# A Puzzle Regarding Relative Clauses: When Frequency and Difficulty Disagree

**Gabriel Doyle and Roger Levy – University of California, San Diego**

## Abstract

We consider an alternation seemingly without semantic or structural differences. The lack of such differences suggests that frequency should drive differential comprehension, but we show that the observed differences in reading times point opposite the frequency effects.

## Background

- Comprehension difficulty in relative clauses (RCs) affected by composition of the relative clause.
- Gordon et al (2001) showed similarity-based interference; similar extracted & embedded NP types impede comprehension.
- Traxler et al (2002) showed crucial role of plausibility; similar extracted & embedded NP plausibilities impede comprehension.
- Reali & Christiansen (2007) showed frequency of exposure to different RC types influences comprehension difficulty, independently of complexity or cognitive limitations.
- Corpus frequency and comprehension difficulty pattern together; surprisal theory (Hale 2001, Levy 2008).

**How sensitive are comprehenders to word/structure cooccurrences that are purely arbitrary (not semantically based)?**

## Linking Hypotheses

- Dependency Locality Theory
- Filler-gap retrieval
- Similarity-based interference
- Surprisal

## Our Alternation

Restrictive relative clauses with an animate extracted NP have two possible relative pronouns:

(1a) The man **that** I saw smiled.
(1b) The man **who** I saw smiled.

- Structural equivalence
- Approx. semantic equivalence
- No apparent discourse differences
- Only differ in surprisal linking hypothesis

Without obvious difference in complexity, we expect frequency effects to determine comprehension difficulty.

## Experimental Design

2x2x2 design:

- Relativizer (*that/who*)
- Extraction Type (Subject/Object)
- Embedded NP Type (Pronoun/Full NP)

Stimuli:
**[ORC-pro]** The chef {that/who} you watched was famous for her butternut squash soup.
**[SRC-pro]** The chef {that/who} watched you was famous for her butternut squash soup.
**[ORC-full]** The chef {that/who} the waiter watched was famous for her butternut squash soup.
**[SRC-full]** The chef {that/who} watched the waiter was famous for her butternut squash soup.

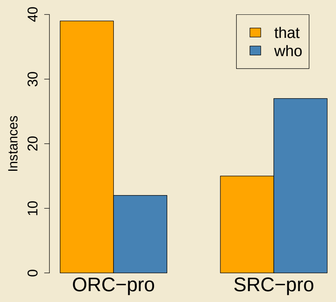
## Experiment 1: Corpus Study

Combined the Brown, Switchboard, and Wall Street Journal corpora.
Performed tgrep searches to find restrictive RCs with animate extracted NPs.

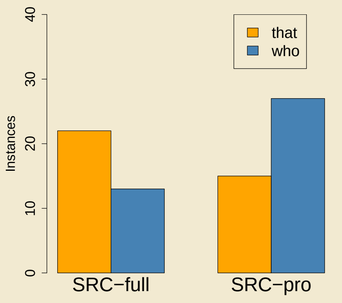
| | Relative Pronoun | |
|---|---|---|
| | *that* | *who* |
| ORC-pro | 39 | 12 |
| SRC-pro | 15 | 27 |
| ORC-full | 11 | 9 |
| SRC-full | 22 | 13 |

[SRC-full counts are a subsample of the corpus.]

**ORC-pro/SRC-pro ($p < .001$)**




**SRC-full/SRC-pro ($p = .02$)**



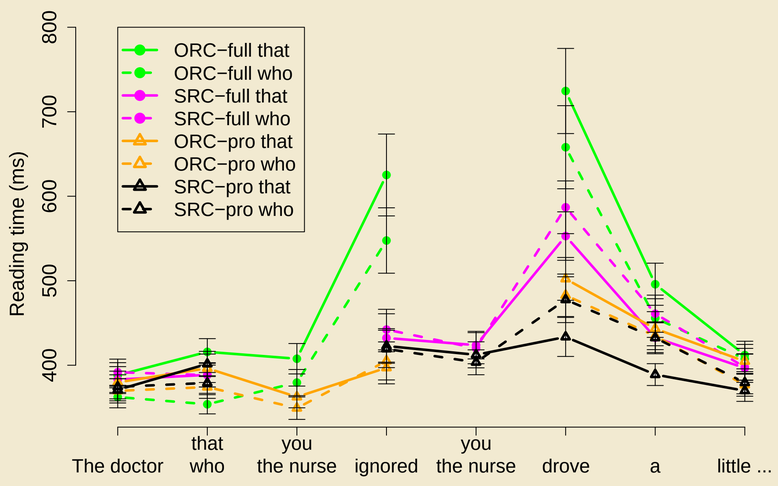

Fisher's exact tests: significant differences between ORC-pro and SRC-pro RCs and between SRC-full and SRC-pro RCs.

