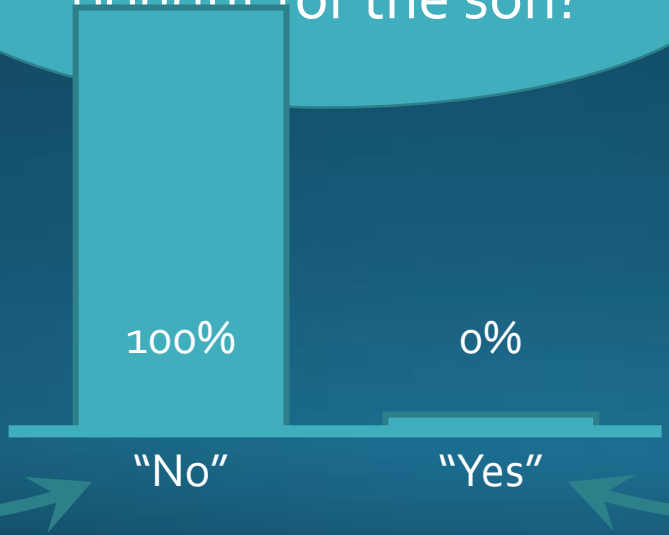
Structure-sensitive noise inference: comprehenders expect exchange errors

Till Poppels and Roger Levy
UCSD Linguistics

The phenomenon

The father bought his son for a bicycle.

Was something bought for the son?



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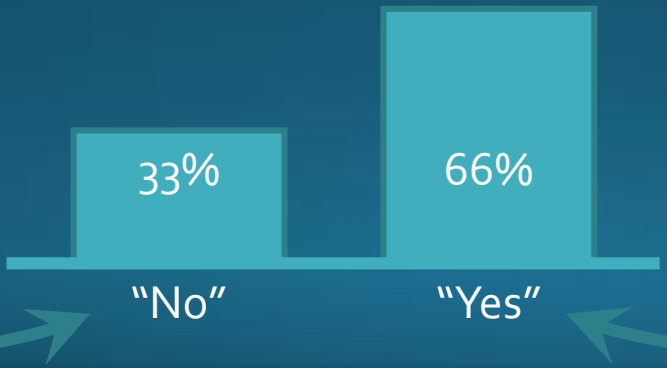
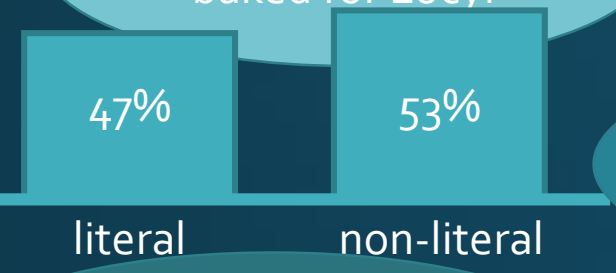


The cook baked Lucy for a cake.

Was something baked for Lucy?

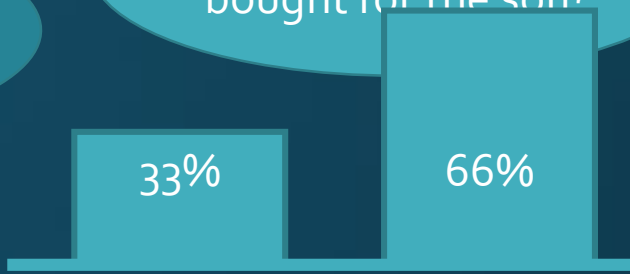


The apprentice fetched a hammer the carpenter.

Was something fetched for the carpenter?

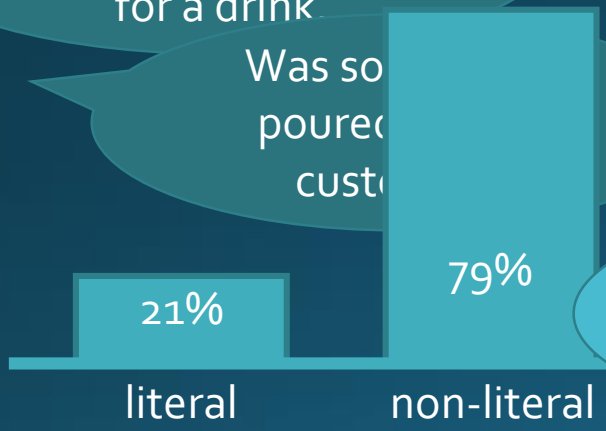
The father bought his son for a bicycle.

Was something bought for the son?



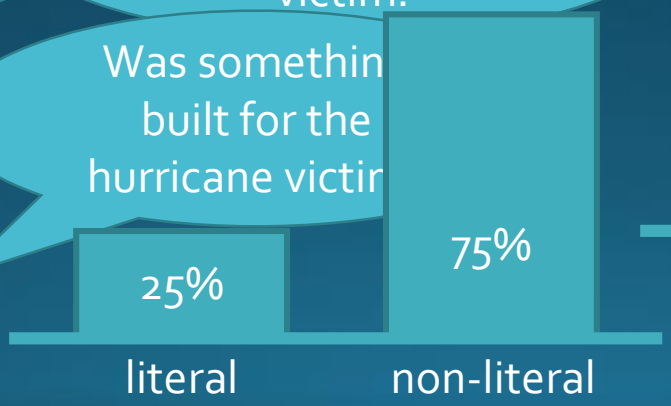
The bartender poured the customer for a drink.

Was so poure cust



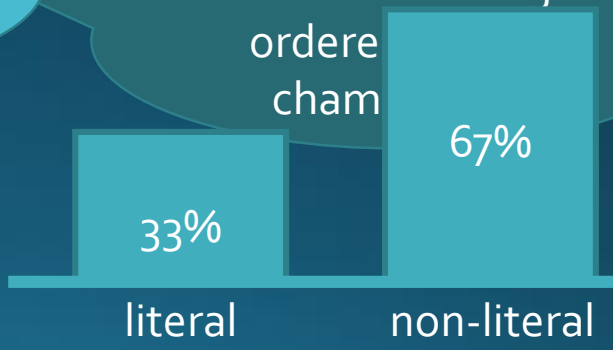
The charity built a house the hurricane victim.

