Modeling retrieval processes of sentence comprehension in aphasia

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1. Introduction

When hearing a sentence, comprehenders keep words in memory in order to connect them with upcoming elements. For instance, in

- *The boy* who hugged the girl *chased* the woman

when encountering *chased*, one must recover the subject *the boy* in order to understand the sentence. This is a linguistic **dependency**. Two models of sentence comprehension explain how dependency resolution is carried out:

- Lewis and Vasishth ACT-R model (LV05) [2]
- McElree's direct-access model (DA) [3]

2. Aims

1. Implement DA and LV05 in Stan (building on [4]). Modified version of DA for aphasia
2. Test the models against behavioral data from patients with aphasia
3. Assess predictive performance, model comparisons

3. Data

- **Subjects:** 33 patients with aphasia, 46 matched controls [1]
- **Task**: Self-paced listening and picture selection
- **Items**: Subject versus object relative clauses:
  - Subject relative: The boy who hugged the girl chased the woman
  - Object relative: The brother who the sister followed kissed the woman
- **Dependent measures:** aggregated listening times per sentence in ms (LT) and accuracies (correct/incorrect)

4.Direct-Access Model

Implemented as hierarchical Bayesian mixture model:

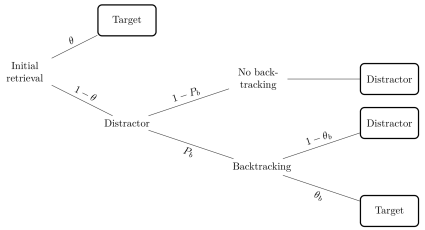

Figure 1: Probability tree of the DA model

- target retrieved at first parse **or** initial misretrieval without backtracking:

$$LT \sim lognormal(\mu, \sigma) \quad (1)$$

(where s stands for the sentence type, μ is the log mean of the listening times, and σ is the log sd)

- initial misretrieval, backtracking and retrieval of the target **or** initial misretrieval, backtracking and second misretrieval:

$$LT \sim lognormal(\mu, +\delta, \sigma); \quad (2)$$

(where δ is the time taken for reanalysis, in log ms.)

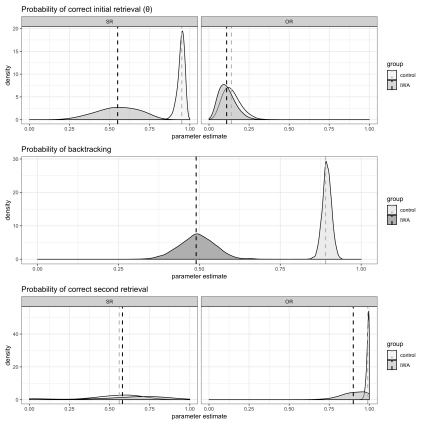

Figure 2: Main parameters of the model

5. LV05: Activation-based model

- Implemented as a **log-normal race of accumulators** with different variances.
- Two accumulators of evidence, one for each possible interpretation: Subject/object relative clause.
- Accumulator with faster rate of accumulation fires, i.e, chosen interpretation.
- For each trial, the finishing time T of an interpretation i is sampled from a log-normal distribution with standard deviation σ_{group}:

$$RT_i \sim lognormal(b - (\alpha_i + \beta_i * rc_{type}), \sigma_{group}) \quad (3)$$

where b is an arbitrary constant to constrain α_i to positive values.

- By-participant adjustments added to α_i and to the relative clause effect β_i, and by-item adjustments to α_i. A slope for group type, and an interaction between group and relative clause type are included.

6. Posterior predictive checks

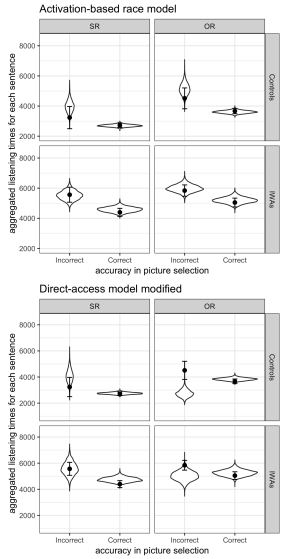

Figure 3: Dots indicate the mean of the data and bars 95% CI

7. 10-fold cross-validation

$$\hat{elpd}_{DA} = -28237, (SE = 69)$$

$$\hat{elpd}_{activation} = -28107\ (SE = 68)$$

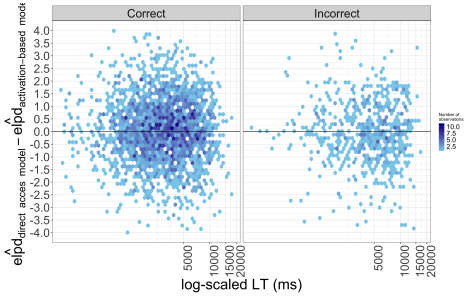

Figure 4: Predictive accuracy for each data point

8. Conclusion

The posterior predictive checks and the cross-validation results show that the activation-based model presents a better fit to the data from individuals with aphasia.

9. References

1 Caplan, D., Michaud, J., & Hufford, R. (2015). Mechanisms underlying syntactic comprehension deficits in vascular aphasia: new evidence from self-paced listening. Cognitive Neuropsychology, 32(5), 283-313.

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3 McElree, B. (2000). Sentence comprehension is mediated by content-addressable memory structures. Journal of Psycholinguistic Research, 29(2), 111-123.

4 Nicenboim, B., & Vasishth, S. (2018). Models of retrieval in sentence comprehension: A computational evaluation using Bayesian hierarchical modeling. Journal of Memory and Language, 99, 1-34.

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