# It's all in your head: How to get abstract representations in there

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# Questions

- How are grammar and lexicon acquired (at the same time)?
  - How do children acquire abstract phonological representations for words from the speech signal?
    - How is final devoicing acquired, i.e. how do children acquire the distinction pont/pond?

# Answers

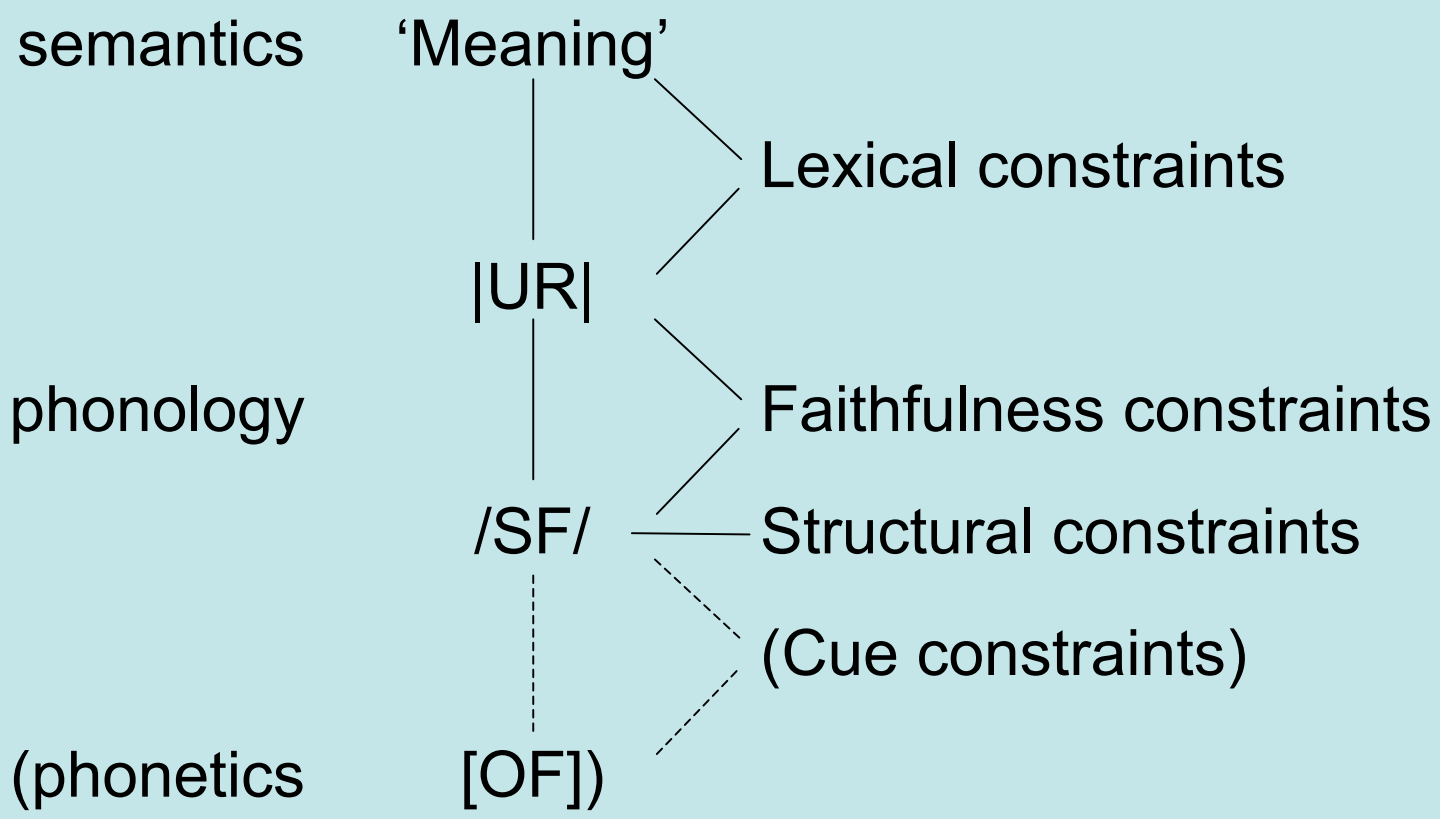
- Grammar and lexicon can be learned simultaneously with a constraint-based grammar and lexicon
  - Learners/speakers can choose between different surface forms and different underlying forms
    - Learners can acquire final devoicing with the help of alternation (in e.g. singular and plural forms).

