A Quantitative Model Of The Language Familiarity Effect In Infancy

Craig Thorburn, Naomi Feldman, Thomas Schatz | NECPhon 2019

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The Language Familiarity Effect

English Learner *(native)* ✓

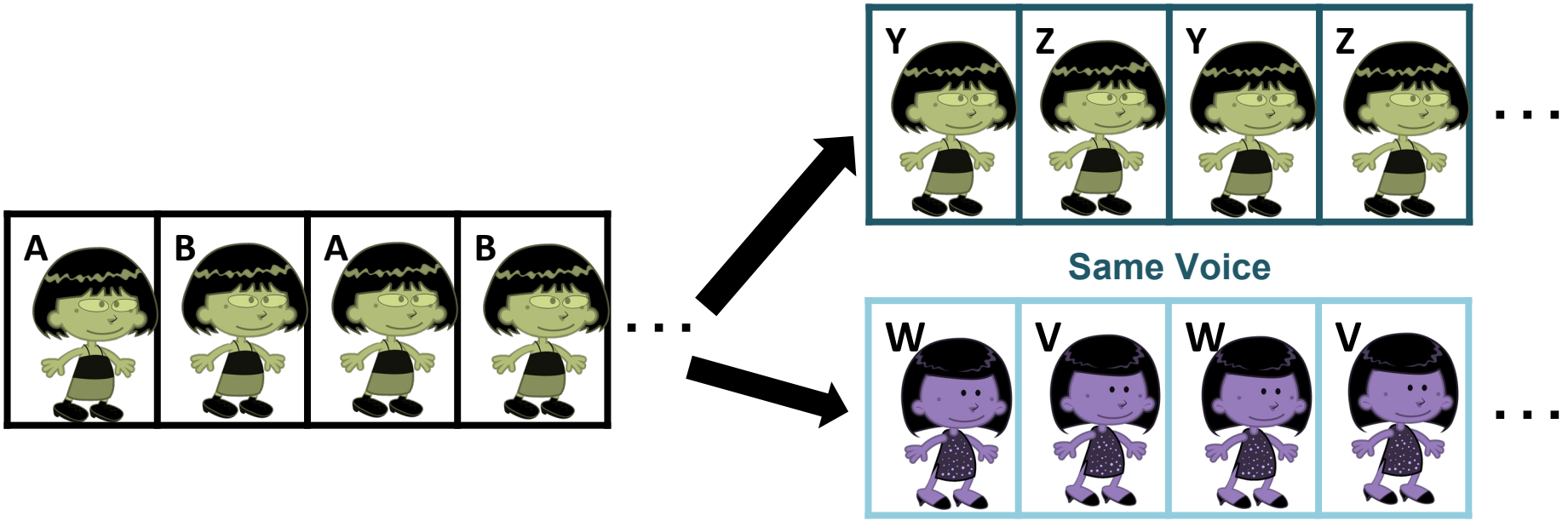
Japanese Learner *(non-native)* ✗

English Learner *(non-native)* ✗

Japanese Learner *(native)* ✓

Johnson, Westreck & Cutler 2011; Fecher & Johnson 2019

Visual Fixation Procedure



Fecher & Johnson 2019

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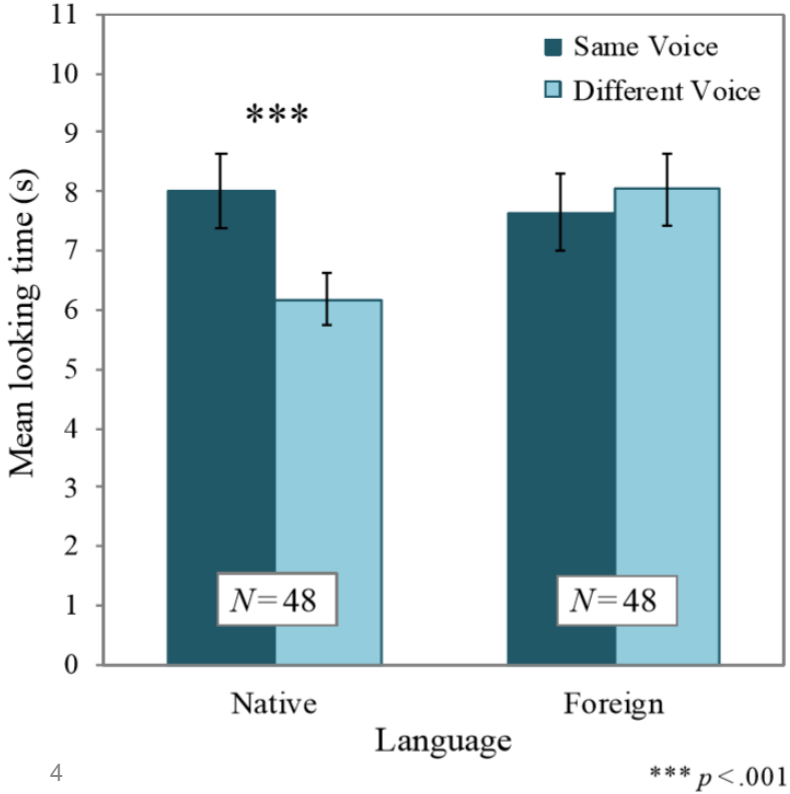
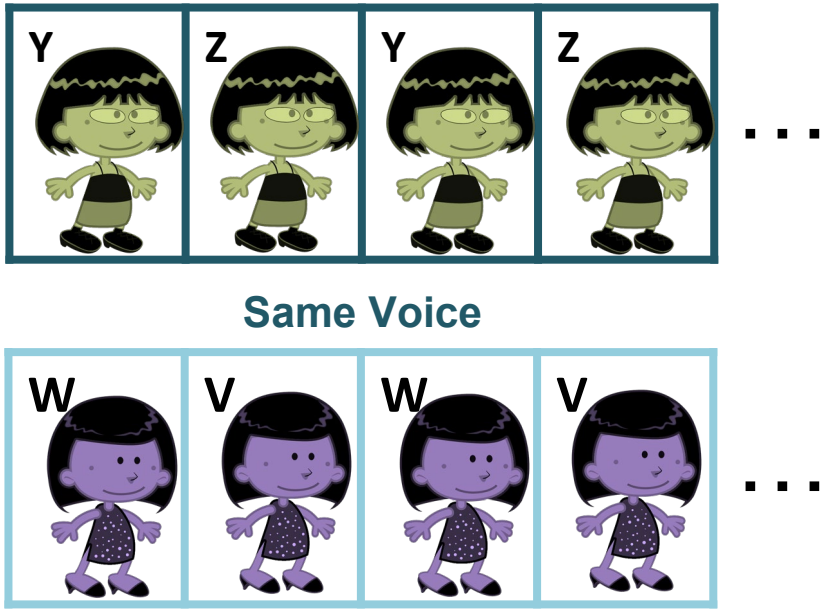




