Models of retrieval in sentence comprehension

Bruno Nicenboim & Shravan Vasishth

University of Potsdam

How do we make sense of sentences?

How do we make sense of sentences?

Who did what to whom?

+

The

boy

who

defeated

the

king's

pets

was

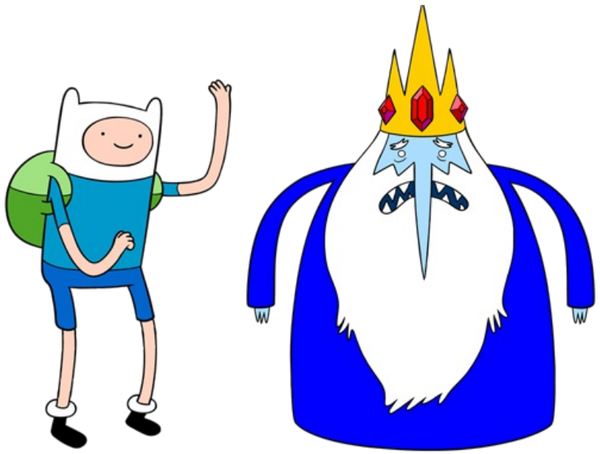
imprisoned.

+

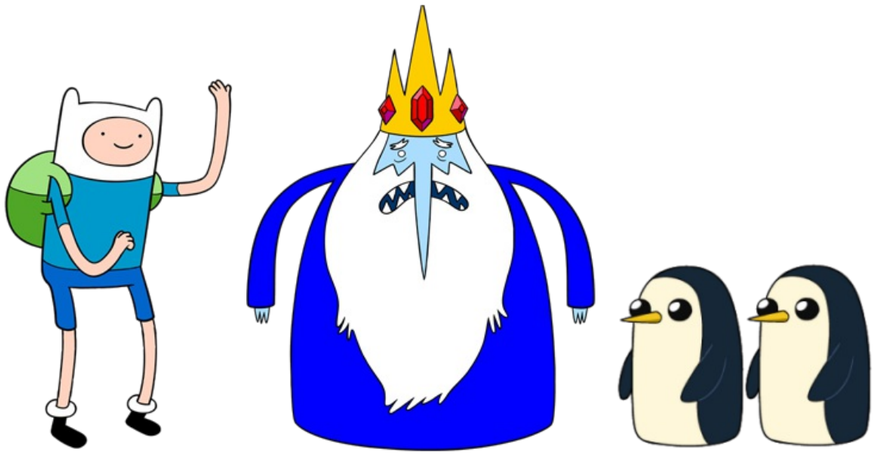
Who was imprisoned?

