# How useful is information theory in predicting patterns of language use?

Joel C. Wallenberg
joel.wallenberg@ncl.ac.uk


14th May, 2019

# Overall Points

- **Shameless trick:** I don't really know *how* useful, and it's a limited domain of "language use".
  - But the results are still very surprising, and at a level of detail that is only rivalled by one or two other results in the field.
- **Main idea:** speakers unconsciously manipulate linguistic structure so that their utterances are more resistant to "noise" events that could destroy a whole message.
- "noise" is any interference, including: noise, memory, other processing costs, etc.

# Outline

# Crash course

- The amount of information a sender can theoretically communicate about an event is the uncertainty ("entropy") the receiver has about the event.
- Shannon (1948)'s formula for information in an event with $n$ discrete outcomes with probabilities $p_1 ... p_n$:

$$\sum_{1}^{n} p_i log_2 \frac{1}{p_i}$$

- The $log_2 \frac{1}{p_i}$ part is the *information content* (or "surprisal") of an outcome.

# Crash course

- The amount of information in a fair coin toss is 1 bit.
- The amount of information in an unfair coin toss with
$$p = \frac{1}{3}, \frac{2}{3}$$
is less, even though less probable events have higher information content.

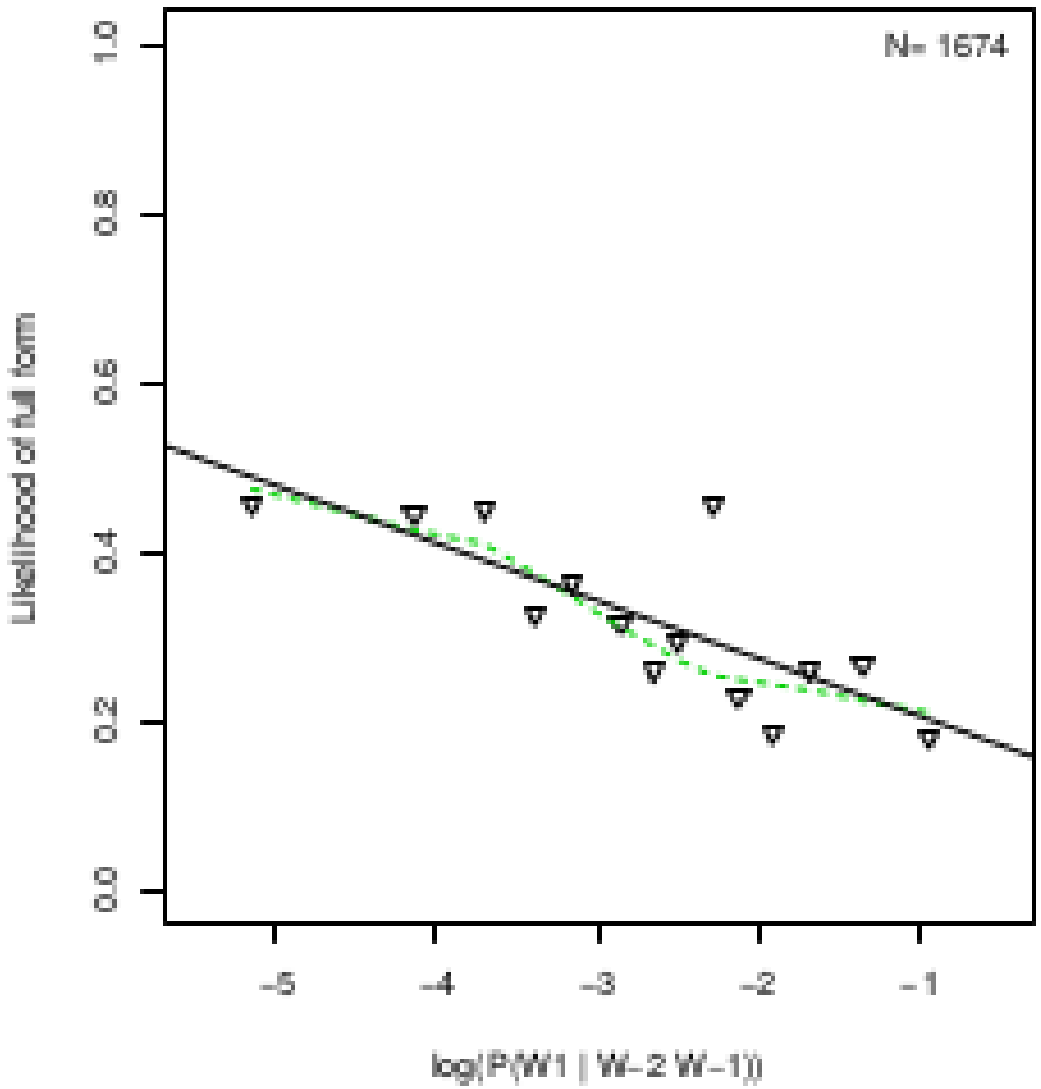
# "Uniform Information Density" in language

Speakers spread information content across utterances as uniformly as possible, (possibly) so that utterances are more resistant to noise events (Aylett and Turk, 2004; Jaeger and Levy, 2007; Levy, 2008).