Fecher & Johnson 2019

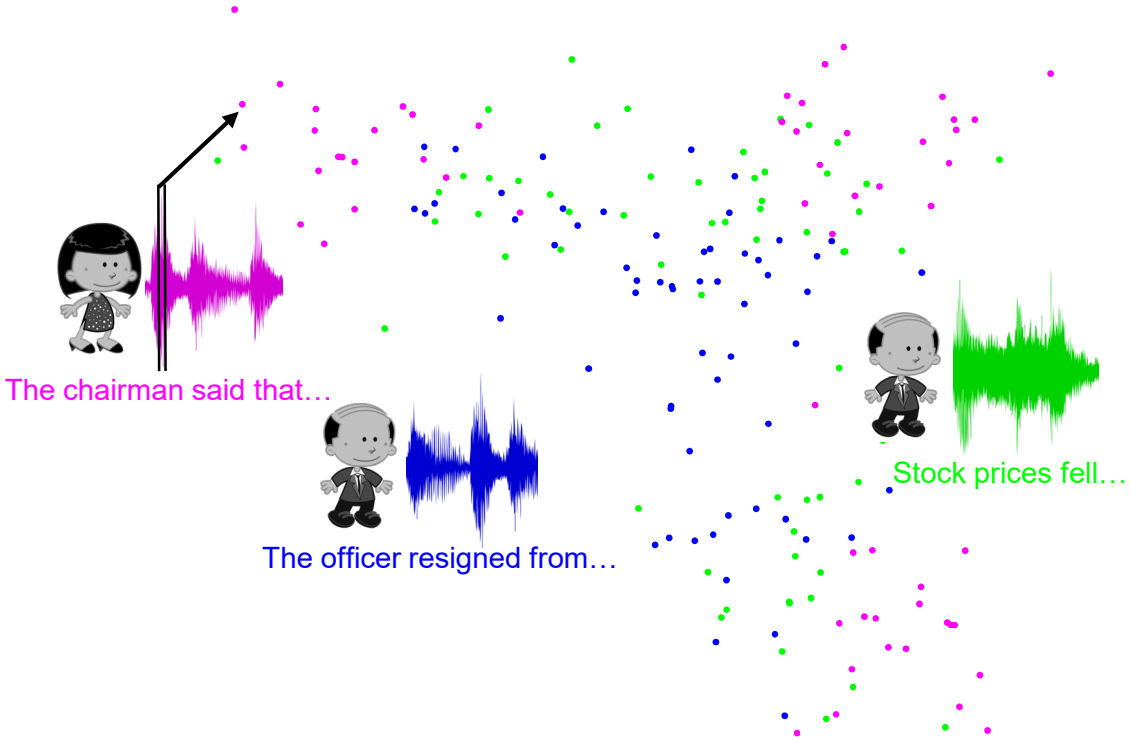
How could infants learn this?

- We can look to adults
  - Adults are also known to show a language familiarity effect
  - Thought to require some abstract phonological knowledge or comprehension
- We can model this using acoustic properties of input
  - We will look at higher and lower level features at two timescales