The boy

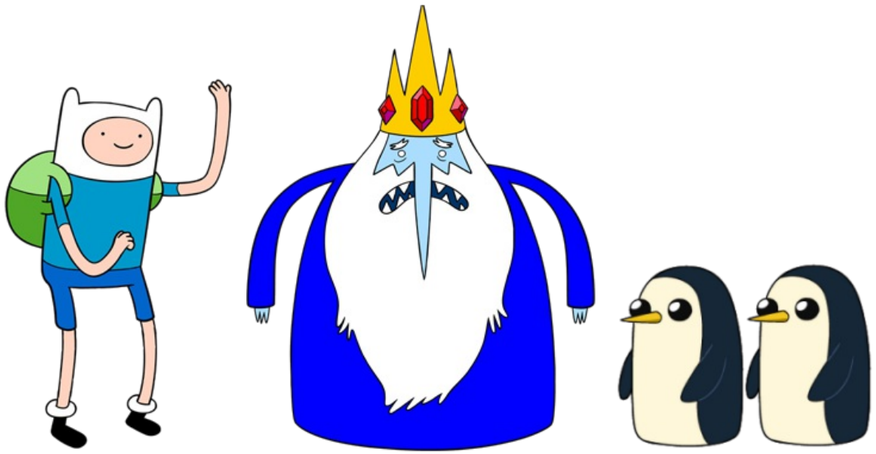
The boy who defeated the king's



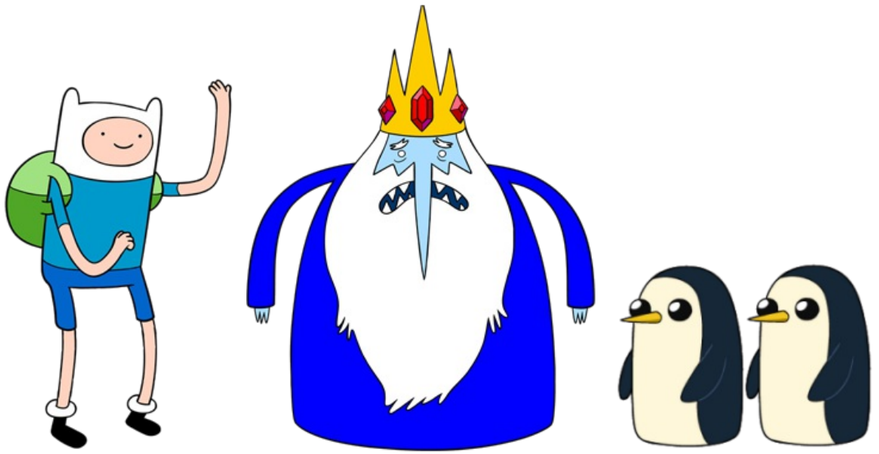
The boy who defeated the king's pets



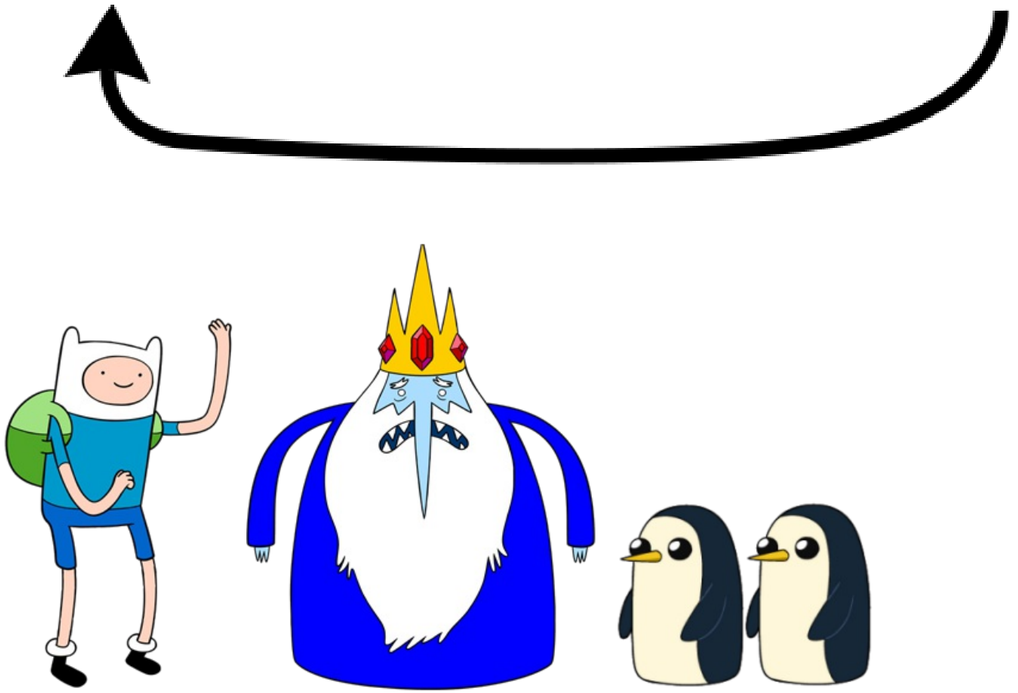
The boy who defeated the king's pets was imprisoned.