## Experiment 2: Reading-Time

We expect comprehenders to use this information in comprehension, and to find the same pattern in reading times.
Corpus frequency (Expt 1) predicts:

- interaction between ORC-pro and SRC-pro, ORC-pro favoring *that*.
- interaction between SRC-full and SRC-pro, SRC-full favoring *that*.
- corpus and RT bars should be **reversed**.

Moving window self-paced reading-time study with 56 participants.




Solid lines are RTs with *that*, dashed lines are RTs with *who*. Circles indicate embedded NP is full, triangles indicate embedded NP is pronominal *you*.

## References

[1] Gibson, E. (1998). Linguistic complexity: Locality of syntcatic dependencies. *Cognition 68*
[2] Gordon, P., Hendrick, R., & Johnson, M. (2001). Memory interference during language processing. *J. of Expt. Psych: LMC 27.6*
[3] Hale, J. (2001). A probabilistic Earley parser as a psycholinguistic model. *NAACL 2*
[4] Levy, R. (2008). Expectation-based syntactic comprehension. *Cognition 106*.
[5] Reali, F., & Christiansen, M. (2007). Processing of relative clauses is made easier by frequency of occurrence *JML 57*.
[6] Traxler, M., Morris, R., & Seely, R. (2002). Processing subject and object relative clauses: Evidence from eye movements *JML 47*.

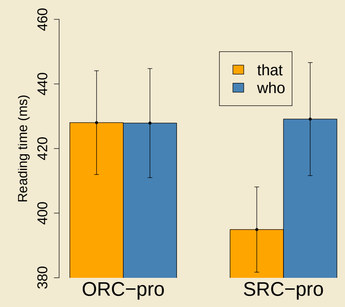
## Contact

{gdoyle,rlevy}@ling.ucsd.edu

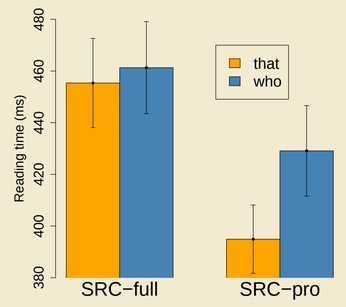
## Experiment 2 (continued)

For the significant corpus distinctions, we examine the sum of reading times over RC verb, main verb, and first spillover word in reading-time study.

**Pronominal RCs ($p = .01$)**




**Subject-extracted RCs ($p = .1$)**



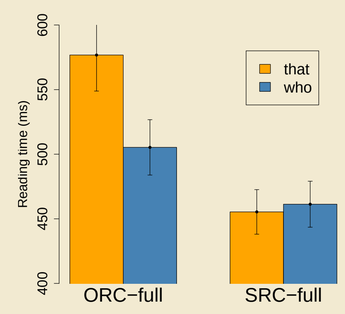

Two-tailed t-tests reveal

- significant interaction between ORC-pro vs. SRC-pro, but ORC-pro read faster with *who* ($p < .01$ by subject)
- marginal interaction between SRC-full and SRC-pro, but SRC-full read faster with *who* ($p = .1$ by subject)

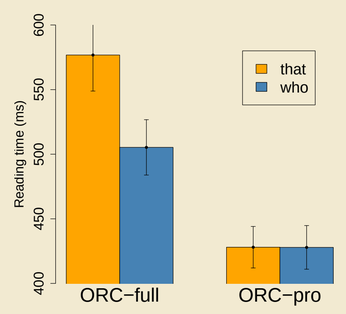
**Both interactions point opposite the corpus predictions!**

## Additional Manipulations

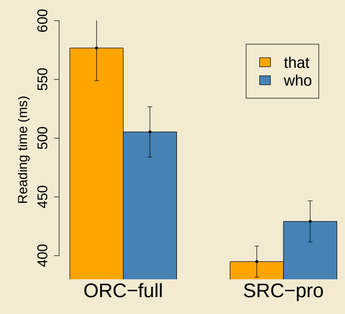
**Full NP RCs ($p < .001$)**



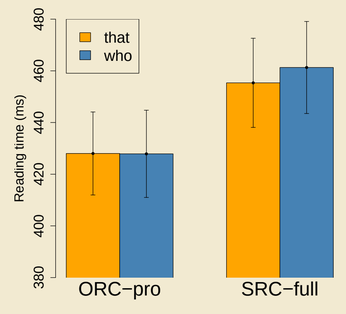

**Object-extracted RCs ($p < .001$)**




**ORC-full/SRC-pro ($p < .001$)**




**ORC-pro/SRC-full (n.s.)**




Significant interaction between (hardest) ORC-full and every other condition.

Suggests *who* helps comprehender prepare for or process difficult RCs; re-activation by *who*?

## Conclusions

- Comprehension difficulty in *that/who* alternation shows no effect of relative pronoun frequency.
- In fact, difficulty increases with increased corpus frequency.
- This despite apparent lack of other factors influencing comprehension difficulty.

## Future Work

- Use the ANC corpus to obtain better ORC-full counts.
- Sentence completion task to examine production in a more controlled setting.