Short timescale
e.g. Phonetic information

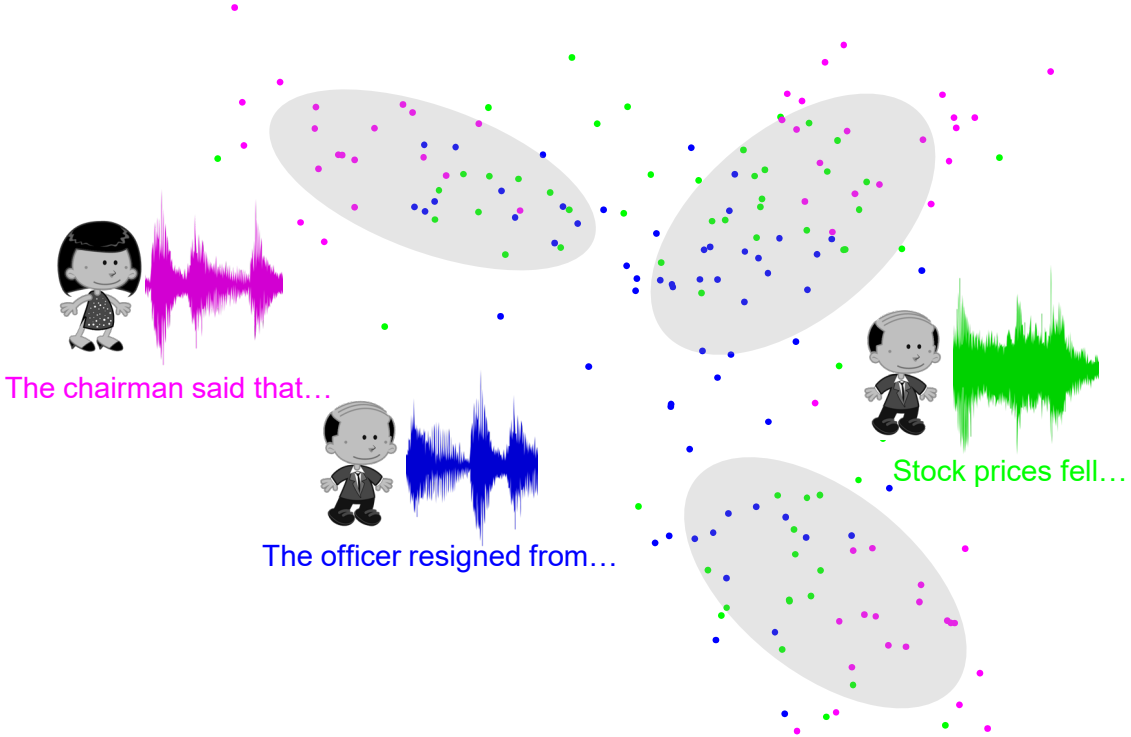
Long timescale
e.g. Speaker information

Short Timescale – Phonetic Information



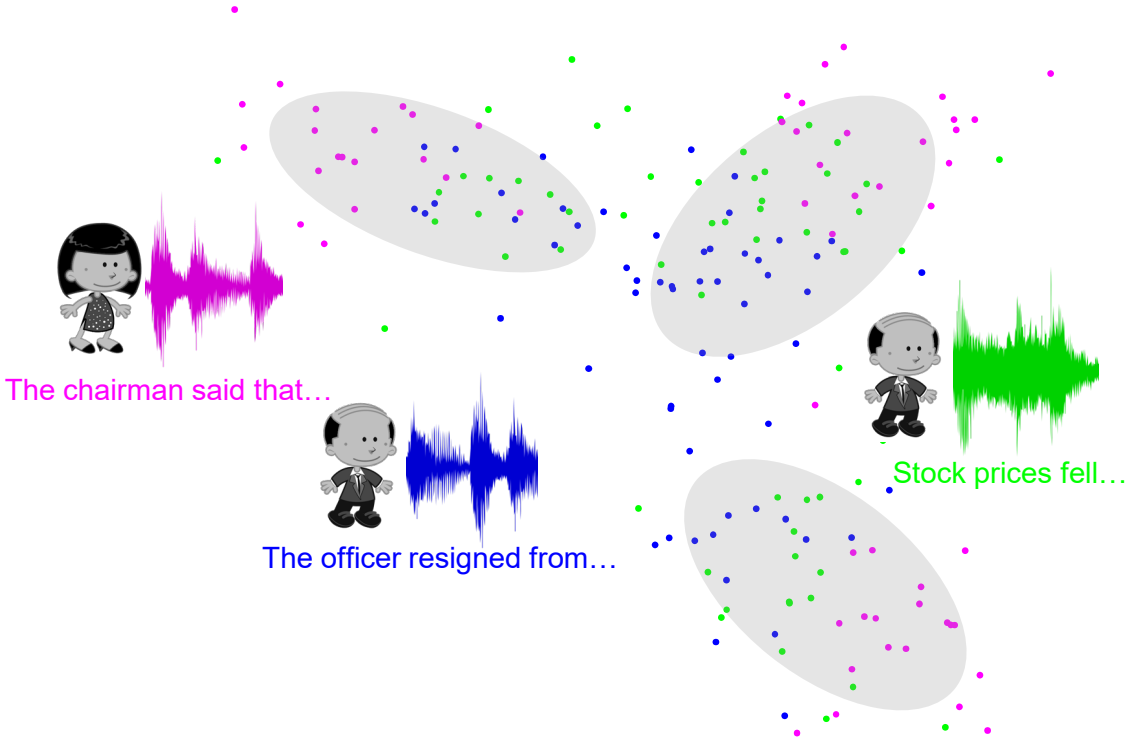
Schatz et al 2019

Short Timescale – Phonetic Information



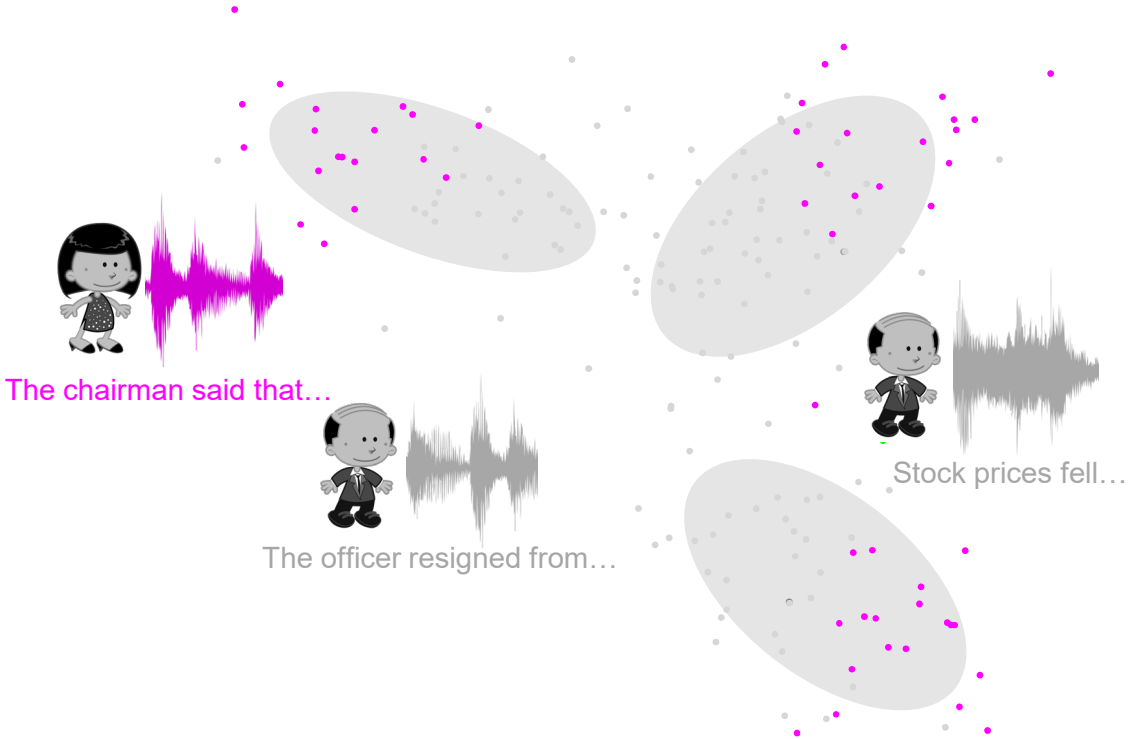
Schatz et al 2019