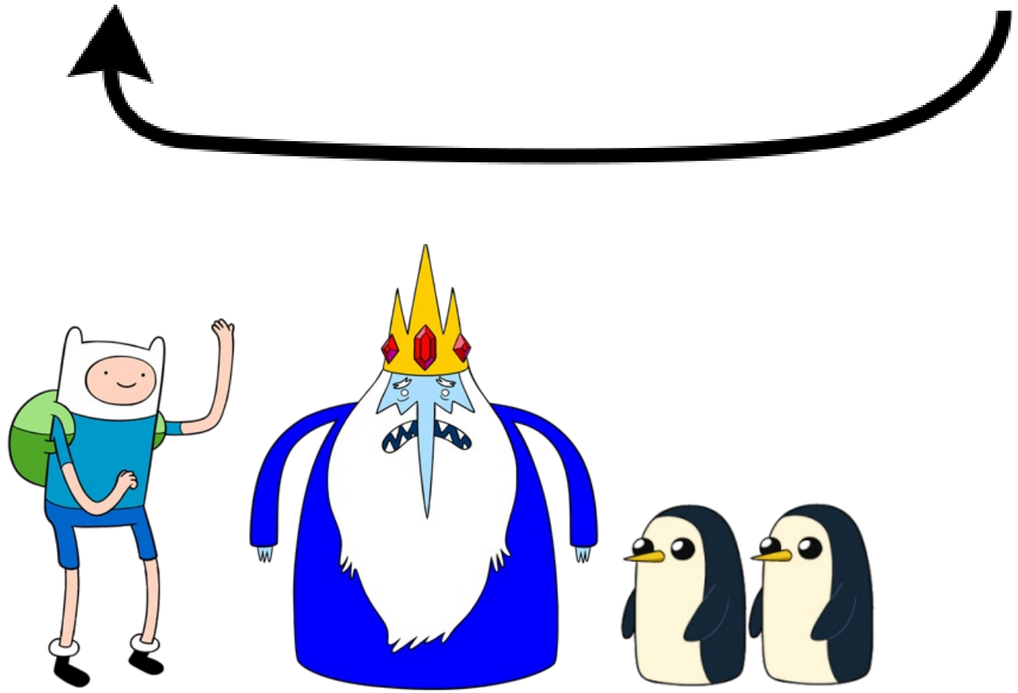
The boy who defeated the king's pets was imprisoned[noun, subject, singular].



The boy who defeated the king's pets was imprisoned[noun, subject, singular].



The boy who defeated the king's pets was imprisoned$_{[\text{noun, subject, singular}]}$.



Account of dependency resolution:

- the retrieval site (e.g., a verb) provides retrieval cues
- retrieval cues distinguish between the target and competitors

Models that assume a cue-based retrieval mechanism:

(1) Activation-based model (Lewis & Vasishth, 2005)

(2) Direct access model (McElree, 2000)

(1) Activation-based model

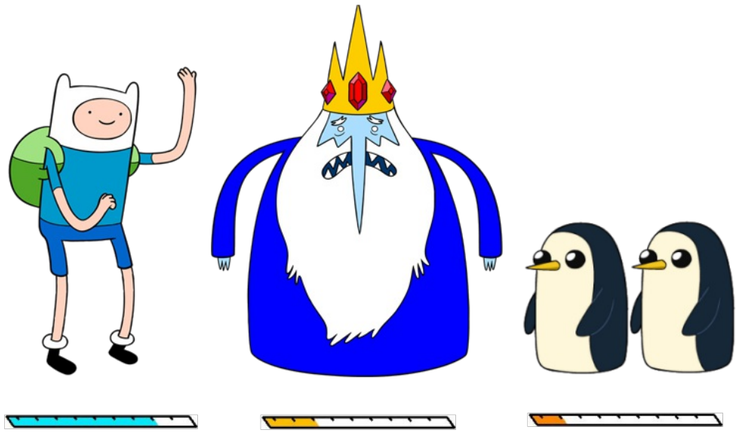
based on ACT-R (Anderson & Lebiere, 1998)

(1) Activation-based model

based on ACT-R (Anderson & Lebiere, 1998)