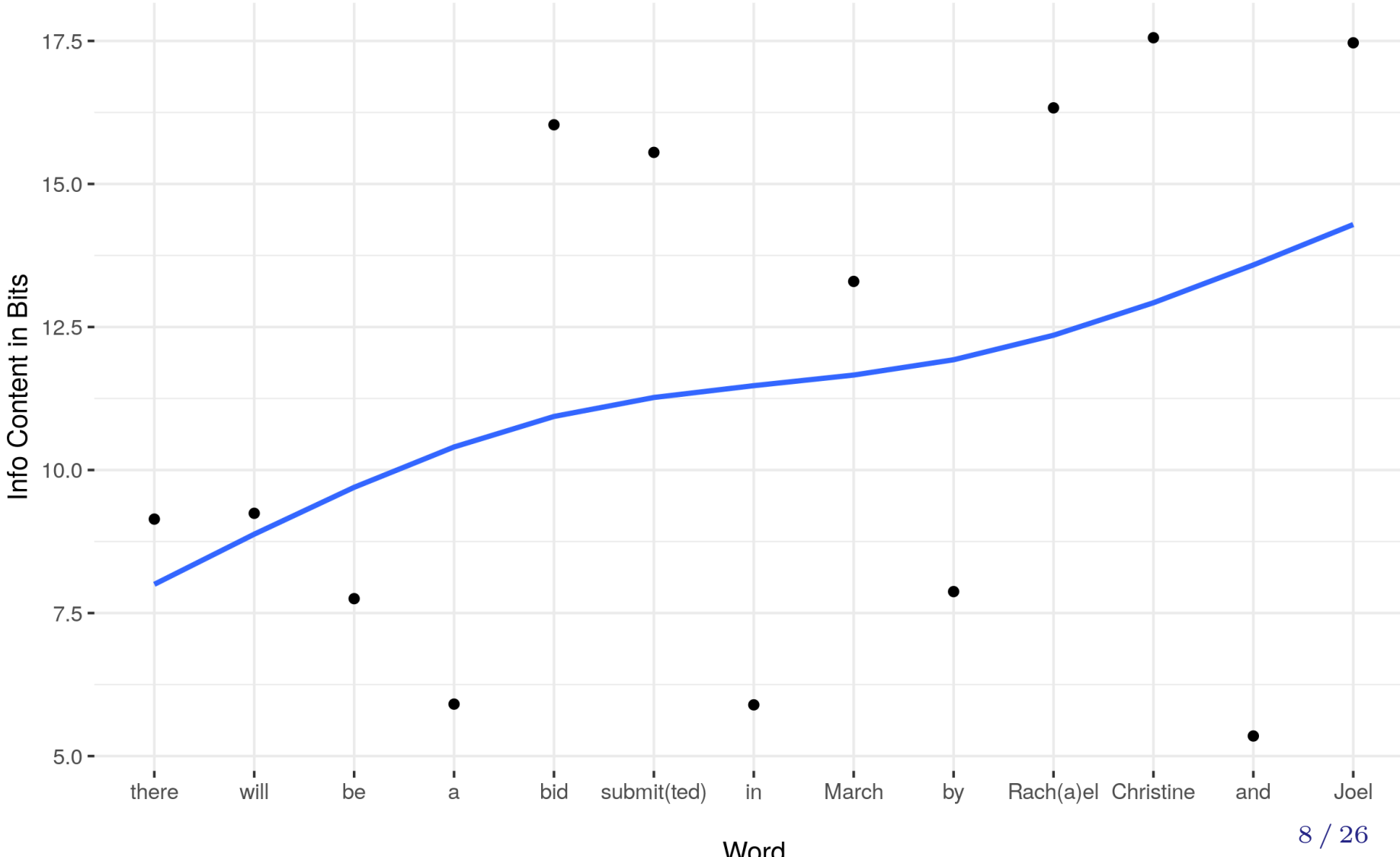
(1) How big is the family [(that) you cook for]?

If *that* is deleted, more information is carried by *you*, so information is more dense.