Long Timescale – Speaker Information



Dehak et al. 2010

Long Timescale – Speaker Information



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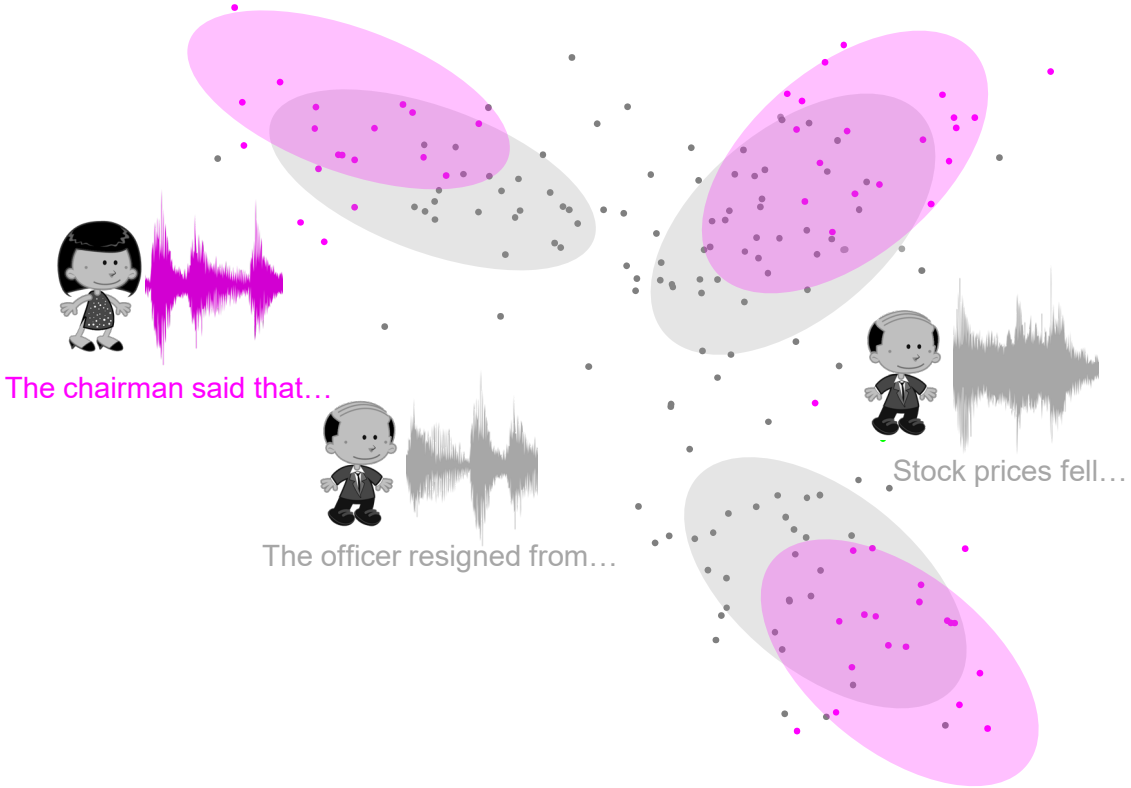
Long Timescale – Speaker Information



Dehak et al. 2010

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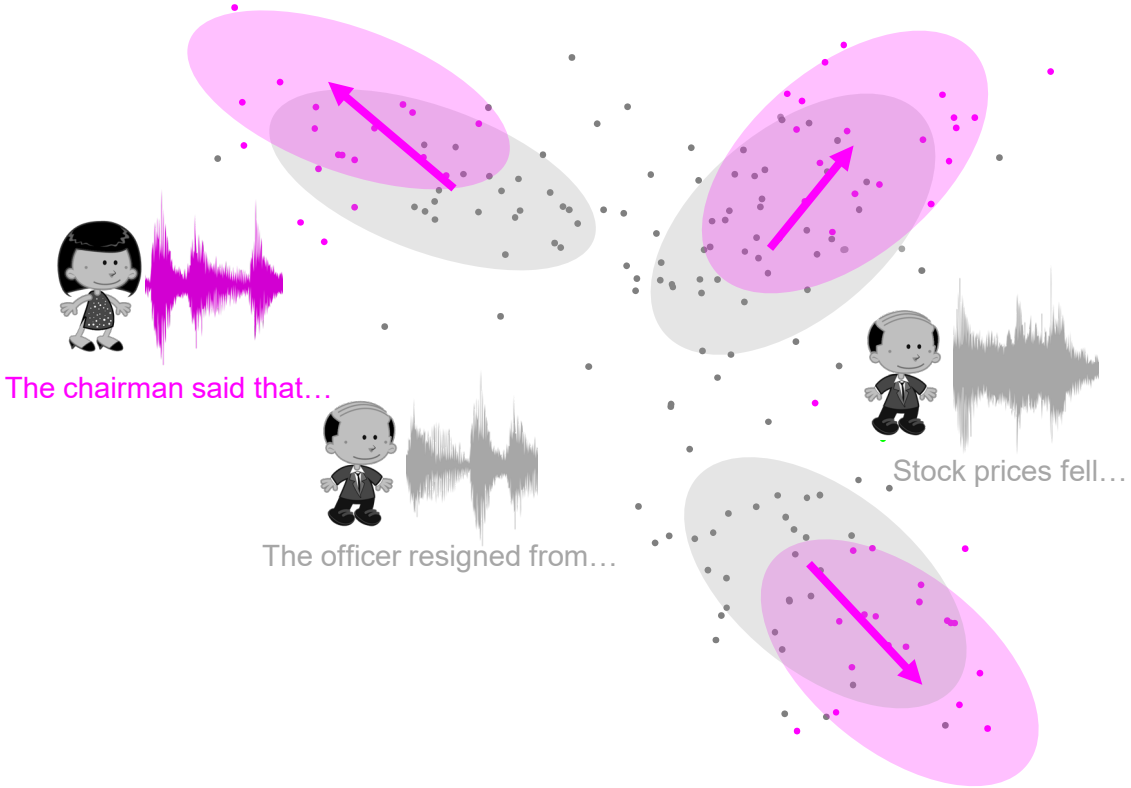