Words in memory have an activation level, which

- depends on the match with the retrieval cues
- is noisy

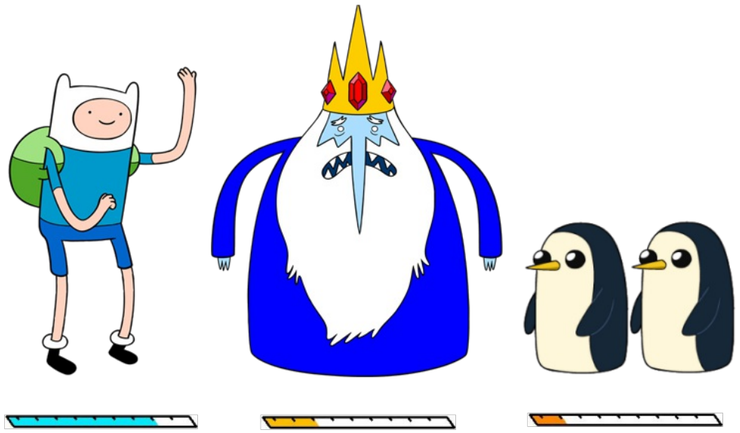


(1) Activation-based model

based on ACT-R (Anderson & Lebiere, 1998)

Words in memory have an activation level, which

- depends on the match with the retrieval cues
- is noisy



The highest activation determines

- which word is retrieved
- the retrieval time ($\propto e^{-Activation}$)

(1) The activation-based model is a Lognormal race between accumulators of evidence

(1) The activation-based model is a Lognormal race between accumulators of evidence

---

$$t_{n,i} \sim lognormal(b - A_{n,i} + k, \sigma)$$

$$t_{n,winner} < t_{n,j}, \forall j \neq winner$$

where:

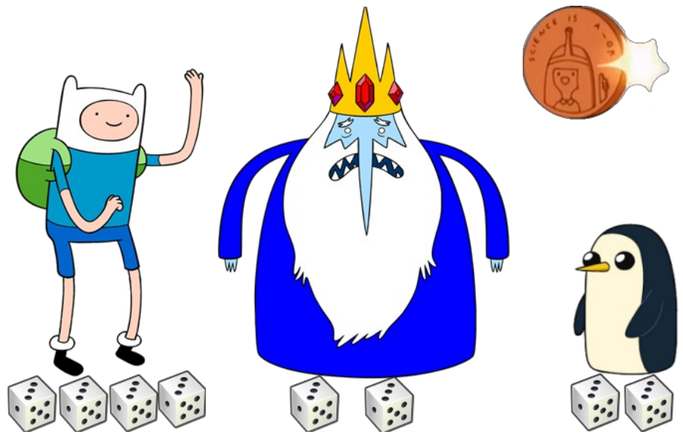
- n: the trial
- i: the item in memory (word)
- A: the rate of accumulation / activation
- t: the time to reach the threshold b

(2) Direct access model

(2) Direct access model

The retrieval of a word in memory

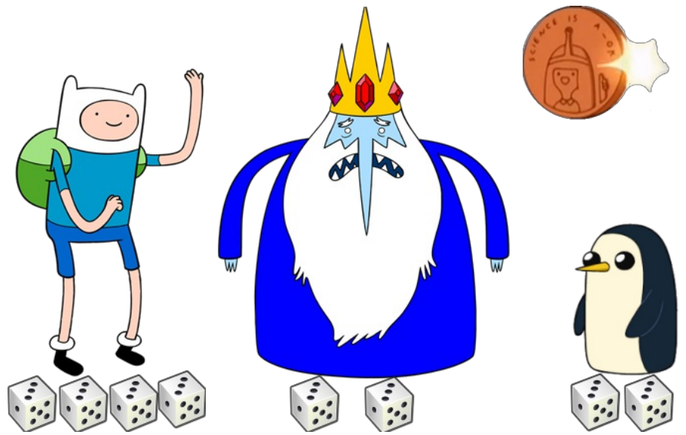
- depends on the match with the retrieval cues
- can be repaired in case of error



(2) Direct access model

The retrieval of a word in memory

- depends on the match with the retrieval cues
- can be repaired in case of error



The observed retrieval time

- is unaffected by the degree of match (i.e. direct access)
- but is inflated by reanalysis (repair mechanism)

(2) The direct access model is a mixture model

(2) The direct access model is a mixture model

$$P(winner_n = correct) = \theta_{correct} + (1 - \theta_{correct}) \cdot P_{reanalysis}$$

(2) The direct access model is a mixture model

$$P(winner_n = correct) = \theta_{correct} + (1 - \theta_{correct}) \cdot P_{reanalysis}$$

• always direct access for incorrect retrievals:

$$t_{n,winner_n \neq correct} \sim lognormal(\mu_{da}, \sigma)$$

• a mixture distribution for correct retrievals:

$$t_{n,winner_n = correct} \sim \begin{cases} lognormal(\mu_{da}, \sigma) & \text{, if there is no reanalysis} \\ lognormal(\mu_{da} + \mu_{reanalysis}, \sigma) & \text{, if there is reanalysis} \end{cases}$$

where

• μ_{da} : location of the distribution of direct access time

• $\mu_{da} + \mu_{reanalysis}$: location of the distribution of repaired retrievals

But how should we think about the retrieval process?