# Final devoicing

- e.g. Dutch:

| | Singular | Plural |
|---|---|---|
| pont ‘ferry’: | [pɔnt] | [pɔntə] |
| pond ‘pound’: | [pɔnt] | [pɔndə] |

# The model




Apoussidou 2007, Boersma 2007

# A paradigm of final devoicing

| | Singular | Plural |
|---|---|---|
| ‘ferry’ | /pɔnt/ | /pɔntə/ |
| ‘pound’ | /pɔnt/ | /pɔndə/ |
| ‘coat’ | /bɔnt/ | /bɔntə/ |
| ‘union’ | /bɔnt/ | /bɔndə/ |

# An artificial language

| | Singular | Plural |
|---|---|---|
| Morpheme 1: | /tat/ | /tate/ |
| Morpheme 2: | /tat/ | /tade/ |
| Morpheme 3: | /dat/ | /date/ |
| Morpheme 4: | /dat/ | /dade/ |

# The initial grammar

Structural constraints:

- NoVoicing
- NoSyllFinalDevoicing
- InterVocalicVoicing

Faithfulness:

- IdVoicing

Lexical constraints:

- *|tat| ‘morph1’
- *|tad| ‘morph1’
- *|tat| ‘morph2’
- *|tad| ‘morph2’
- *|dat| ‘morph3’
- *|dad| ‘morph3’
- *|dat| ‘morph4’
- *|dad| ‘morph4’

# Error-driven, gradual learning

Comprehending /tade/ ‘morph2+Pl’

| /tade/ ‘morph2+Pl’ | IDV | *\|tad\| ‘morph2’ | NV | IVV | *\|tat\| ‘morph2’ | NSFV |
|---|---|---|---|---|---|---|
| ‘morph2’ \|tat+e\| /tade/ | *! | | * | | * | |
| 👂 ‘morph2’ \|tad+e\| /tade/ | | * | * | | | |

Producing /tade/ ‘morph2 +Pl’

| ‘morph2-Pl’ | IDV | *\|tad\| ‘morph2’ | NV | IVV | *\|tat\| ‘morph2’ | NSFV |
|---|---|---|---|---|---|---|
| 👄 ‘morph2’ \|tat+e\| /tate2/ | | | | ←* | ←* | |
| ‘morph2’ \|tat+e\| /tade2/ | *! | | * | | * | |
| 👂 ‘morph2’ \|tad+e\| /tade2/ | | *!→ | *→ | | | |
| ‘morph2’ \|tad+e\| /tate2/ | *! | * | | * | | |

# Error-driven, gradual learning

Comprehending /tade/ ‘morph2+Pl’ again

| /tade/ ‘morph2+Pl’ | IDV | IVV | *\|tat\| ‘morph2’ | *\|tad\| ‘morph2’ | NV | NSFV |
|---|---|---|---|---|---|---|
| ‘morph2’ \|tat+e\| /tade/ | *! | | * | | * | |
| 👂 ‘morph2’ \|tad+e\| /tade/ | | | | * | * | |

Producing /tade/ ‘morph2+Pl’ again

| ‘morph2-Pl’ | IDV | IVV | *\|tat\| ‘morph2’ | *\|tad\| ‘morph2’ | NV | NSFV |
|---|---|---|---|---|---|---|
| ‘morph2’ \|tat+e\| /tate2/ | | *! | * | | | |
| ‘morph2’ \|tat+e\| /tade2/ | *! | | * | | * | |
| 👂 👄 ‘morph2’ \|tad+e\| /tade2/ | | | | * | * | |
| ‘morph2’ \|tad+e\| /tate2/ | *! | * | | * | | |

# Error-driven, gradual learning

Comprehending /tat/ ‘morph2-Sg’

| /tat/ ‘morph2’ | IDV | IVV | *\|tat\| ‘morph2’ | *\|tad\| ‘morph2’ | NV | NSFV |
|---|---|---|---|---|---|---|
| 👂 ‘morph2’ \|tat\| /tat/ | | | * | | ** | * |
| ‘morph2’ \|tad\| /tat/ | *! | | | * | ** | * |

Producing /tat/ ‘morph2-Sg’

| ‘morph2’ | IDV | IVV | *\|tat\| ‘morph2’ | *\|tad\| ‘morph2’ | NV | NSFV |
|---|---|---|---|---|---|---|
| 👂 ‘morph2’ \|tat\| /tat2/ | | | *!→ | | **→ | |
| ‘morph2’ \|tat\| /tad2/ | *! | | * | | * | * |
| 👄 ‘morph2’ \|tad\| /tad2/ | | | | ←* | * | ←* |
| ‘morph2’ \|tad\| /tat2/ | *! | | | * | ** | |