Was somethin built for the hurricane victi

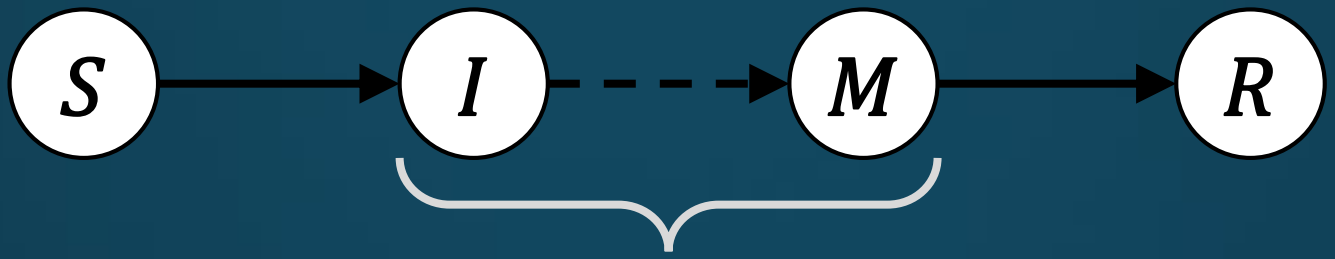


The man ordered his girlfriend for some champagne.

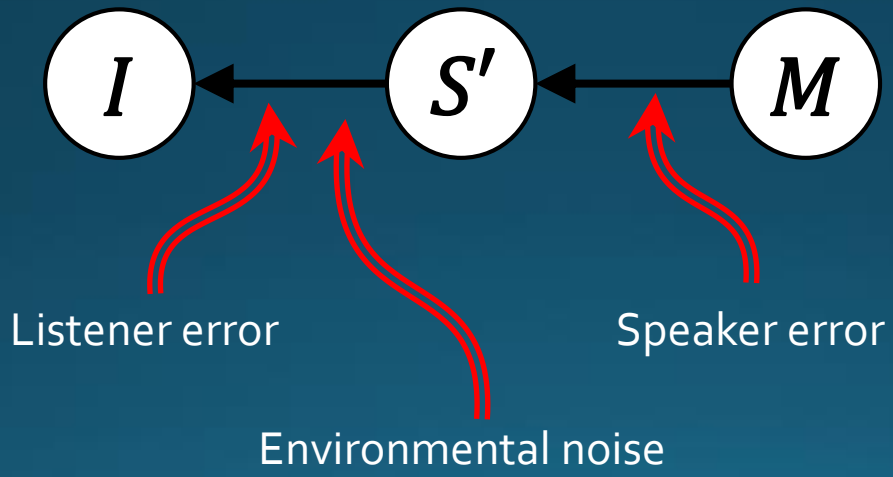
Was something ordere cham



Noisy-channel theory



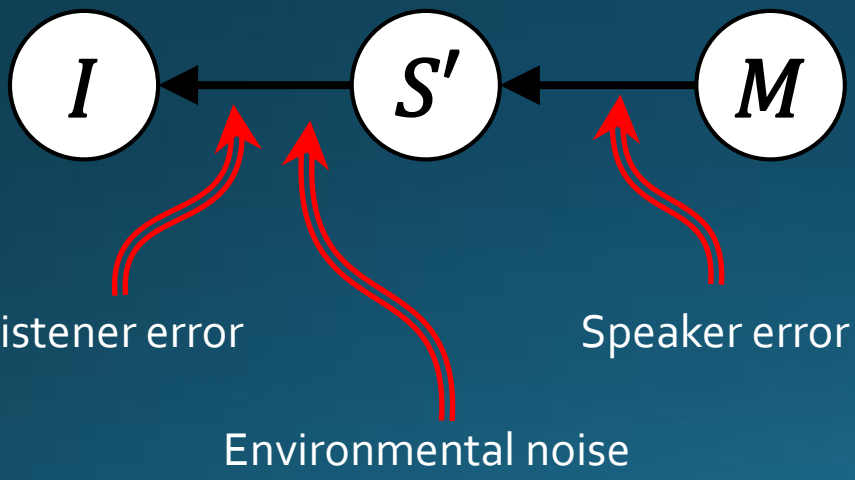
$$P(M|I)$$



Anderson (1990); Levy (2008)

Noisy-channel theory

$$P(M|I) \propto \underbrace{P(I|M)P(M)}$$



Plausibility

Manipulating priors and likelihoods

$$P(M|I) \propto P(I|M)P(M)$$

Was something bought for the son?

Yes — 1 insertion: $P(I|M) = P(ins: for)$ — No

- The father bought his son for a bicycle.
- The father bought his son a bicycle.

$P(I|M) = 1$

Did the dryer shrink something?

Yes — 1 deletion: $P(I|M) = P(del: inside)$ — No

- The t-shirt shrank the dryer.
- The t-shirt shrank inside the dryer.

$P(I|M) = 1$

Did the girl kick something?