Does the cue-based retrieval mechanism lead to

(1) an activation-based retrieval

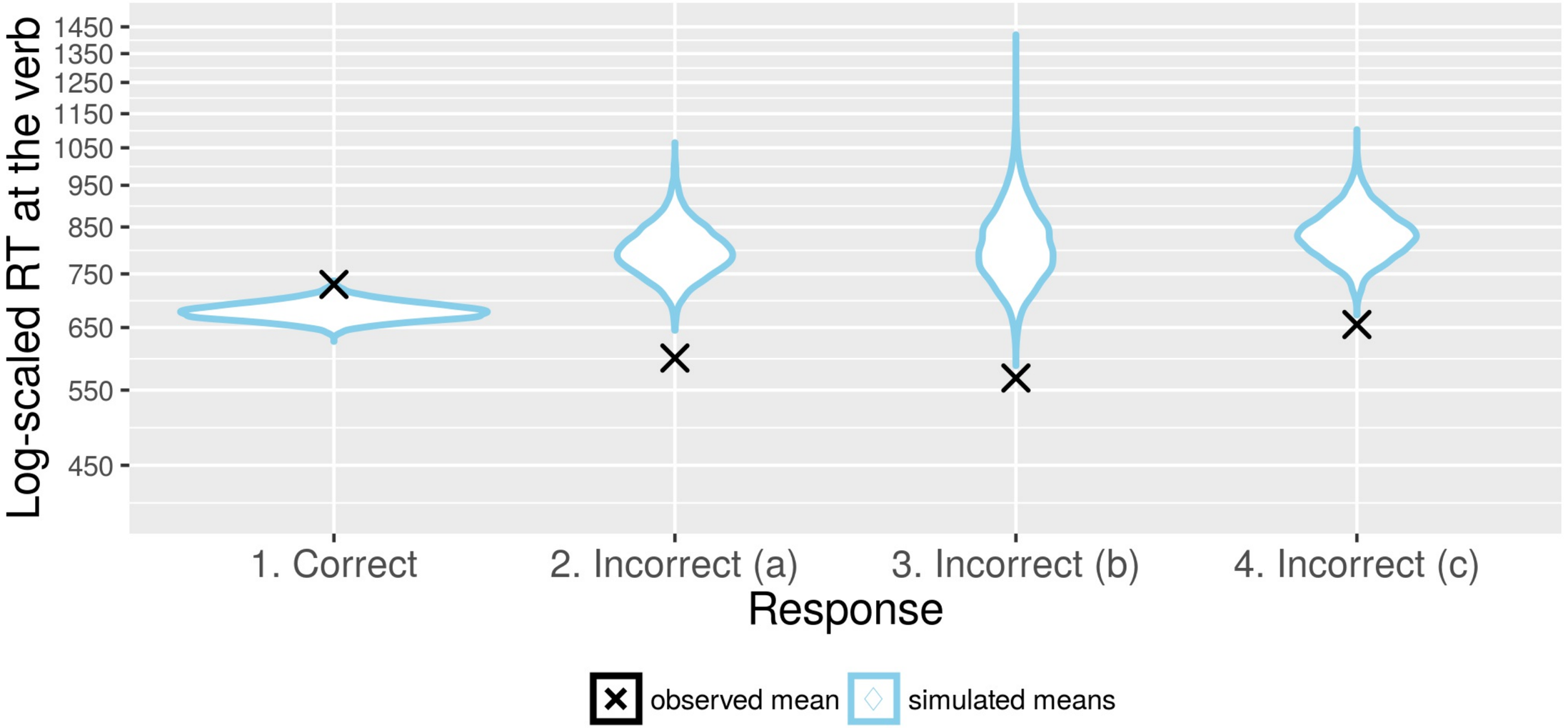
or

(2) the direct access of items in memory?