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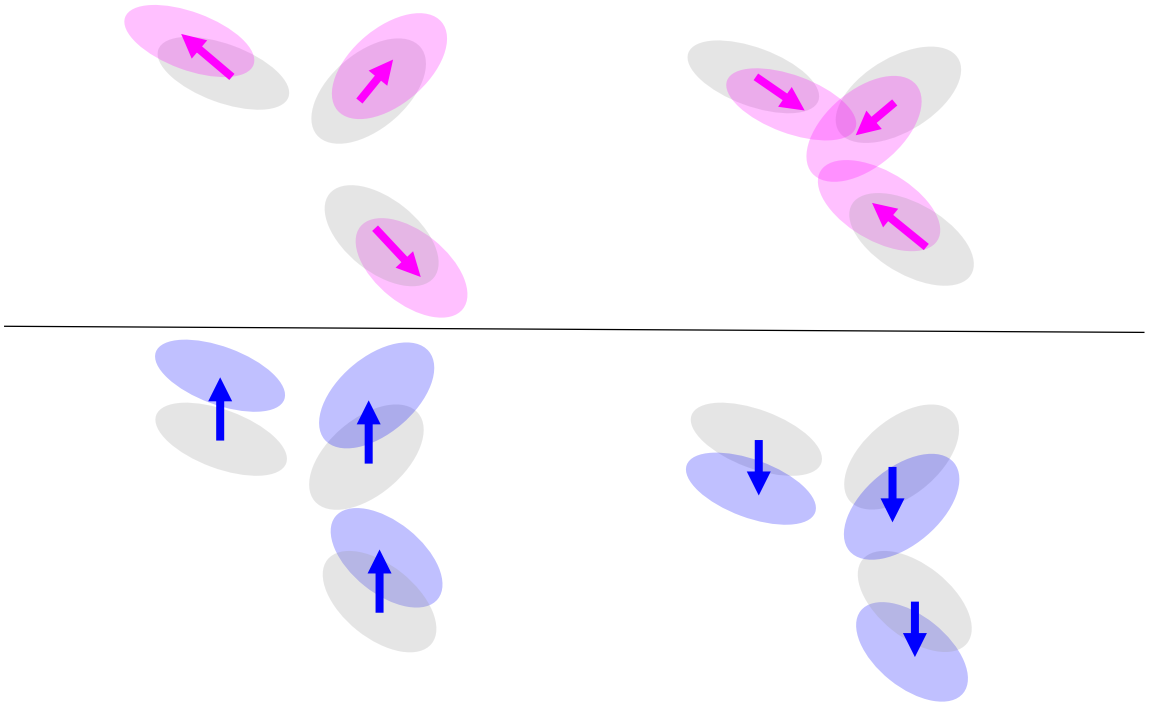
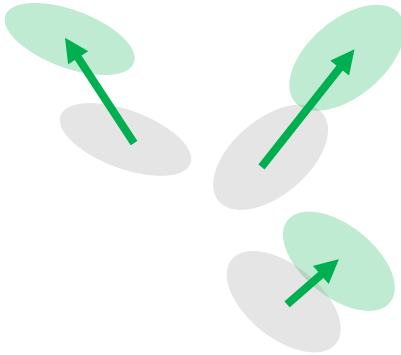
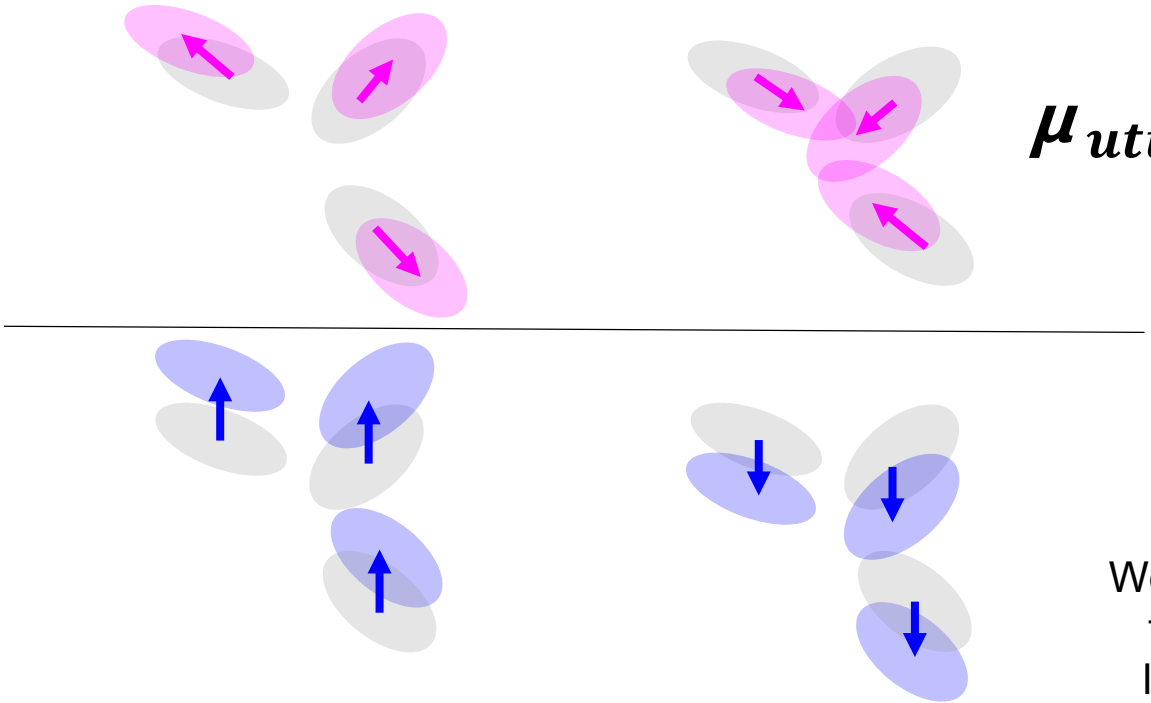




$$I_{utt} = \begin{bmatrix} 0.4 \\ \\ \\ 0.7 \end{bmatrix}$$

Dehak et al. 2010

Long Timescale – Speaker Information



$$\boldsymbol{\mu}_{utt} = \boldsymbol{\mu} + T * I_{utt}$$

$$I_{utt} = \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ \\ \dots \\ \\ I_{400} \end{bmatrix}$$