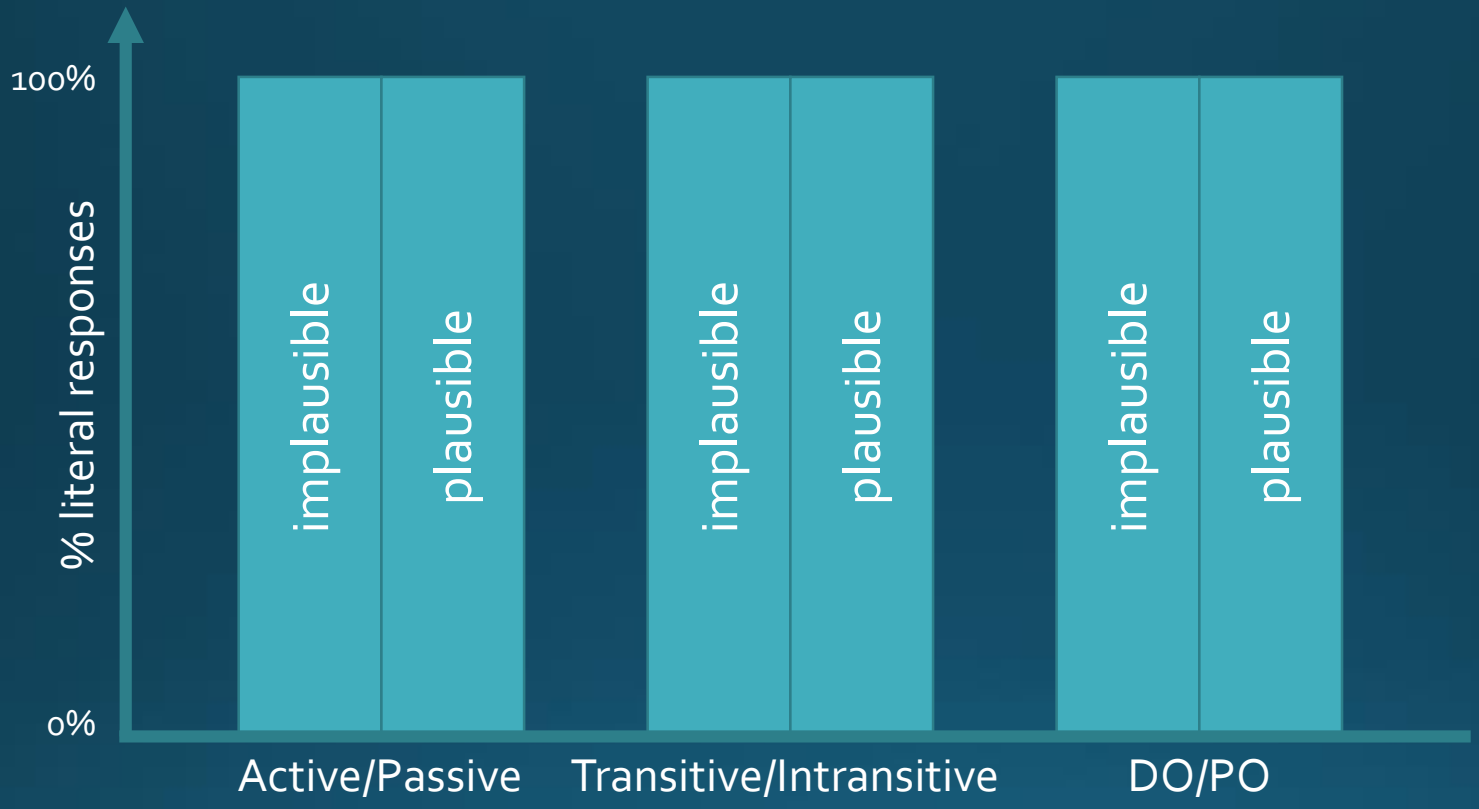
Yes — 2 insertions: $P(I|M) = P(ins: was)P(ins: by)$ — No

- The girl was kicked by the ball.
- The girl kicked the ball
- The ball was kicked by the girl.
- The ball kicked the girl.

2 deletions: $P(I|M) = P(del: was)P(del: by)$

$P(I|M) = 1$

Replicating Gibson *et al.* (2013)



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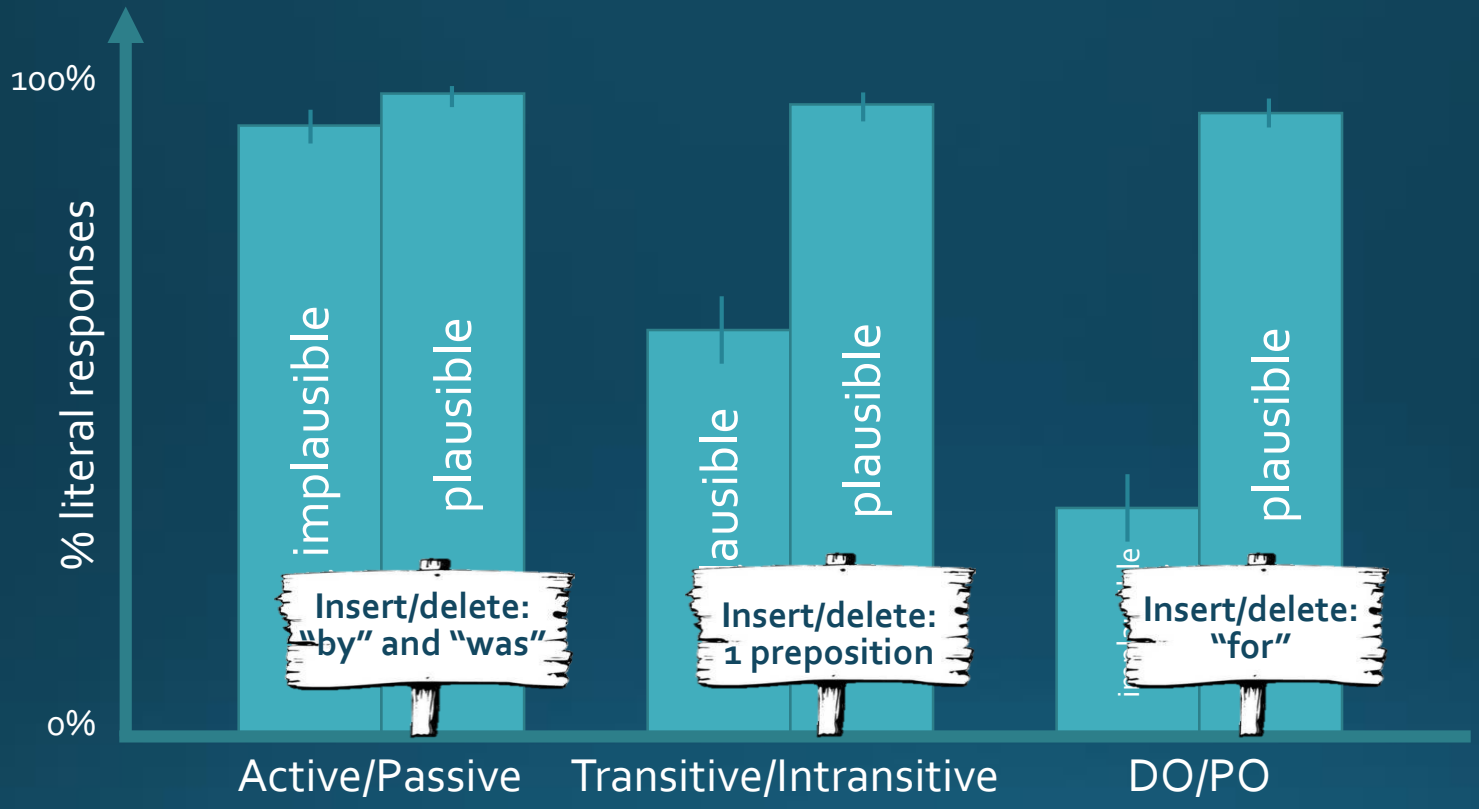