# "Uniform Information Density"



# UID and noise resistance



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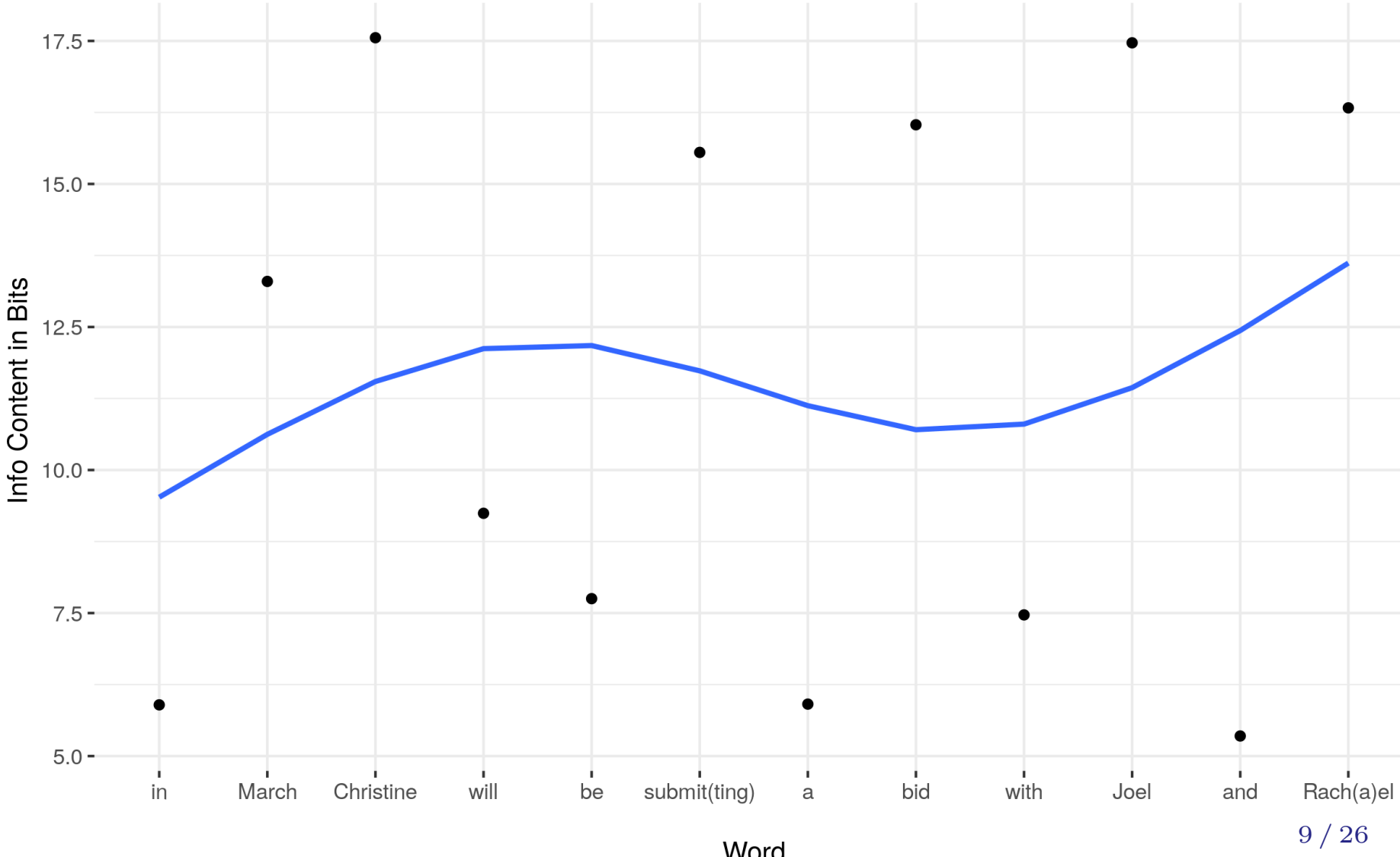
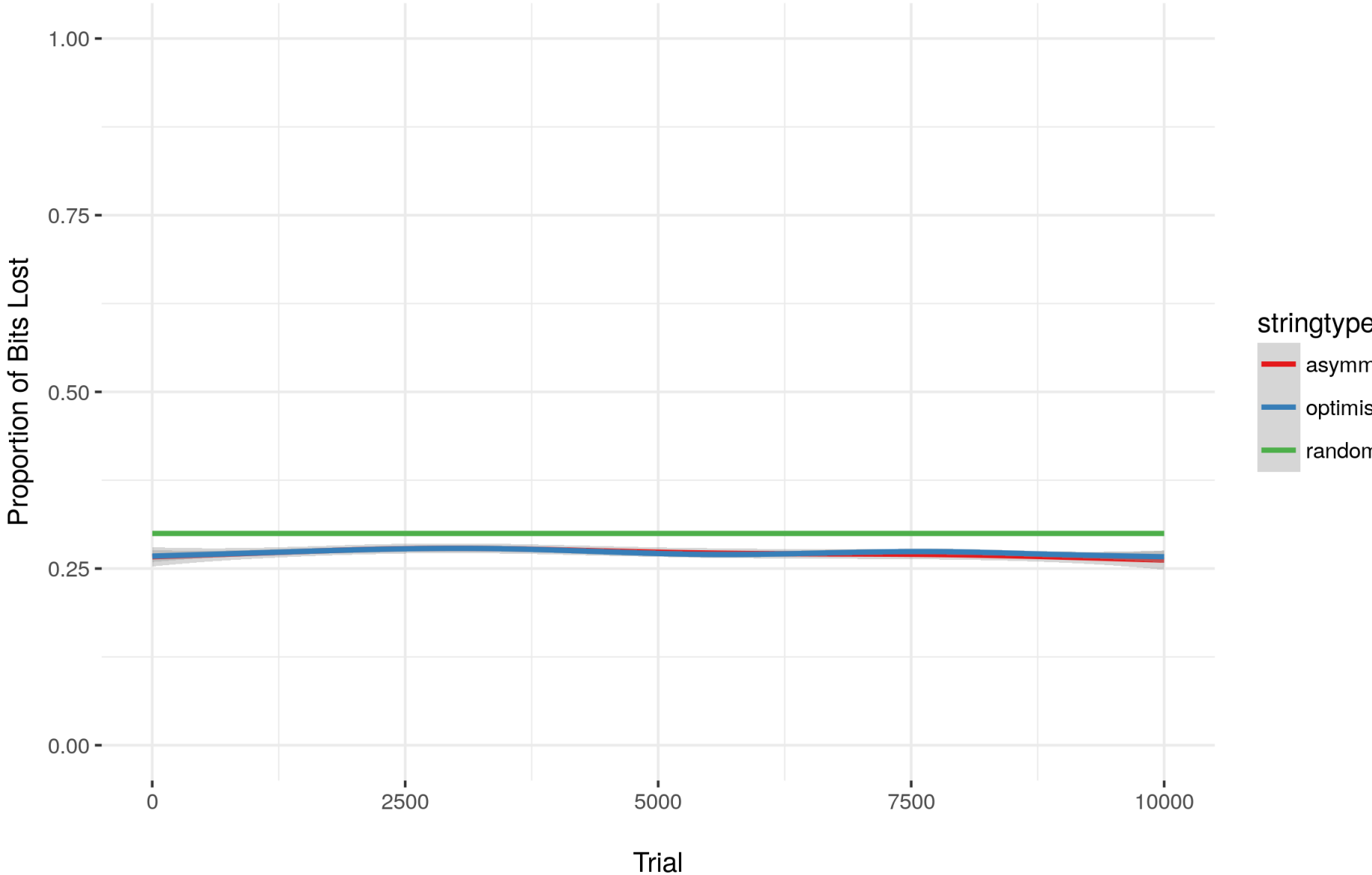