Weight matrix learned through maximum likelihood mapping

Dehak et al. 2010, Carbajal et al. 2016

Short timescale
Phonetic information

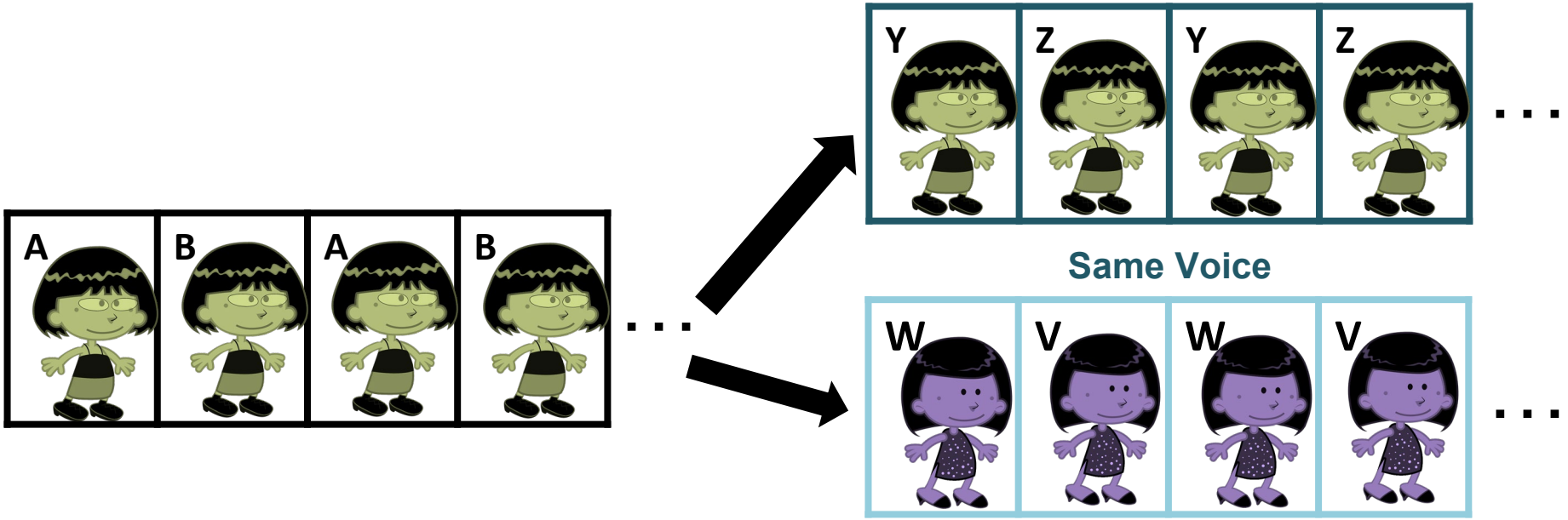
Frame-level Gaussian Activations

Long timescale
Speaker information

Utterance-level I-Vectors

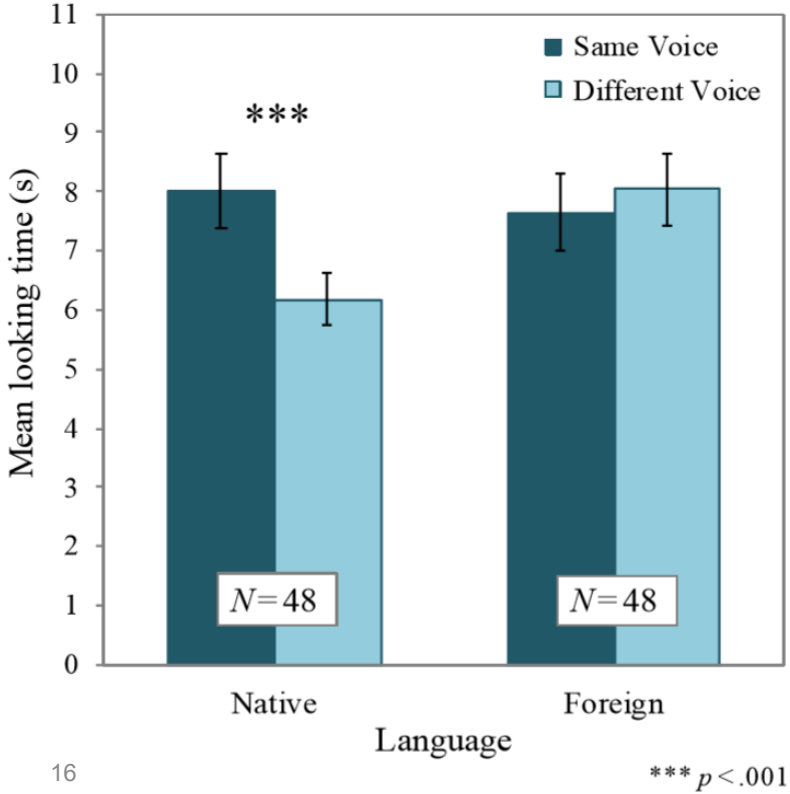
- Infants were able to discriminate between speakers of their native language but not of a non-native language
- We have built a model of how infants could represent speech and can now use this to test for a language familiarity effect