from to

The package fell ~~to~~ the table ~~from~~ the floor.

The case for exchange errors

The package [$_{VP}$ fell $_{PP}$ to the table] [$_{PP}$ from the floor]].

The package fell to the table from the floor.

cf. "spoonerisms" (e.g. MacKay, 1970)

Waste the term → Taste the werm

Fighting a liar → Lighting a fire

Battle ships and cruisers → Cattle ships and bruisers

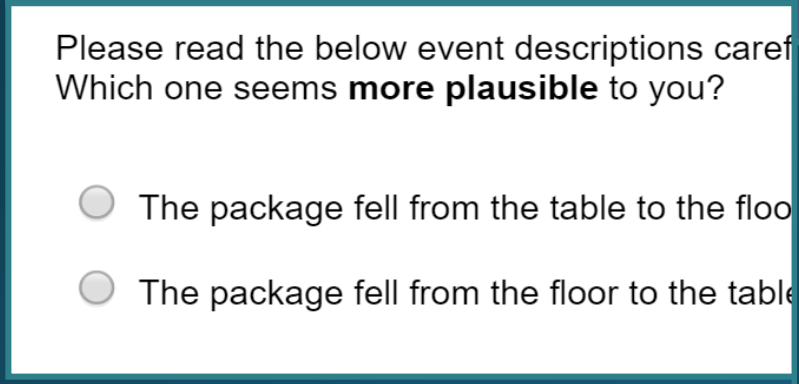
Busy Dean → Dizzy bean

Methods

The package [$_{VP}$ fell …]

implausible 3%	plausible 97%	
[$_{PP}$ to the table] [$_{PP}$ from the floor]	[$_{PP}$ to the floor] [$_{PP}$ from the table]	non-canonical 5%
[$_{PP}$ from the floor] [$_{PP}$ to the table]	[$_{PP}$ from the table] [$_{PP}$ to the floor]	canonical 95%