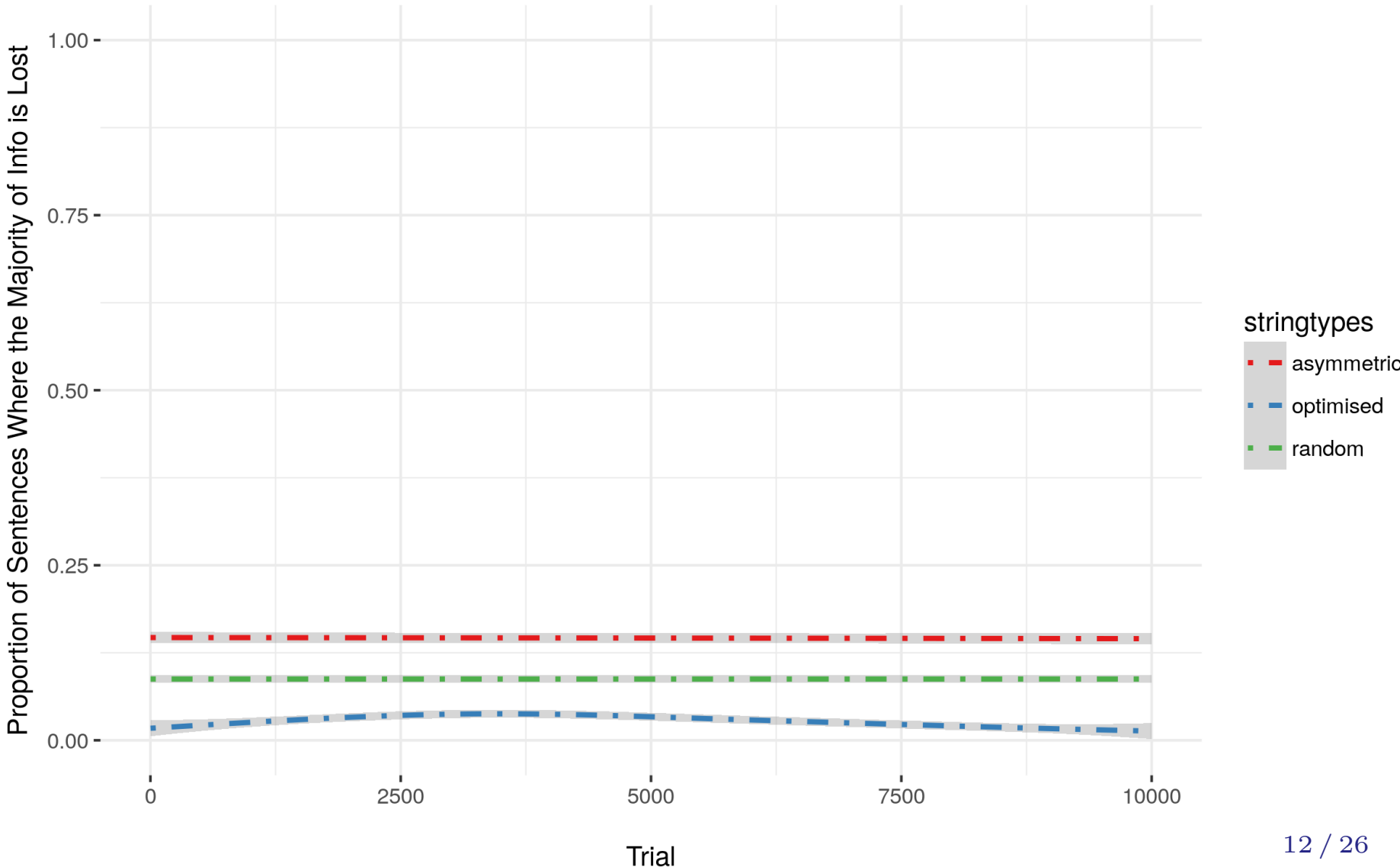
# Noise resistance simulation

1. Generate 10-item sequences of probabilities.
2. Order them randomly, by size ("asymmetric"), or hyperdispersed ("optimised").
3. A noise event randomly destroys a 3-item sub-sequence.
4. See how much information the noise events destroy (over many trials)!

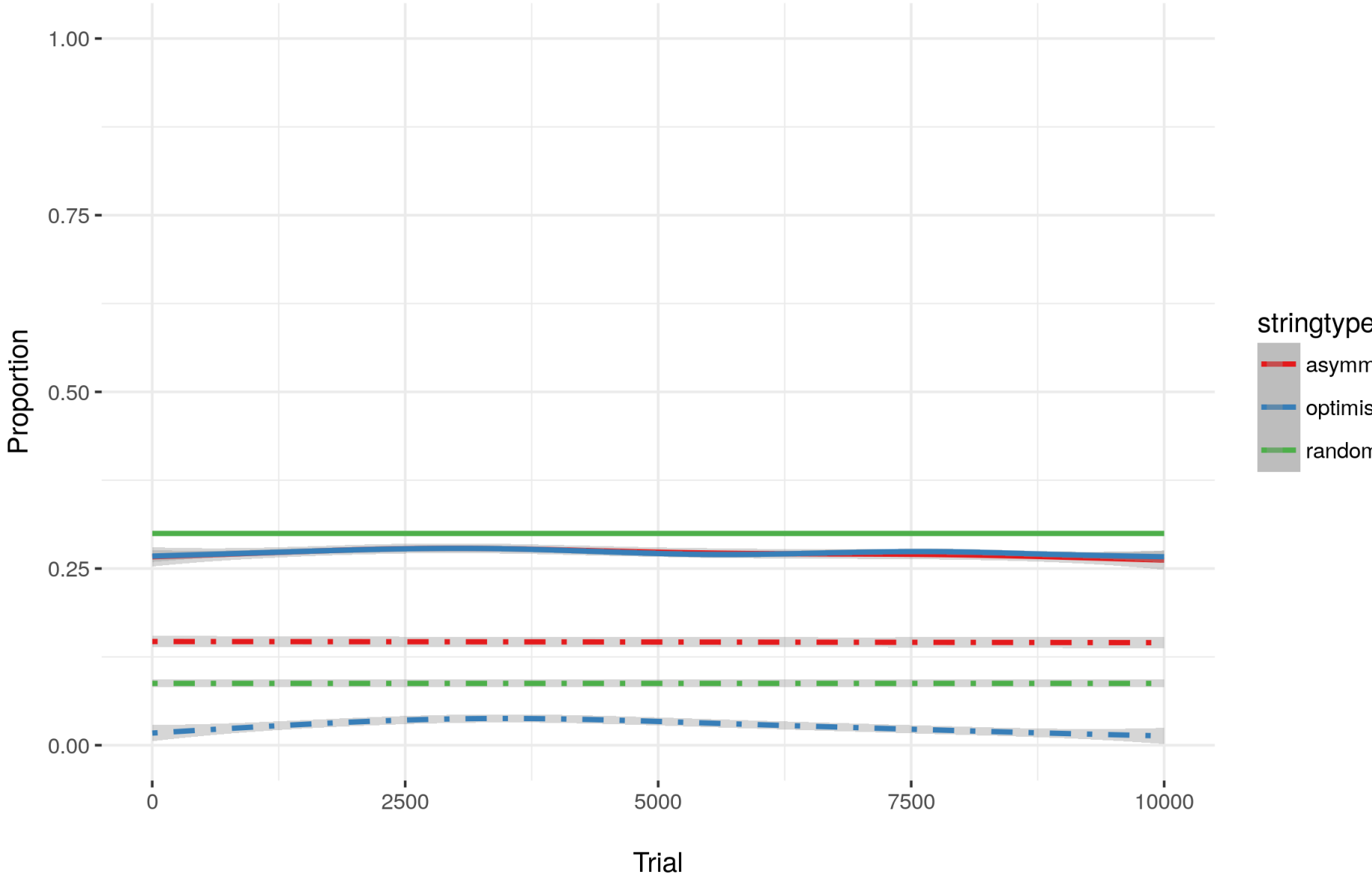
# Noise Resistance Simulation: proportion of bits lost