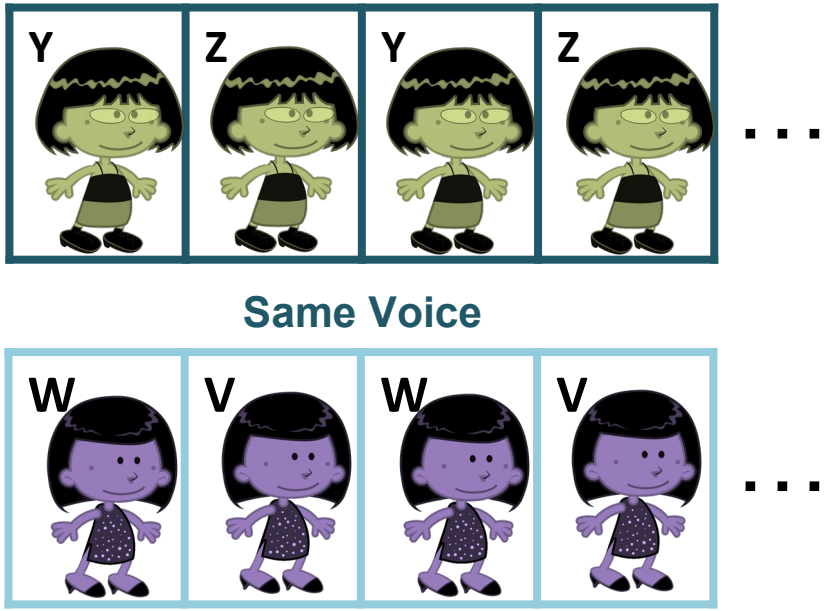
Visual Fixation Procedure



Fecher & Johnson 2019

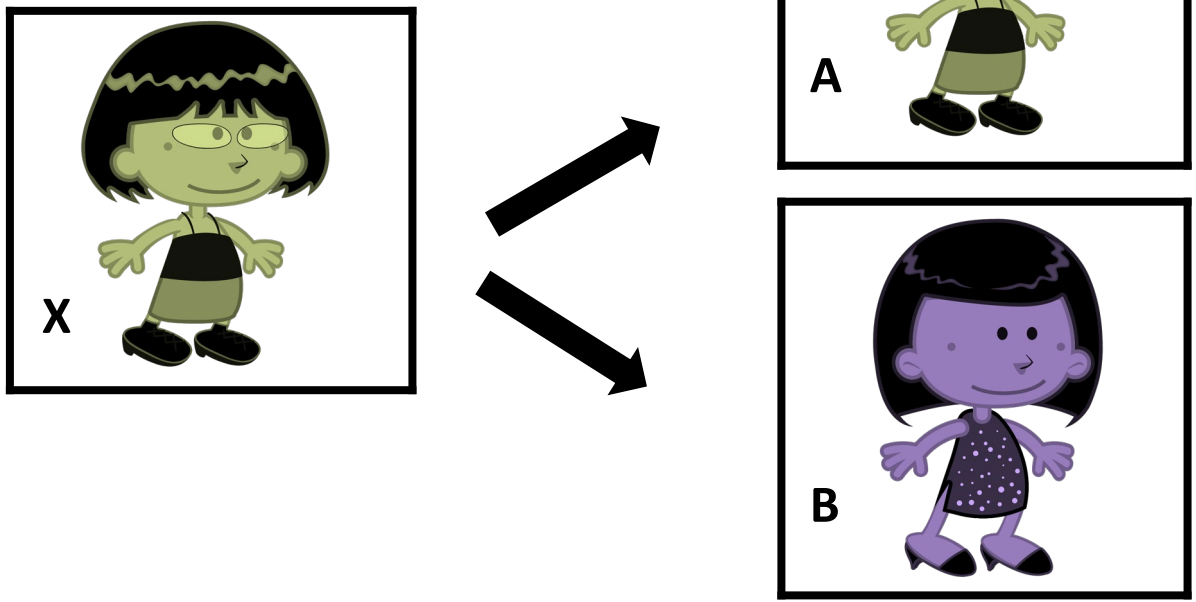
Visual Fixation Procedure





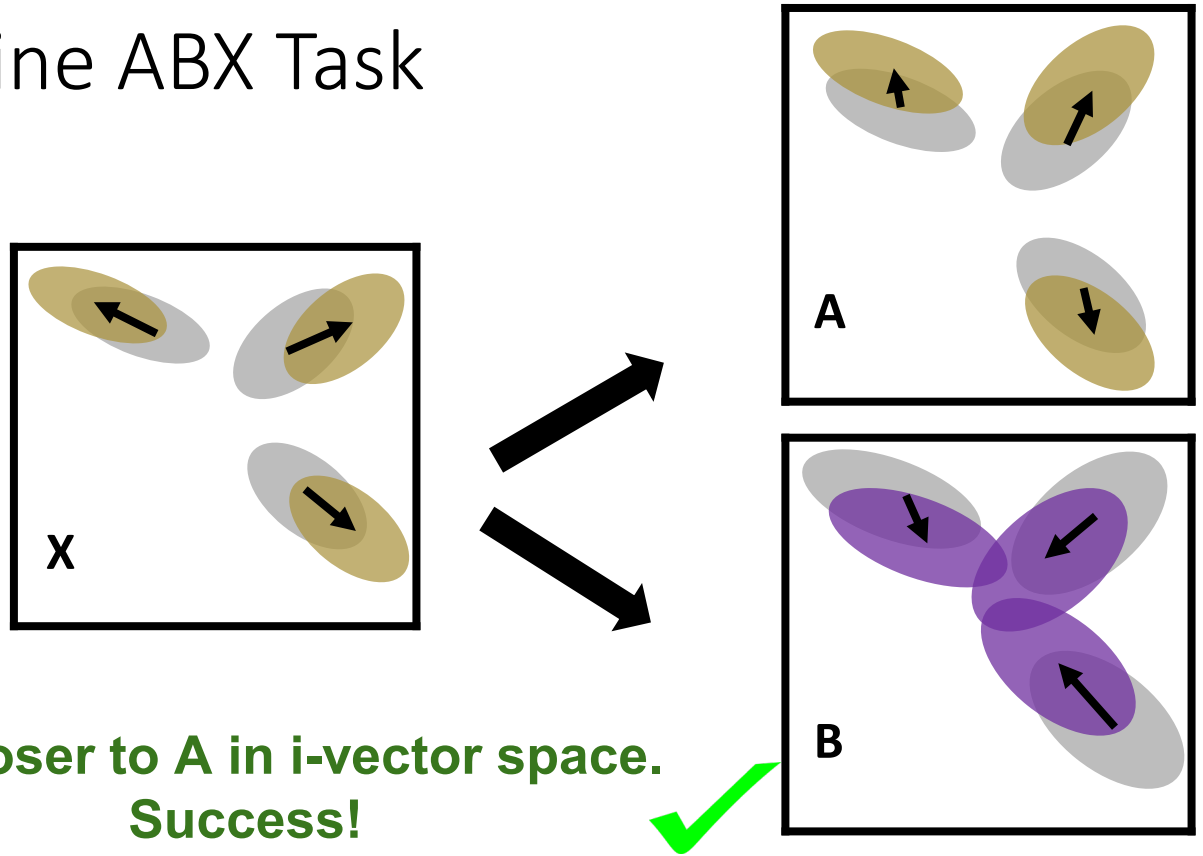
Fecher & Johnson 2019

Machine ABX Task



Schatz et al 2013, Schatz 2016

Machine ABX Task

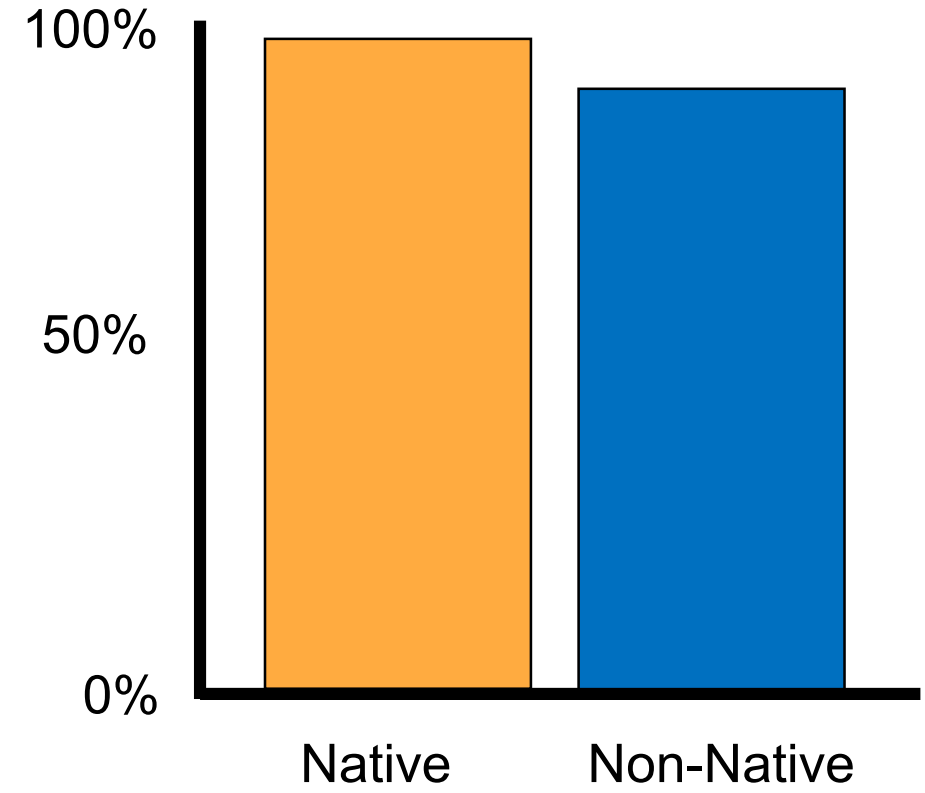


X is closer to A in i-vector space.
Success!