Plausibility Norming



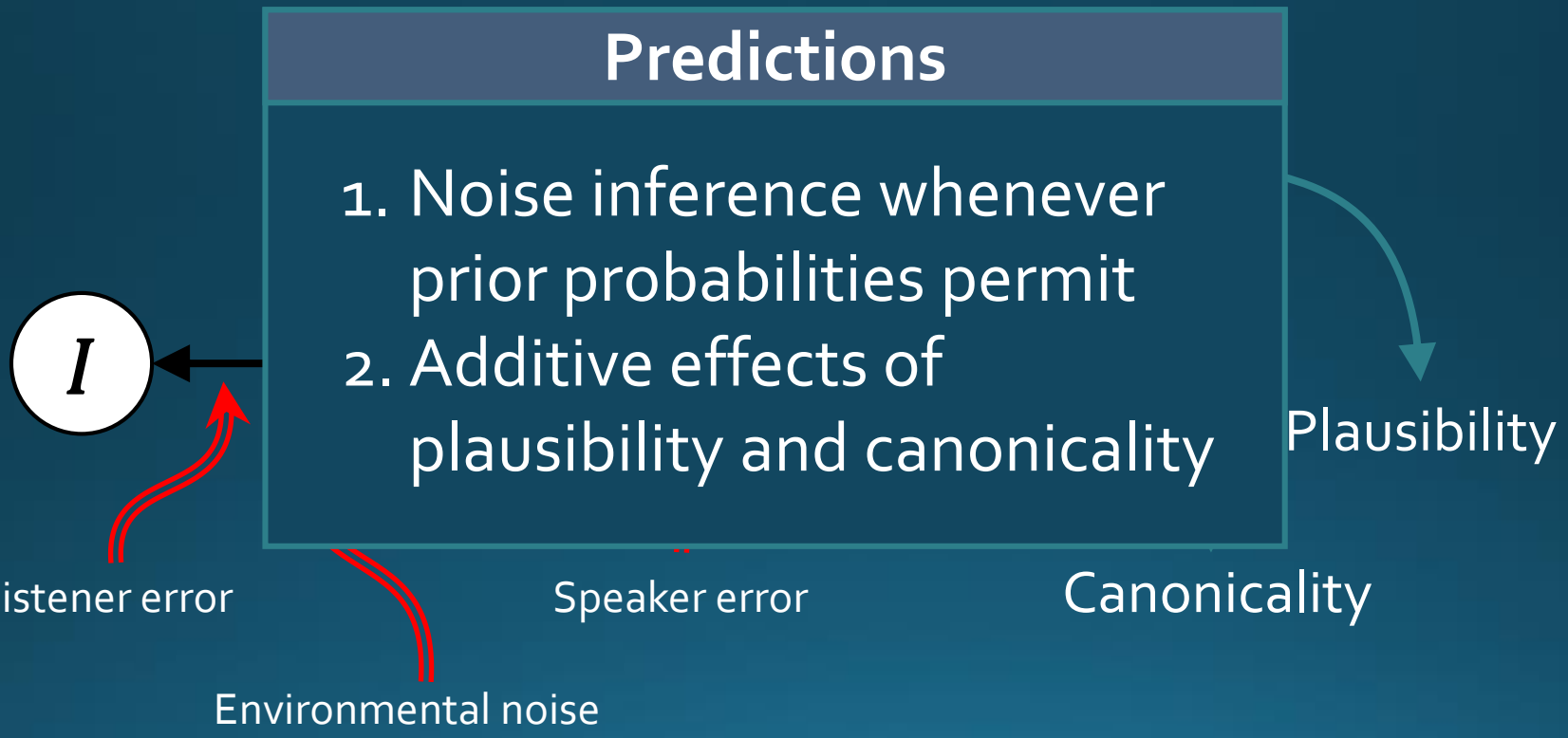
Canonicality Norming

[$_{PP}$ **from** …] [$_{PP}$ **to** …] 95% - 5% [$_{PP}$ **to** …] [$_{PP}$ **from** …]
[$_{PP}$ **with** …] [$_{PP}$ **about** …] 80% - 20% [$_{PP}$ **about** …] [$_{PP}$ **with** …]
[$_{PP}$ **to** …] [$_{PP}$ **about** …] 81% - 19% [$_{PP}$ **about** …] [$_{PP}$ **to** …]
[$_{PP}$ **from** …] [$_{PP}$ **about** …] 67% - 33% [$_{PP}$ **about** …] [$_{PP}$ **from** …]
[$_{PP}$ **for** …] [$_{PP}$ **in** …] 51% - 49% [$_{PP}$ **in** …] [$_{PP}$ **for** …]
[$_{PP}$ **in** …] [$_{PP}$ **at** …] 58% - 42% [$_{PP}$ **at** …] [$_{PP}$ **in** …]

```
response ~ plausibility + canonicality
           + (1 + plausibility + canonicality || item)
           + (1 + plausibility + canonicality || subject)
```

Predictions & Results

$$P(M|I) \propto \underbrace{P(I|M)P(M)}$$



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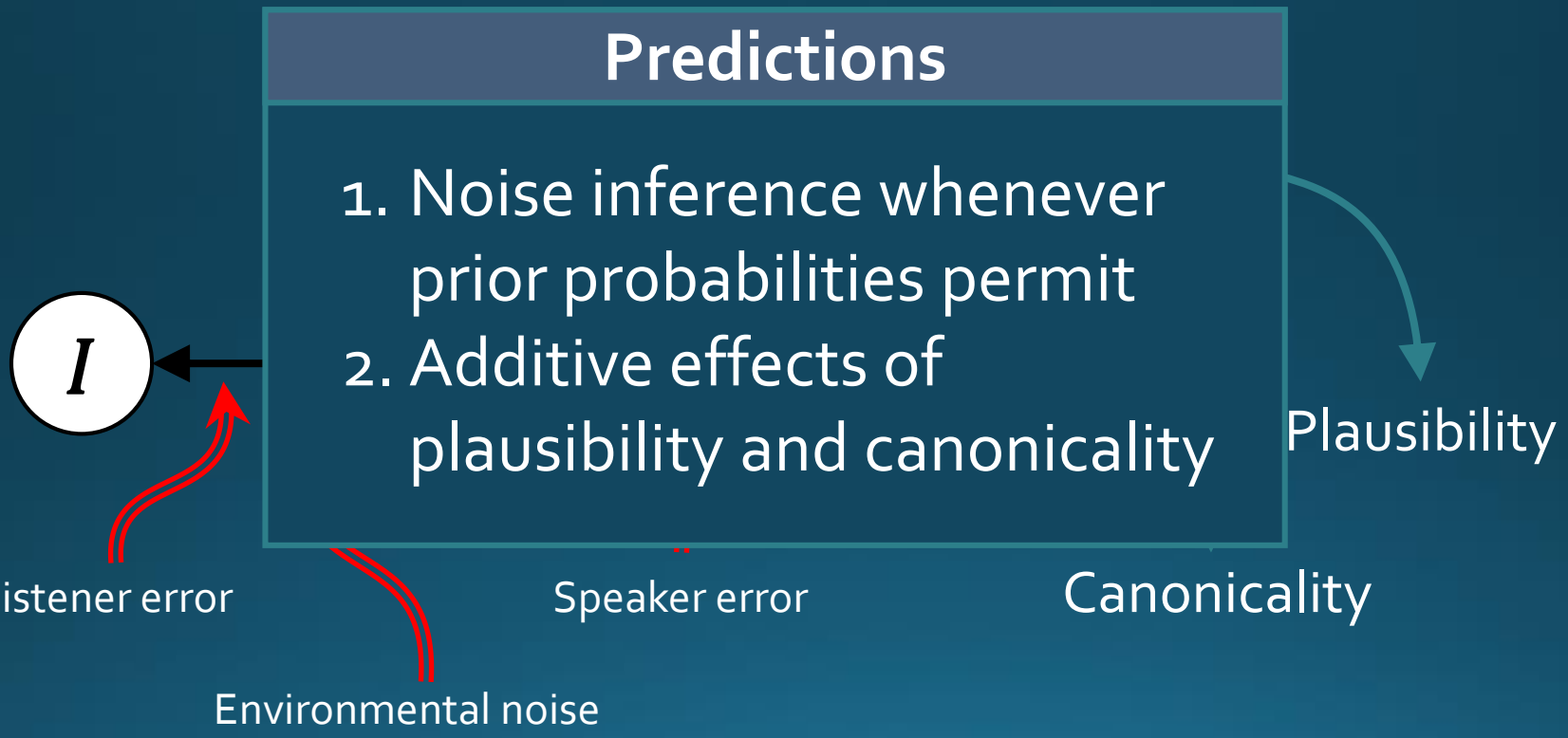