# Noise Resistance Sim: proportion of "sentences" where bits lost > 50% bits in sentence



# Noise Resistance Sim: bits lost and big bit losses

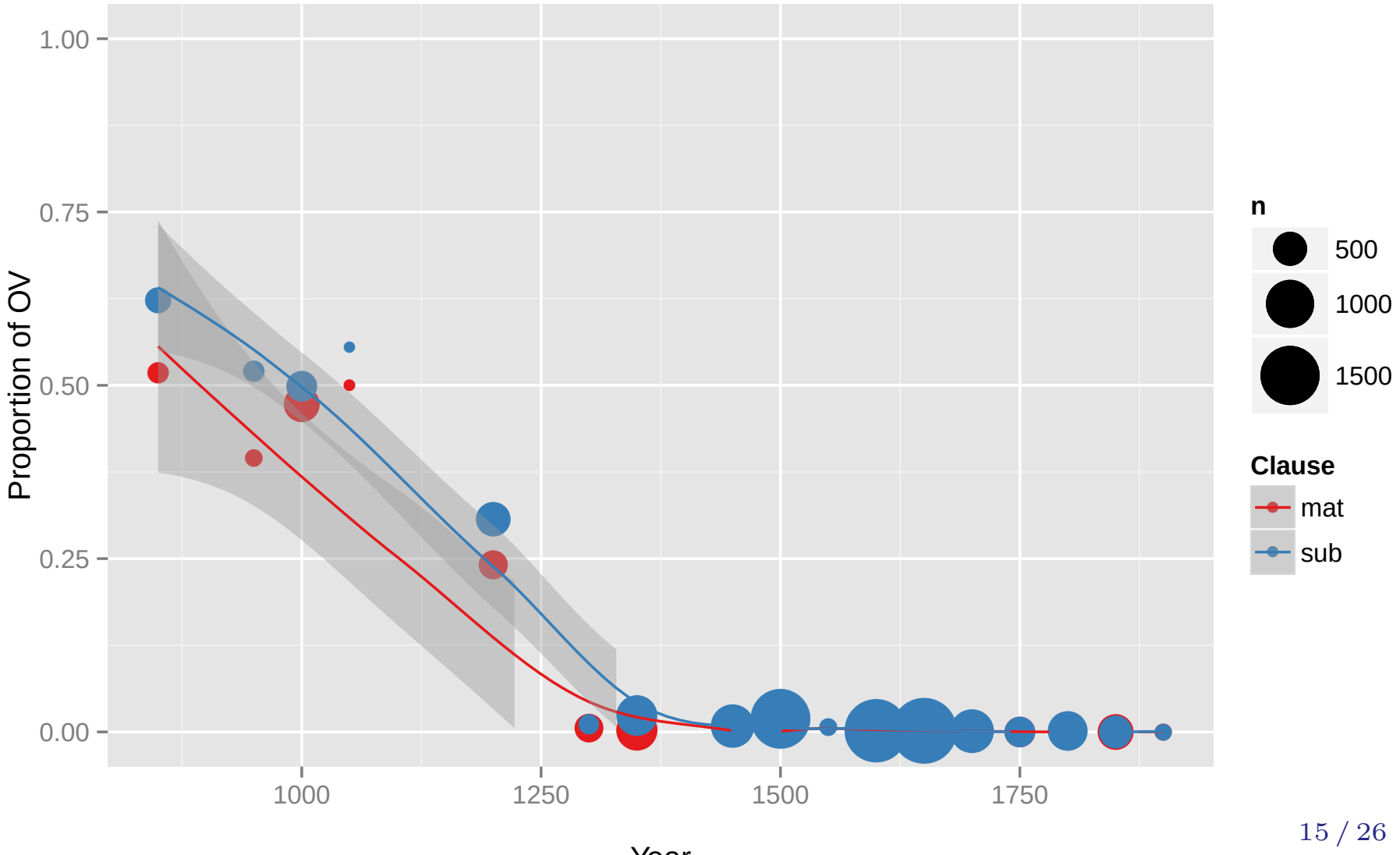


# OV to VO Change in English

(2) tu mihht ec **gastlike laf** Onn oþerr wise ȝarrkenn
you might also spiritual loaf in another way prepare
"In this way, you will let go of your sins."
(*Ormulum*, Lincoln, date: 1200)

(3) Ne maȝȝ he nohht rihht cnawenn **me**
NEG may he not right know me
"He may not rightly know me"
(*Ormulum*, Lincoln, date: 1200)

# OV to VO Change in English



# Some grammatical preliminaries...

(4) $[_{Matrix}$ Malvina Reynolds implied $[_{Sub}$ that you should not like little boxes $]_{Sub}$ $]_{Mat}$.

