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?

- **Literal**
  - 100% answered "Yes"

- **Non-literal**
  - No one answered "Yes"
The father bought his son for a bicycle.

Was something bought for the son?

- **Literal**
  - 33% answered "No"
  - 66% answered "Yes"

- **Non-literal**
  - 33% answered "No"
  - 66% answered "Yes"
The cook baked Lucy for a cake.  

Was something baked for Lucy?  

47% literal  
53% non-literal

The bartender poured the customer for a drink.  

Was something poured for the customer?  

21% literal  
79% non-literal

The charity built a house for the hurricane victim.  

Was something built for the hurricane victim?  

25% literal  
75% non-literal

The father bought his son for a bicycle.  

Was something bought for the son?  

33% literal  
66% non-literal

The man ordered his girlfriend for some champagne.  

Was something ordered for the champagne?  

33% literal  
67% non-literal

The apprentice fetched a hammer for the carpenter.  

Was something fetched for the carpenter?  

33% literal  
67% non-literal

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Noisy-channel theory

\[ P(M|I) \]

\[ S \rightarrow I \rightarrow M \rightarrow R \]

Listener error
Speaker error
Environmental noise

Anderson (1990); Levy (2008)
Noisy-channel theory

\[ P(M|I) \propto P(I|M)P(M) \]

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Structure-sensitive noise inference: undoing exchange errors
Manipulating priors and likelihoods

\[ P(M|I) \propto P(I|M)P(M) \]

**Was something bought for the son?**

- Yes: 1 insertion
  \[ P(I|M) = P(\text{ins: for}) \]
- No: 1 deletion
  \[ P(I|M) = P(\text{del: for}) \]

**Did the dryer shrink something?**

- Yes: 1 deletion
  \[ P(I|M) = P(\text{del: inside}) \]
- No: 1 insertion
  \[ P(I|M) = P(\text{ins: inside}) \]

**Did the girl kick something?**

- Yes: 2 insertions
  \[ P(I|M) = P(\text{ins: was})P(\text{ins: by}) \]
- No: 2 deletions
  \[ P(I|M) = P(\text{del: was})P(\text{del: by}) \]
Replicating Gibson et al. (2013)

- % literal responses
- Active/Passive: implausible, plausible
- Transitive/Intransitive: implausible, plausible
- DO/PO: implausible, plausible
The package fell **to the table from the floor.**

The bar chart shows the percentage of literal responses for different sentence structures and types of sentence transformations:

- **Active/Passive:** Implausible responses include insertions or deletions of prepositions and pronouns.
- **Transitive/Intransitive:**Implausible responses include insertions or deletions of prepositions and pronouns.
- **DO/PO:** Implausible responses include insertions or deletions of prepositions and pronouns.

Examples of plausible and implausible responses:

- **Plausible:** The package fell to the table from the floor.
- **Implausible:** The package fell to the table by the floor.
- **Implausible:** The package fell to the floor for the table.
The package fell to the table from the floor.

cf. “spoonerisms” (e.g. MacKay, 1970)

Waste the term → Taste the worm
Fighting a liar → Lighting a fire
Battle ships and cruisers → Cattle ships and bruisers
Busy Dean → Dizzy bean
Methods

The package $[\text{VP fell}]$

Plausibility Norming

Please read the below event descriptions carefully. Which one seems more plausible to you?

- The package fell from the table to the floor
- The package fell from the floor to the table

response $\sim$ plausibility + canonicality

+ (1 + plausibility + canonicality $||$ item)
+ (1 + plausibility + canonicality $||$ subject)

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 ...] |
| [pp for ...] [pp in ...] 51% - 49% [pp in ...] [pp for ...] | [pp in ...] [pp at ...] 58% - 42% [pp at ...] [pp in ...] |
Predictions & Results

\[ P(M|I) \propto P(I|M)P(M) \]

**Predictions**

1. Noise inference whenever prior probabilities permit
2. Additive effects of plausibility and canonicality
Predictions & Results

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**Predictions**

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

<table>
<thead>
<tr>
<th>% literal responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>implausible non-canonical</td>
</tr>
</tbody>
</table>

Legend:
- Implausible non-canonical
- Implausible canonical
- Plausible non-canonical
- Plausible canonical

- Canonicality
- Plausibility

Listener error
Speaker error
Environmental noise
Exchange what?

[pp to the table] [pp from the floor] [pp from the table] [pp to the floor]

Implausible Plausible Implausible Plausible

% literal responses

0% 100%

Active/Passive Transitive/Intransitive DO/PO

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Swapping nouns in active/passive?

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

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.”
2 common concerns

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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.”

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.”
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

[Bar chart showing mean values for different conditions: [- plausible] [- canonical], [- plausible] [+ canonical], [+ plausible] [- canonical], [+ plausible] [+ canonical], and FILLERS. Each condition is represented by a bar with error bars indicating variability.]