Predictions & Results

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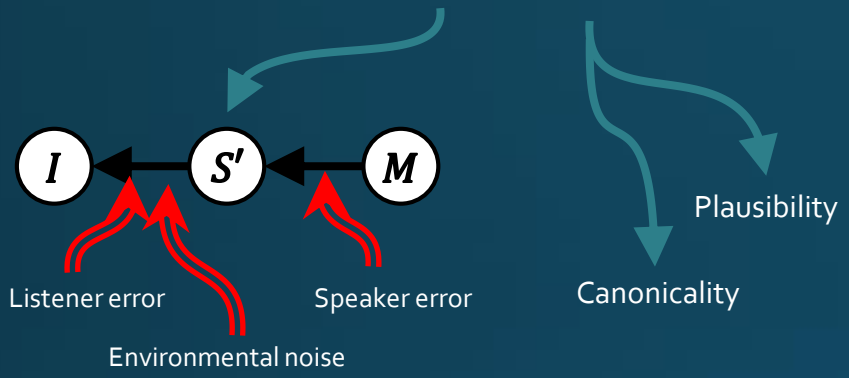
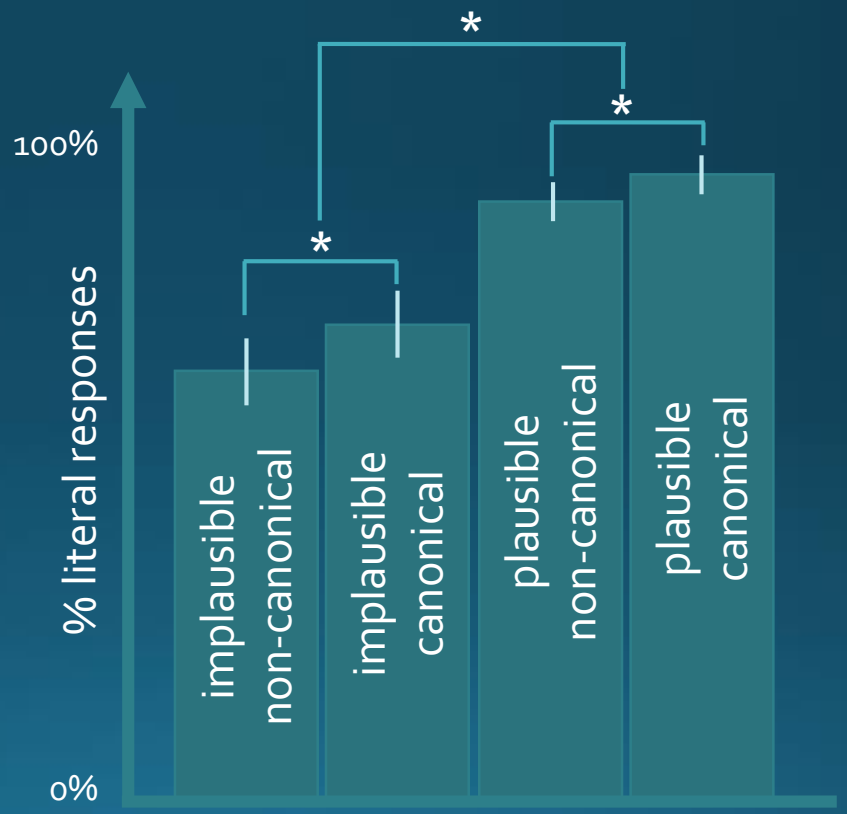
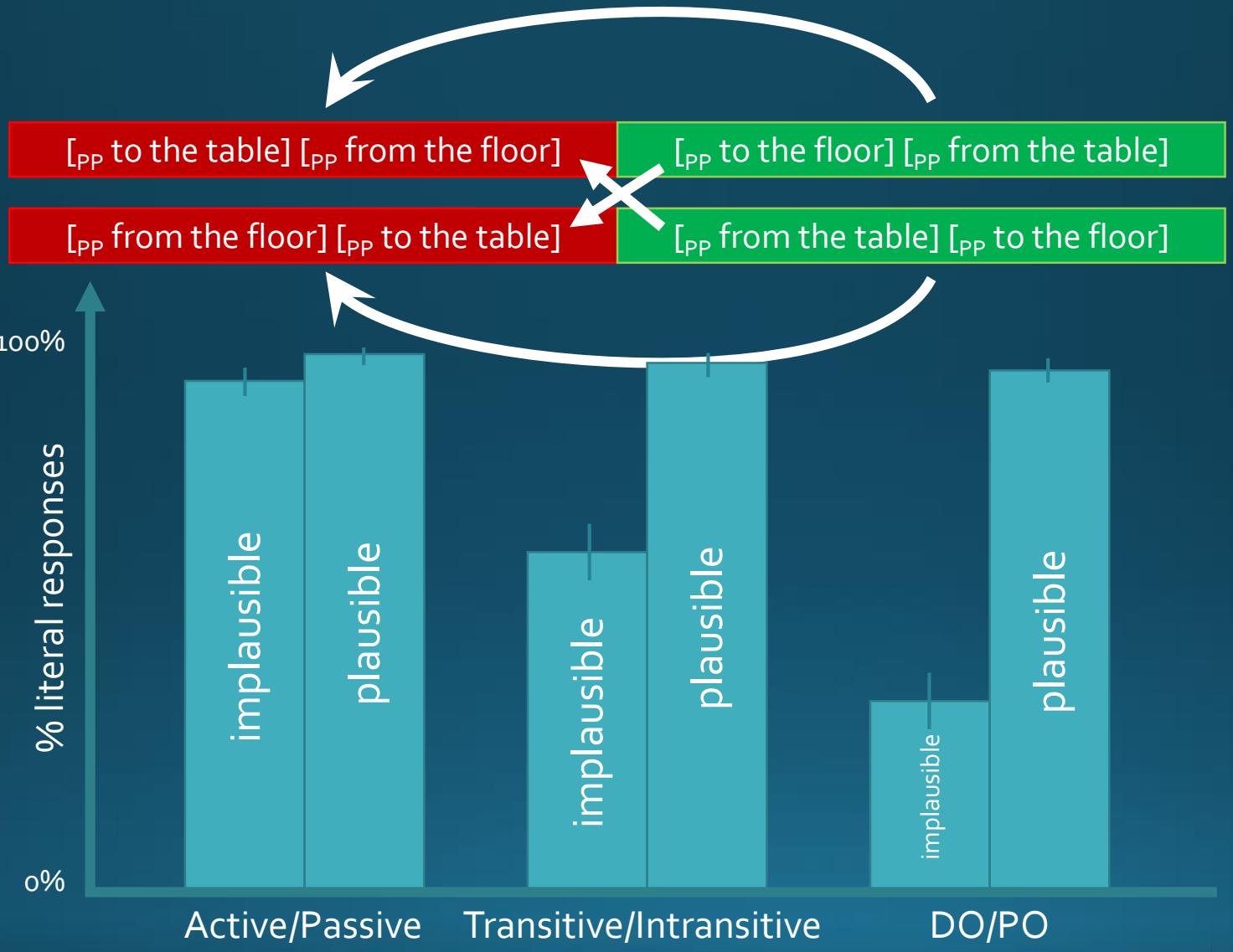