(5) Malvina Reynolds implied that you should not like them. **(Pronoun Object)**

(6) Malvina Reynolds implied that you should not like any/many/most/both/... **(Quantified Object)**

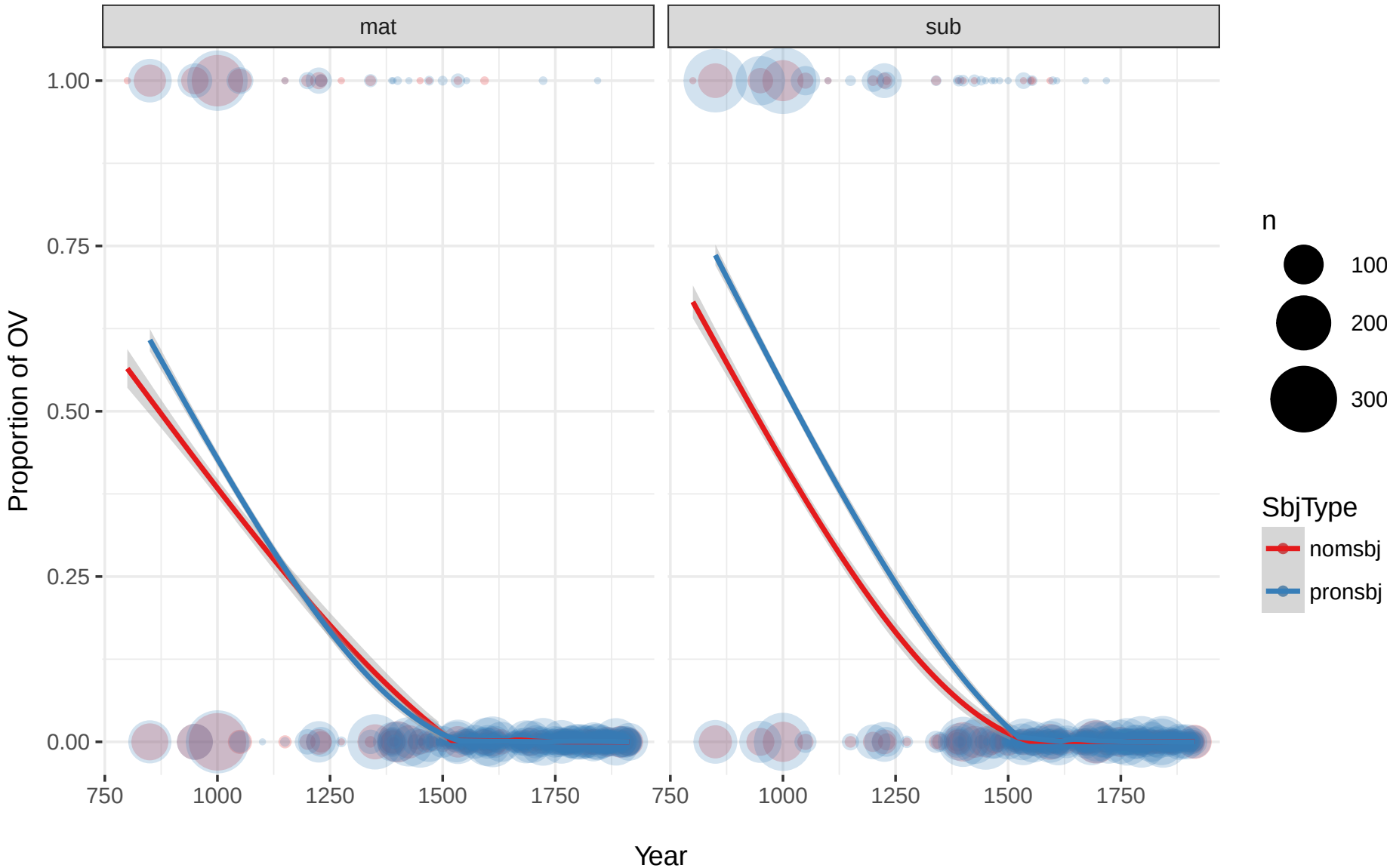
Guestimated information content hierarchy:

**Other nominal Obj or Sbj >**
**Quantified Obj or Sbj , Verbs >**
**Pronoun Obj or Sbj**

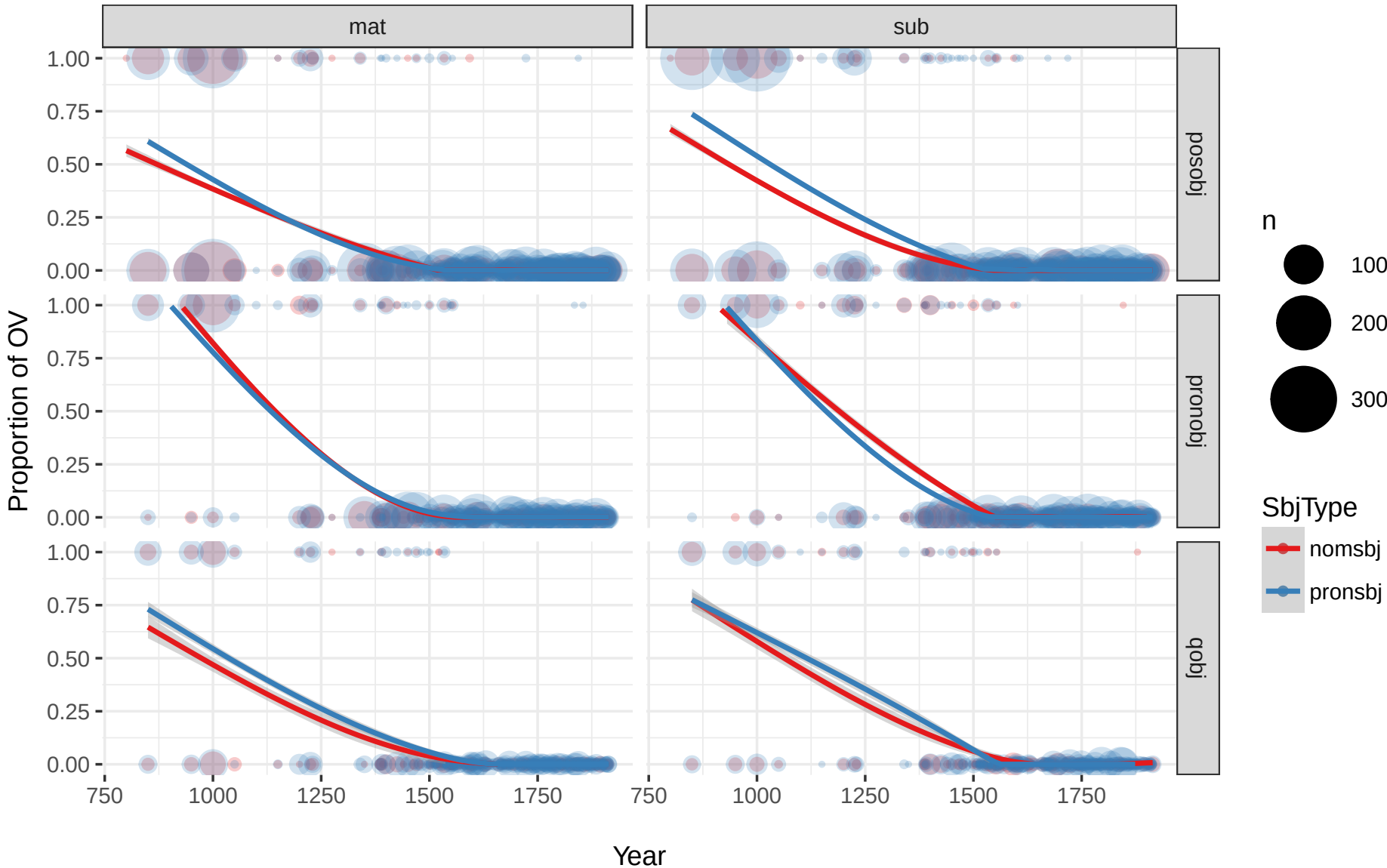
# Hypotheses

1. Pronoun subjects should favour OV more than nominal subjects will, if the object is also nominal: pronSbj-nomObj-V is more uniform in info content than pronSbj-V-nomObj or nomSbj-nomObj-V, and the latter are less uniform than nomSbj-V-nomObj
2. Pronoun subjects should do the *opposite*, i.e. favour more VO, if the Object is also a pronoun: pronSbj-V-pronObj is more uniform than pronSbj-pronObj-V or nomSbj-V-pronObj, and the latter are less uniform than nomSbj-pronObj-V.
3. Quantified Objs should be in-between for all effects.
4. All of these effects should be larger in sub clauses than mat clauses, because of the pressure that preceding information (in the earlier clause) creates.

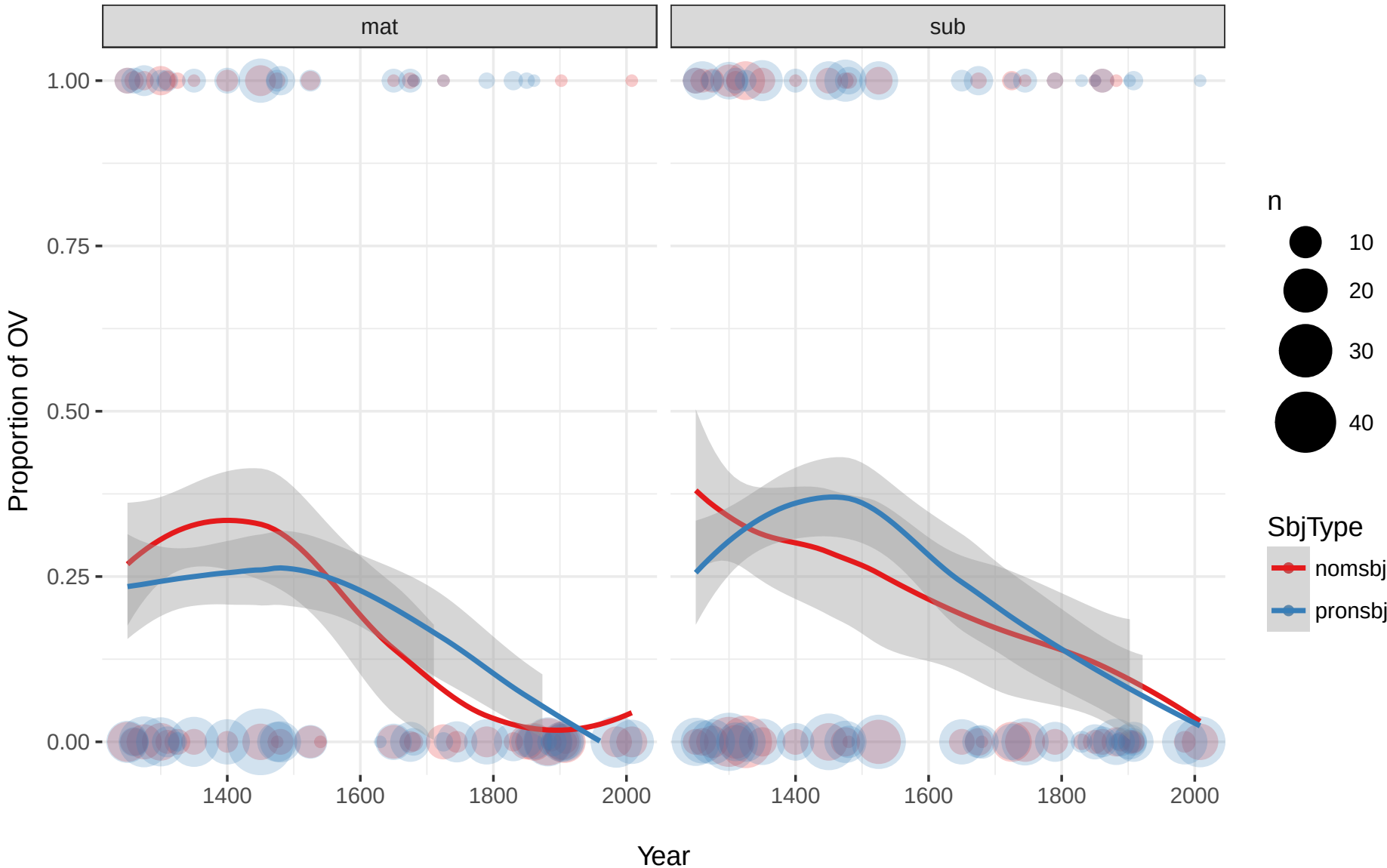
# OV: Subj and Clause Type, English, N = 28,580