Schatz et al 2013, Schatz 2016

Predicted Results

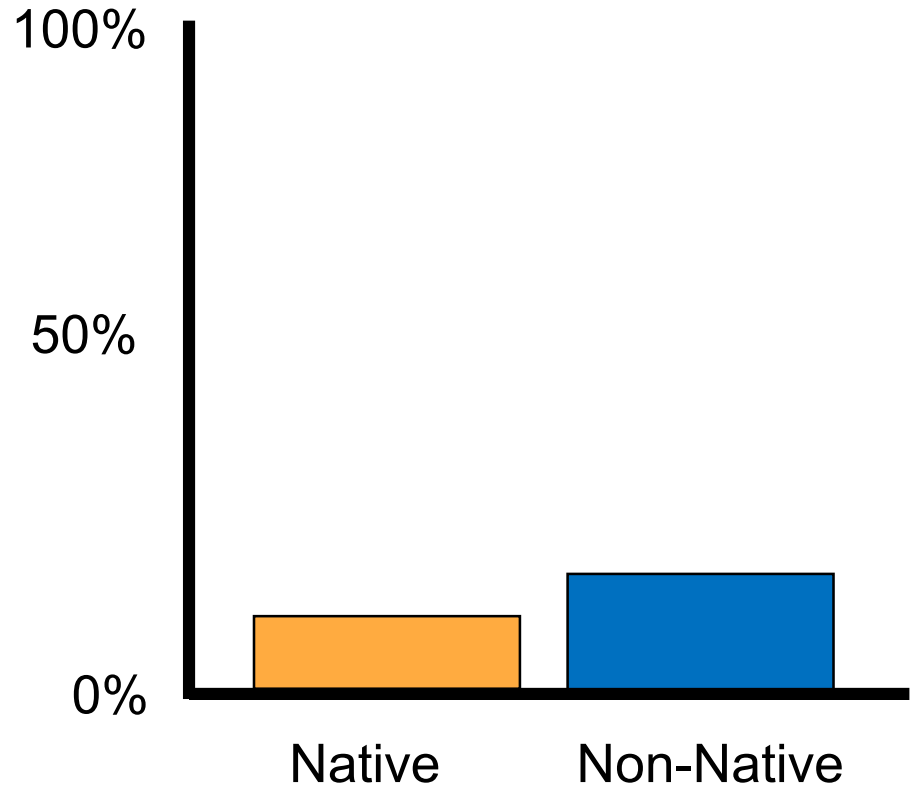
ABX Trials Performed Correctly (%)



Predicted Results

ABX Error Rate (%)

Probability of incorrect judgement



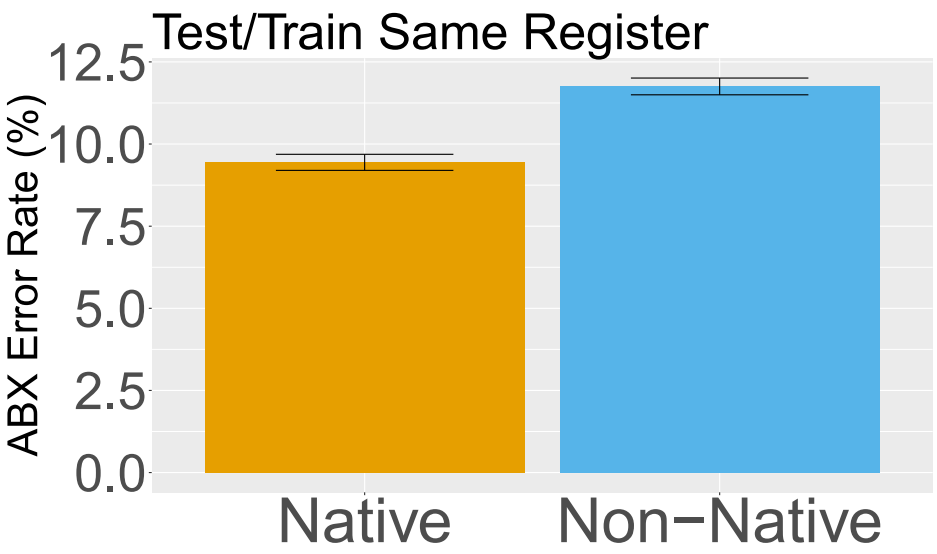
Experimental Paradigm

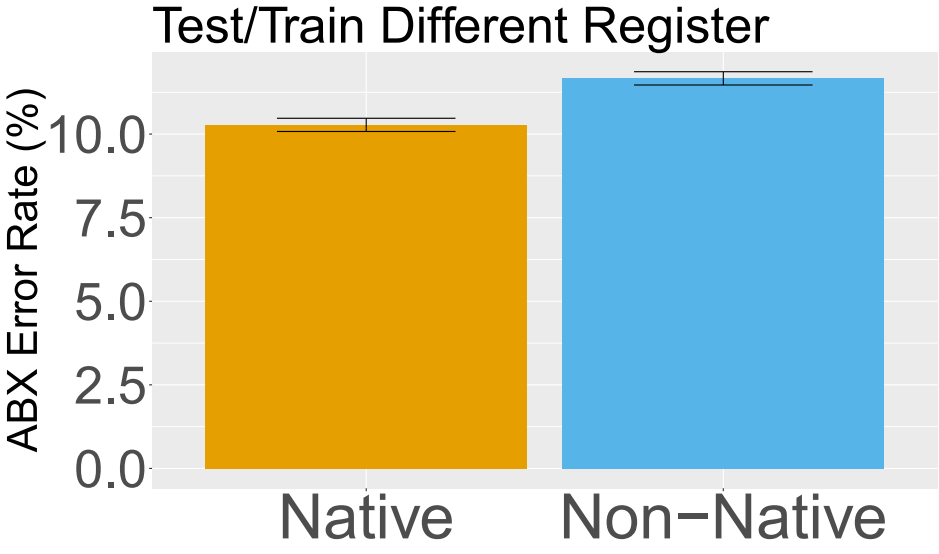
- Train models on four corpora
  - English and Japanese
  - Read and Spontaneous
- Test on utterances from all corpora

Training Language

Test Language	**English**	**Japanese**
English	Native	Non-Native
Japanese	Non-Native	Native

Results


Test/Train Same Register
ABX Error Rate (%)
12.5
10.0
7.5
5.0
2.5
0.0
Native
Non−Native


Test/Train Different Register
ABX Error Rate (%)
10.0
7.5
5.0
2.5
0.0
Native
Non−Native

Conclusion

- Language Familiarity Effect is found in infants at 4.5 months old
- This is the first model to account for this effect
- We propose that the infant uses acoustic variability hierarchically at multiple timescales
- No sophisticated linguistic knowledge required

Next Steps

- Validating against languages and conditions used in infant experiments (ie. Reversed speech)
- Investigating robustness to amount of training data
- Confirming this model empirically in other paradigms
- Connecting this model to the adult mechanism
- Showing other infant native language biases with this model

Acknowledgements

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