Predictions

1. Noise inference whenever prior probabilities permit ✓
2. Additive effects of plausibility and canonicality ✓



Exchange what?



Exchange what?

Swapping nouns in active/passive?

The ball ~~was~~ kicked ~~by~~ the girl.

[PP to the table] [PP from the floor]

[PP to the floor] [PP from the table]

[PP from the floor] [PP to the table]

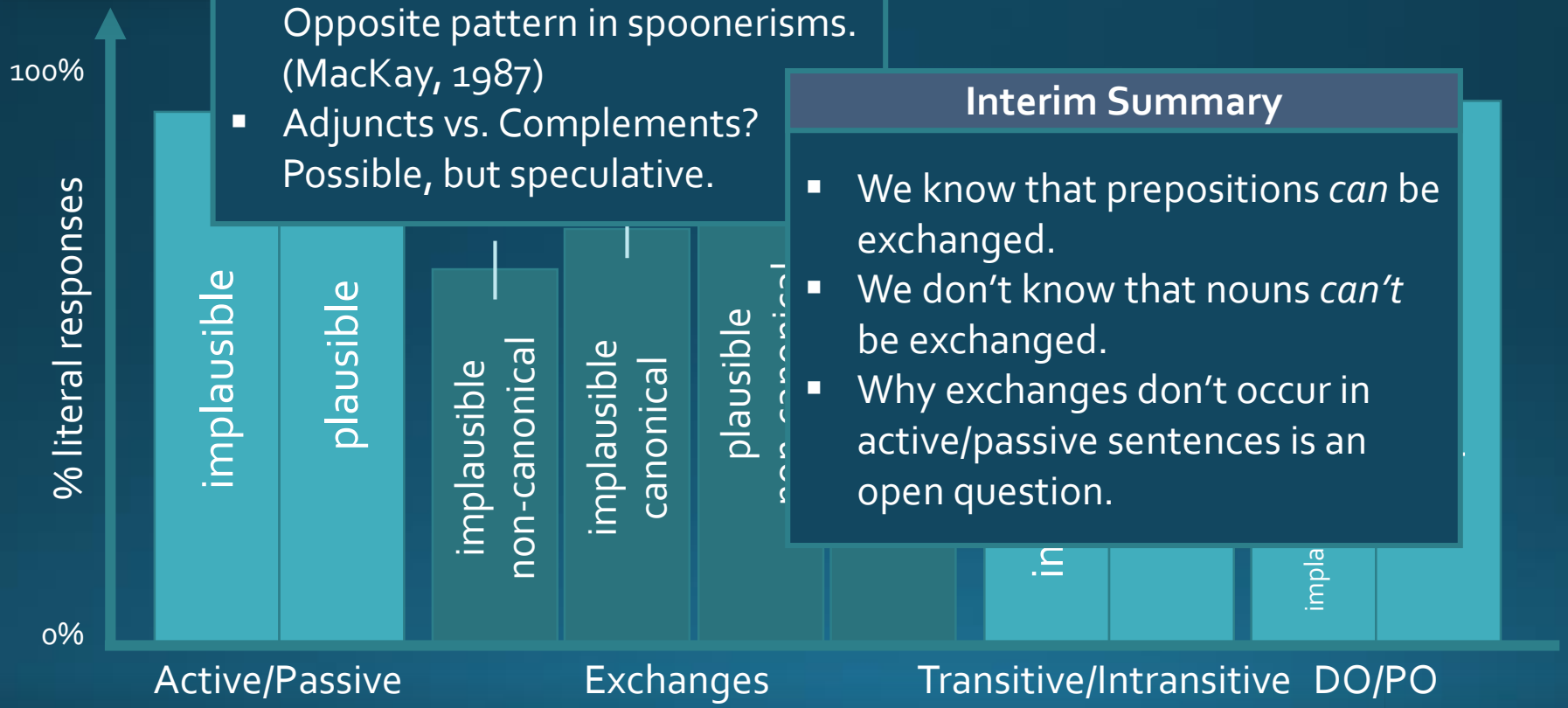
[PP from the table] [PP to the floor]

What's the difference?

- Function vs. content words? Opposite pattern in spoonerisms. (MacKay, 1987)
- Adjuncts vs. Complements? Possible, but speculative.

Interim Summary

- We know that prepositions *can* be exchanged.
- We don't know that nouns *can't* be exchanged.
- Why exchanges don't occur in active/passive sentences is an open question.



2 common concerns

1. Do people REALLY consider
   all conceivable interpretations
   during language comprehension?

"That's not the right kind of process, intuitively."

"That's not a computationally feasible mechanism."