# OV: Subj, Obj and Clause Type, English



# OV: Subj and Clause Type, Icelandic, N = 1,860



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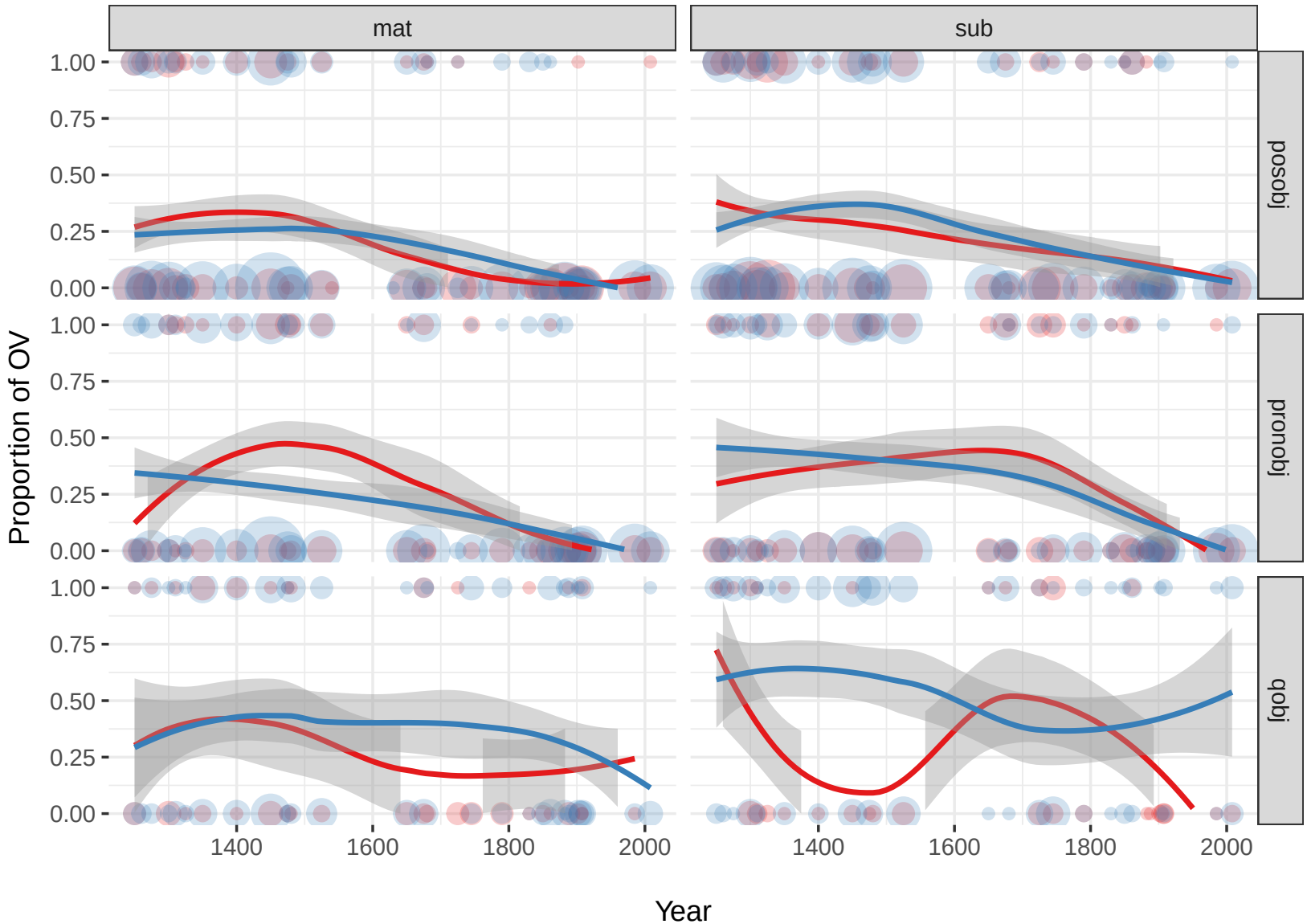

# Conclusions

- Where speakers have an option, i.e. during language change, their choice responds to the resulting density of the entire utterance.
- Project with Christine Cuskley and Rachael Bailes to find out whether they also respond to hearer and other factors, and whether we can graduate to actual probabilities in the above work.
- MRes student Jack Winter (supervised by Rachael), doing an experiment about rhythm and memory, manipulating information density of symbols in a rhythmic sequence.
- ASD vs. typical speakers

# Acknowledgements

Thanks to Rachael Bailes, Christine Cuskley, Tony Kroch, among others.

`https://github.com/joelcw/constantentropy`

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