, and Melinh Lai