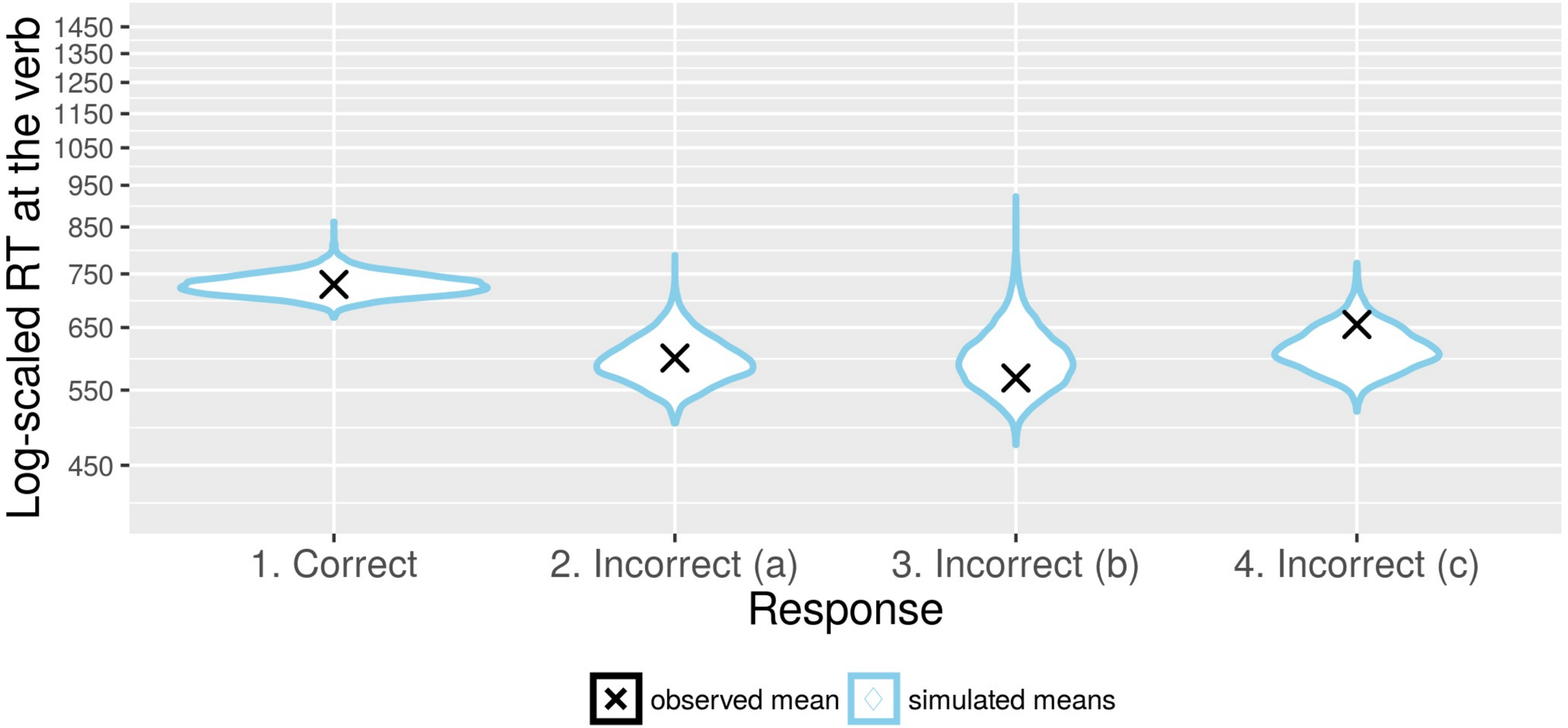
Results

Posterior predictive checks

(1) Activation-based model

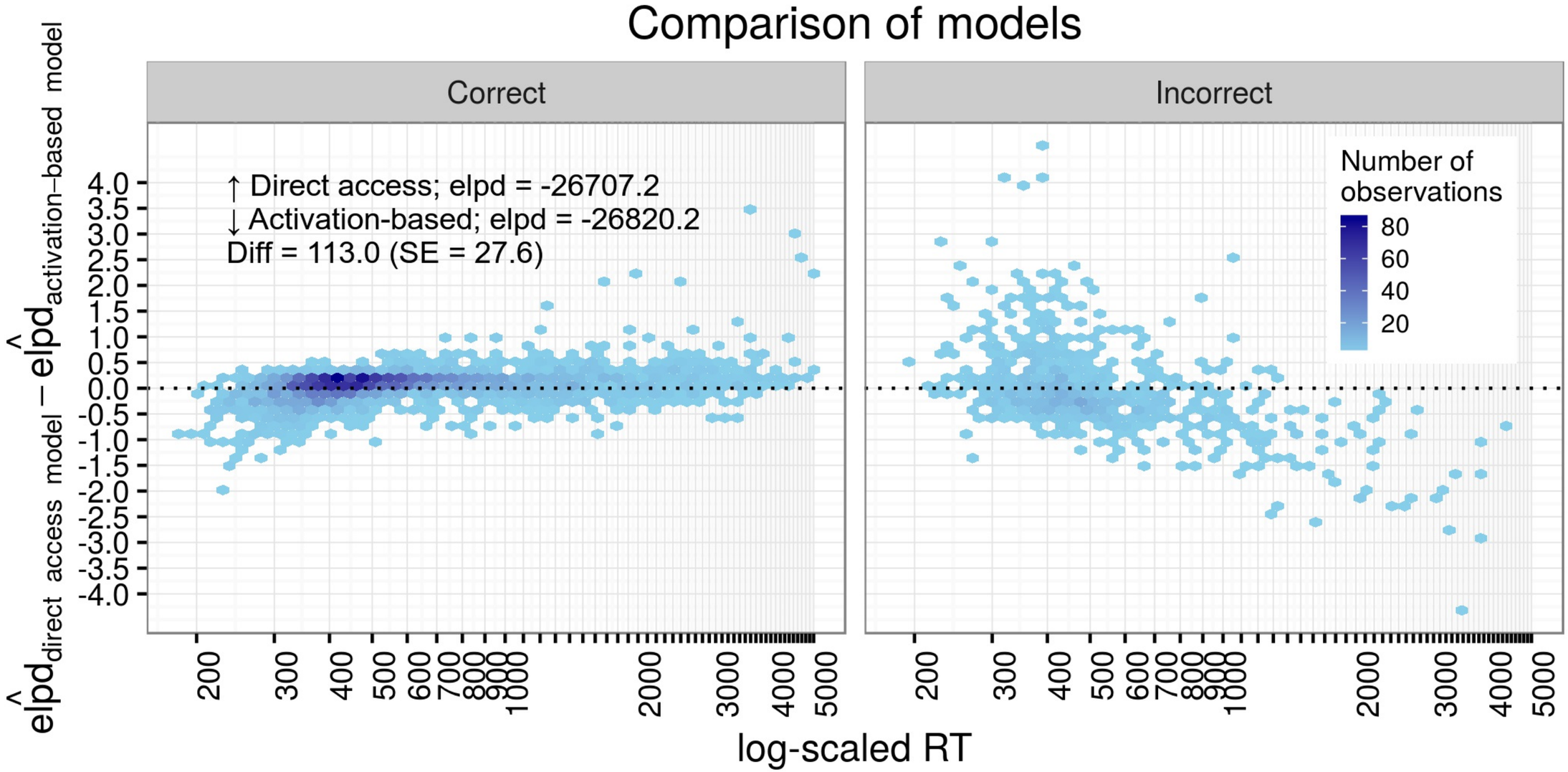


(2) Direct access model



Cross-validation

PSIS-LOO


Comparison of models
Correct
Incorrect
↑ Direct access; elpd = -26707.2
↓ Activation-based; elpd = -26820.2
Diff = 113.0 (SE = 27.6)
Number of observations
80
60
40
20
elpd^direct access model − elpd^activation−based model
log-scaled RT
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
-4.0
200
300
400
500
600
700
800
900
1000
2000
3000
4000
5000