# Computer settings

- Praat programme (Boersma & Weenink 2007)
- 10 virtual learners
- Constraints: 8 lexical, 3 structural, 1 faithfulness
- Training data: 8 “words”
  - Amount of training data: 10 000 (randomly chosen from the set of 8)
- Gradual Learning Algorithm (Boersma 1997, Boersma & Hayes 2001)
  - Evaluation noise: 2.0
  - “Symmetric all”
  - Plasticity: 1.0, decrement 0.1, spreading 0.1

# Results

- The learners found the correct ‘lexicon’ and the correct ‘grammar’
- Integration of the two can lead to variation

# Intertwined lexicon and grammar

NoSFV

>>

IDVoi, *|tad| ‘morph1’, *|dad| ‘morph3’

>>

*|tat| ‘morph2’, *|dat| ‘morph4’

>>

IVV, NoVoi

>>

*|tat| ‘morph1’, *|tad| ‘morph2’, *|dat| ‘morph3’, *|dad| ‘morph4’

# Intertwined lexicon and grammar

IdVoice >> *|tat| ‘morph2’, *|dat| ‘morph4’

| ‘morph2’ | NSFV | IDV | *\|tat\| ‘morph2’ | IVV | NV | *\|tad\| ‘morph2’ |
|---|---|---|---|---|---|---|
| ☞ ‘morph2’ \|tat\| /tat2/ | | | * | | ** | |
| ‘morph2’ \|tat\| /tad2/ | *! | * | * | | * | |
| ‘morph2’ \|tad\| /tad2/ | *! | | | | * | * |
| ☹ ‘morph2’ \|tad\| /tat2/ | | *! | | | ** | * |

*|tat| ‘morph2’ >> IdVoice

| ‘morph2’ | NSFV | *\|tat\| ‘morph2’ | IDV | IVV | NV | *\|tad\| ‘morph2’ |
|---|---|---|---|---|---|---|
| ‘morph2’ \|tat\| /tat2/ | | *! | | | ** | |
| ‘morph2’ \|tat\| /tad2/ | *! | * | * | | * | |
| ‘morph2’ \|tad\| /tad2/ | *! | | | | * | * |
| ☺ ‘morph2’ \|tad\| /tat2/ | | | * | | ** | * |

# Distribution of variation

| Singular: | | | | Plural: | | |
|---|---|---|---|---|---|---|
| `morph1’: | \|tat\| | /tat/ | 100 | \|tat+e\| | /ta.te/ | 98.6 |
| `morph2': | \|tad\| | /tat/ | 25.9 | \|tad+e\| | /ta.de/ | 98.3 |
| | \|tat\| | /tat/ | 73.6 | | | |
| `morph3': | \|dat\| | /dat/ | 100 | \|dat+e\| | /da.te/ | 98.7 |
| `morph4': | \|dad\| | /dat/ | 31 | \|dad+e\| | /da.de/ | 98.8 |
| | \|dat\| | /dat/ | 68.3 | | | |

# The final ‘grammar’

NoSFV >> IDVoi >> IVV, NoVoi:

| | Sg | Pl |
|---|---|---|
| morph1: | /tat/ | /tate/ |
| morph2: | /tat/ | /tade/ |
| morph3: | /dat/ | /date/ |
| morph4: | /dat/ | /dade/ |

# The final ‘lexicon’

*|tad| ‘morph1’ >> *|tat| ‘morph1’

*|tat| ‘morph2’ >> *|tad| ‘morph2’

*|dad| ‘morph3’ >> *|dat| ‘morph3’

*|dat| ‘morph4’ >> *|dad| ‘morph4’

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|tat| ‘1’, |tad| ‘2’, |dat| ‘3’, |dad| ‘4’

# Discussion & Conclusion

- Lexicon and grammar can be learned simultaneously
- The ranking of lexical constraints has a clear preference for certain underlying representations, and the ranking of the ‘grammar’ constraints has a clear preference for other candidates.
- Variation can arise due to constraint interaction

# Outlook

- Test the model with other words (not minimal pairs)
- Test the model with positive lexical constraints (e.g. Boersma & Pater in prep.)
- Alternative: Serial production?

# References


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