Two-year-olds process negation online: Evidence from eye-tracking

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An apparent paradox:

**Two-year-olds** seem to grasp the meaning of “not”

- 2-year-olds spontaneously use negation as denial
  
  e.g. ‘Not a teddybear’  
  
  (Pea 1978, Bellugi 1967)

- **18-27-month-olds** grasp the truth functional meaning of “not” in offline search tasks
  
  (Austin et al. 2014, de Carvalho et al. 2019)

**BUT** online preferential looking tasks don’t confirm

- **2-3-year olds** struggle to understand negative utterances without supportive discourse context and salient QUD
  
  (Nordmeyer & Frank 2014)

- **30-month-olds** only succeed with contrastive block of affirmatives preceding negation
  
  (Reuter et al. 2018)

But **object relatives** might be too complex?

→ acquired between age 4-6  
  
  (Friedmann & Novogrodsky, 2004)
Introduction

Acquisition of Negation

But **object relatives** might be too complex?

→ acquired between age 4-6  (Friedmann & Novogrobsky, 2004)
**Research Questions**

This study: probing negation using *simple* declaratives

- **RQ1.** Do **2-year-olds** understand the truth-functional contribution of “not”?

- **RQ2.** What is the time course of this processing?
  - Is negative meaning derived from affirmative?
  - **two-step model**
    - “the door is not closed”
  - Or is negation immediately processed?
  - **one-step model**
    - (Tian et al. 2010 *inter alia*, Burnsky et al. 2017)

**Question Under Discussion (QUD):**

“Is the door closed?”

“The door is not closed”
Methods

Procedure: Visual World Paradigm
✓ adapted preferential looking paradigm in the form of a guessing game
✓ Test sentence: simple declarative
  e.g., It’s not a bee
✓ Context: salient Question under Discussion (QUD)
  e.g., who’s hiding?
✓ Scene: closed set of alternatives

Participants
N = 15 (M = 2;04; SD = 0;04)
✓ NYC area
✓ 5 excluded due to track loss (original N = 20)
✓ Projected N = 25 (testing stopped due to COVID)

Credit to Sarah Phillips
Methods: Sample trial

1. Trial setup
   Look, this is a bee!
   Look, this is an ant!

2. Probe
   Who’s hiding?

3. Test sentence
   a. **POSITIVE**: It’s also a bee (N=4)
   b. **NEGATIVE**: It’s not a bee (N=4)
   c. **MODAL**: It’s maybe a bee (*not discussed*)

4. Probe 2
   Who is it?

5. Reveal
   Look!
Methods: Experimental trial
Greater proportion of looks to the unmentioned animal **0-1500ms** (Kaup et al. 2006) in **NEGATIVE vs POSITIVE** condition if negation is computed in a one step (vs 2-step) manner.

**Predictions**

<table>
<thead>
<tr>
<th></th>
<th>One step</th>
<th>Two step</th>
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<tbody>
<tr>
<td></td>
<td><img src="#" alt="Graph" /> Proportion of looks to the UNMENTIONED animal</td>
<td><img src="#" alt="Graph" /> Proportion of looks to the MENTIONED animal</td>
</tr>
<tr>
<td>Negative</td>
<td><img src="#" alt="Graph" /> 'It’s not a bee'</td>
<td><img src="#" alt="Graph" /> 'It’s also a bee'</td>
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<tr>
<td>Positive</td>
<td><img src="#" alt="Graph" /> 'It’s also a bee'</td>
<td><img src="#" alt="Graph" /> 'It’s also a bee'</td>
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Analysis

- Analysis window: 1500 ms from *noun onset*
- Trials with >25% trackloss 2500 ms before *noun onset* and 5000 ms after were removed (+-10%)
- Cluster based permutation with 10,000 permutations and threshold of $p < 0.05$ (Maris & Oostenveld, 2007)
- Analyses were conducted in using the eyetrackingR package (Dink & Fergusen, 2015)
Results: Unmentioned

It’s not/also a bee

Proportion looking to the unmentioned animal

Time in milliseconds (ms)

Analysis window (0-1500 ms)

Question: “Who is it?”

Reveal: “Look!”

Significant effect for negative > positive in analysis window of 0-1500ms with cluster at 300-800 ms

bin size = 100ms
Results: Mentioned

- No significant difference between conditions in analysis window of 0-1500ms
- POSITIVE not behaving as expected

bin size = 100ms
We found evidence 2-year-olds:
- Understand the truth-functional meaning of “not”
- Immediately engage in this computation within 1500ms of its occurrence
  → in line with a one-step model of comprehension
These results are in contrast with some prior work

- 4-year-olds spend more time looking at the positive counterpart (Nordmeyer & Frank 2014)
- “identifying the referent of negation requires ruling out the named object” p.36

- both adults and 4-5 year-olds activate positive counterpart in the processing of negation (Doyle et al. 2019)

But in line with others,

- no differences in processing time and accuracy between affirmative and negation sentences in 3-year-olds (Reuter et al. 2018)

- “looks to the affirmative referent in prior studies are a consequence of pragmatic accommodation of the negative and not a necessary step in the semantic processing of negation” p.379
Evidence against two-step model?

- Our results are compatible with two possibilities

1. Evidence for two-step processing (i.e. initial activation affirmative counterpart) is artefact of task design (Tian et al. 2010)

   - without salient QUD or context for negation
   
   participants accommodate and assertive QUD

   “the door is not closed”

Why would you talk about what’s not the case??
Evidence against two-step model?

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  “the door is not closed”

Maybe it’s because the QUD is: “Is the door closed?”
Evidence against two-step model?

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“the door is not closed”
Discussion
One or Two Steps?

Evidence against two-step model?

✔ Our results are compatible with two possibilities

2. Two-step processing is **skipped** when there is salient QUD and pragmatic context

→ e.g. because of pre-activation of alternatives?

→ semantics of question thought to be set of its possible answers (e.g. Hamblin 1973, Karttunen 1977)

“Who’s hiding?”
Evidence against two-step model?

- Our results are compatible with two possibilities:
  2. Two-step processing is **skipped** when there is salient QUD and pragmatic context
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“It’s not a bee”
Notably,

- Our paradigm does not follow classic linking hypothesis where looking = searching for referent (the referent is the *hidden* character)
- Looking behavior seems guided by predictions
- Expands our methodological repertoire for online processing of proposition level operators
Conclusion

2-year-olds compute negation immediately within 1500 ms of its occurrence

- in preferential looking paradigm with eye-tracking

**when provided with:**

- simple declarative sentences
- salient Question under Discussion (QUD)
- closed set of alternatives

Compatible with one-step model of negation processing (e.g. Tian et al. 2010, Reuter et al. 2018)
Acknowledgements

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References

Appendix: Looks to Hidden

[Graph showing the proportion looking to the hidden animal over time in milliseconds (ms)]

Proportion looking to the hidden animal

Time in milliseconds (ms)
Appendix: Modal mentioned
Appendix: Modal

Proportion looking to the unmentioned animal

Time in milliseconds (ms)
Appendix: Modal hidden
Appendix: Individual variation

- Cluster of outliers skew very young (<28 months)
- Less variation in the NEGATIVE condition compared to the POSITIVE condition.
- Effect of negation fairly robust across age range.
Appendix: Individual variation mentioned

Some outliers in both conditions are younger than 30 months.

Still, lots of variation in the ALSO condition.

Effect possibly driven by alternatives generated by also.