Conclusion

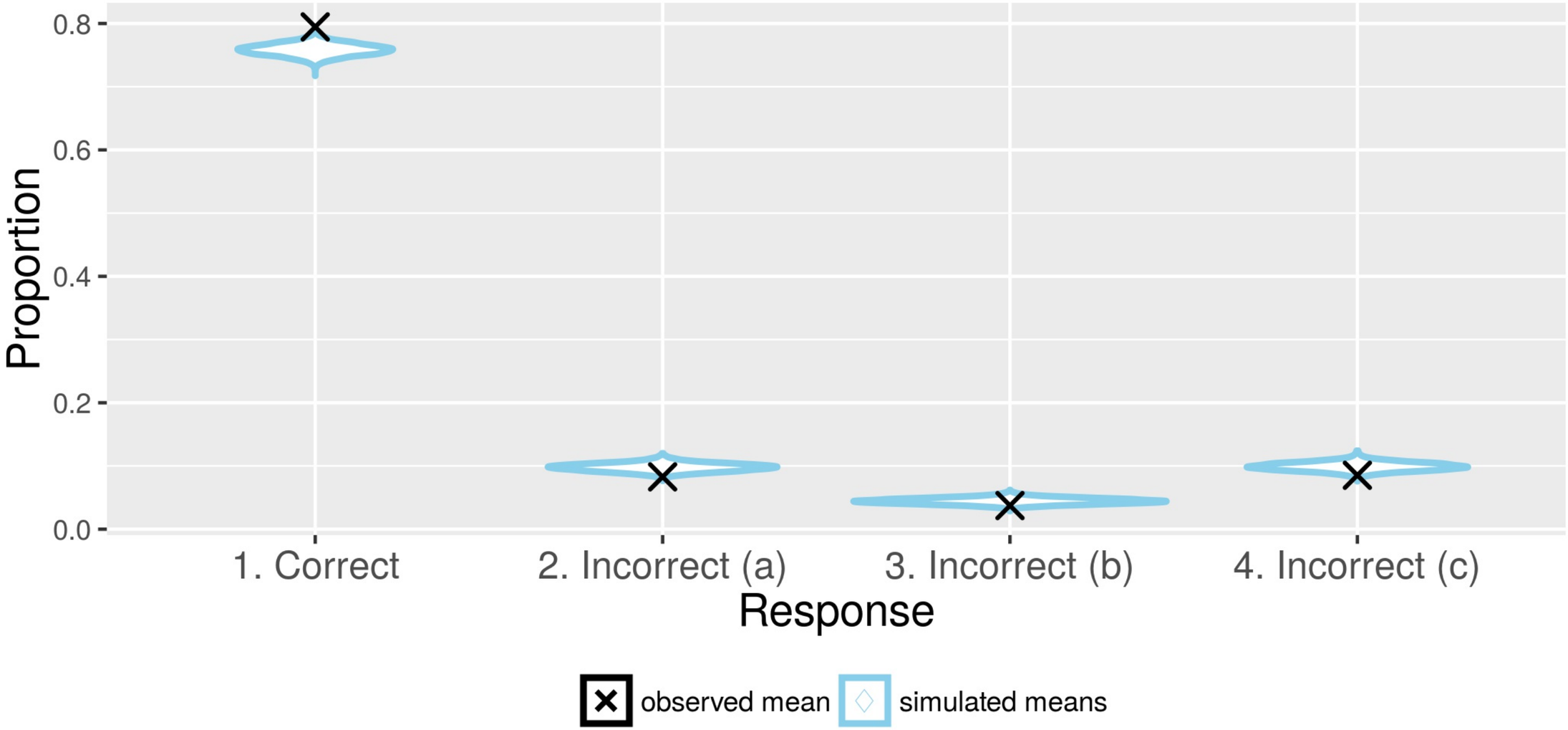
Conclusion

- We evaluated two well-known models of retrieval in sentence comprehension
- The activation-based model cannot account for the pattern in the data
- The direct access model provides a better fit and predictive accuracy than the activation-based model
- This has implications for our better understanding of the relationship between sentence processing and our memory system

Thanks

Appendix

Activation-based model



Direct access model