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2 common concerns

Marr (1982)

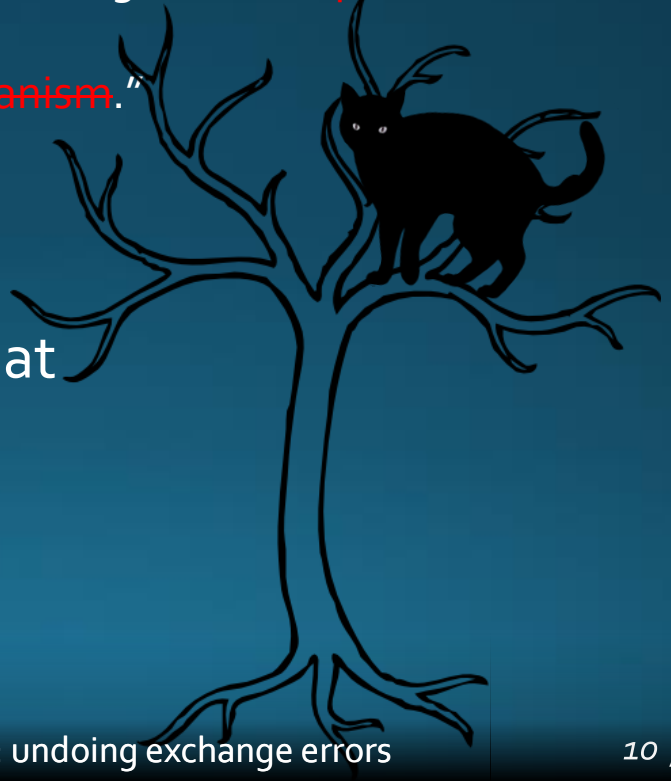
"In order to understand **bird flight**, we have to understand **aerodynamics**; only then do the structure of feathers and the different shapes of birds' wings make sense.

1. Do people REALLY consider all conceivable interpretations during language comprehension?

"That's not the right kind of ~~process~~, ~~intuitively~~."

"That's not a computationally feasible ~~mechanism~~."

2. If we open the door to non-literal interpretations, does that mean that anything goes? What about: "The cat is on the mat."

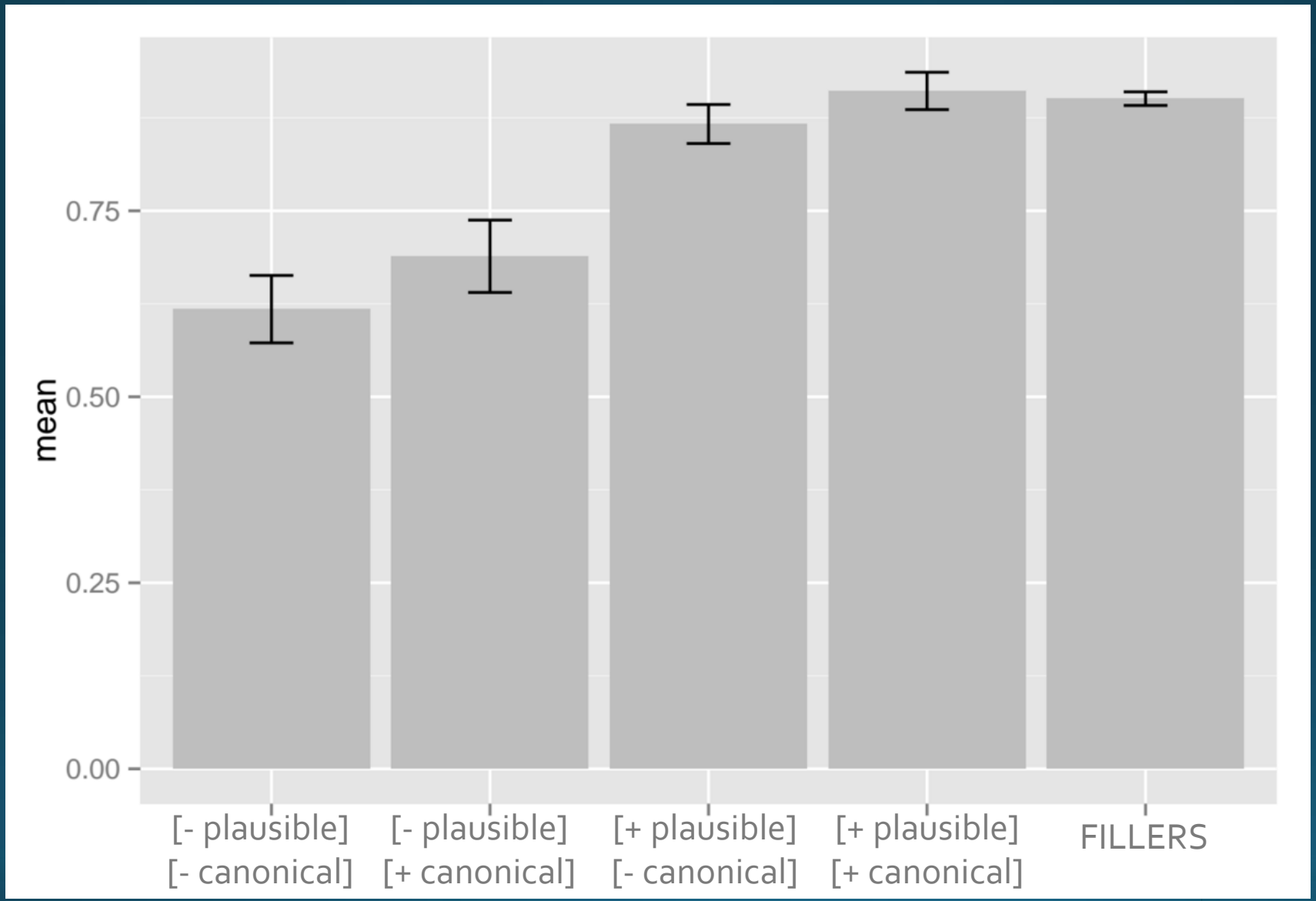


Conclusion

- Noise inference occurs whenever (and to the extent that) literal interpretations are unlikely
- Replicated results with active/passive, transitive/intransitive, and DO/PO materials
- Comprehenders undo **exchange errors**
- Utterance priors driven by content and form

Comprehenders' **noise model** exhibits

Structure sensitivity!

Thank you.

Exchange Results