Modeling developmental changes in infants' discrimination of English vowels

Megha Sundara & Connor Mayer, UCLA Department of Linguistics

How does speech perception develop?

- Two mechanisms
  - Bottom-up: Domain-general distributional learning (e.g. Saffran et al., 1996)
  - Interactive: Concurrent word learning facilitates learning of phonetic categories (e.g., Swingley, 2009)

Distributional vs. Interactive learning

- Both mechanisms available in the first year of life
  - Distributional learning: 6- to 8-mo (Maye et al., 2002)
  - Interactive learning: 6- to 9-mo (Bergelson & Swingley, 2012)
- Computational implementation
  - Feldman et al.'s (2013) Bayesian model
  - Input
    - Acoustic distribution: steady state F1 & F2 from Hillenbrand corpus
    - Frequencies of words: CHILDES corpora
  - Interactive model outperforms distributional learning model

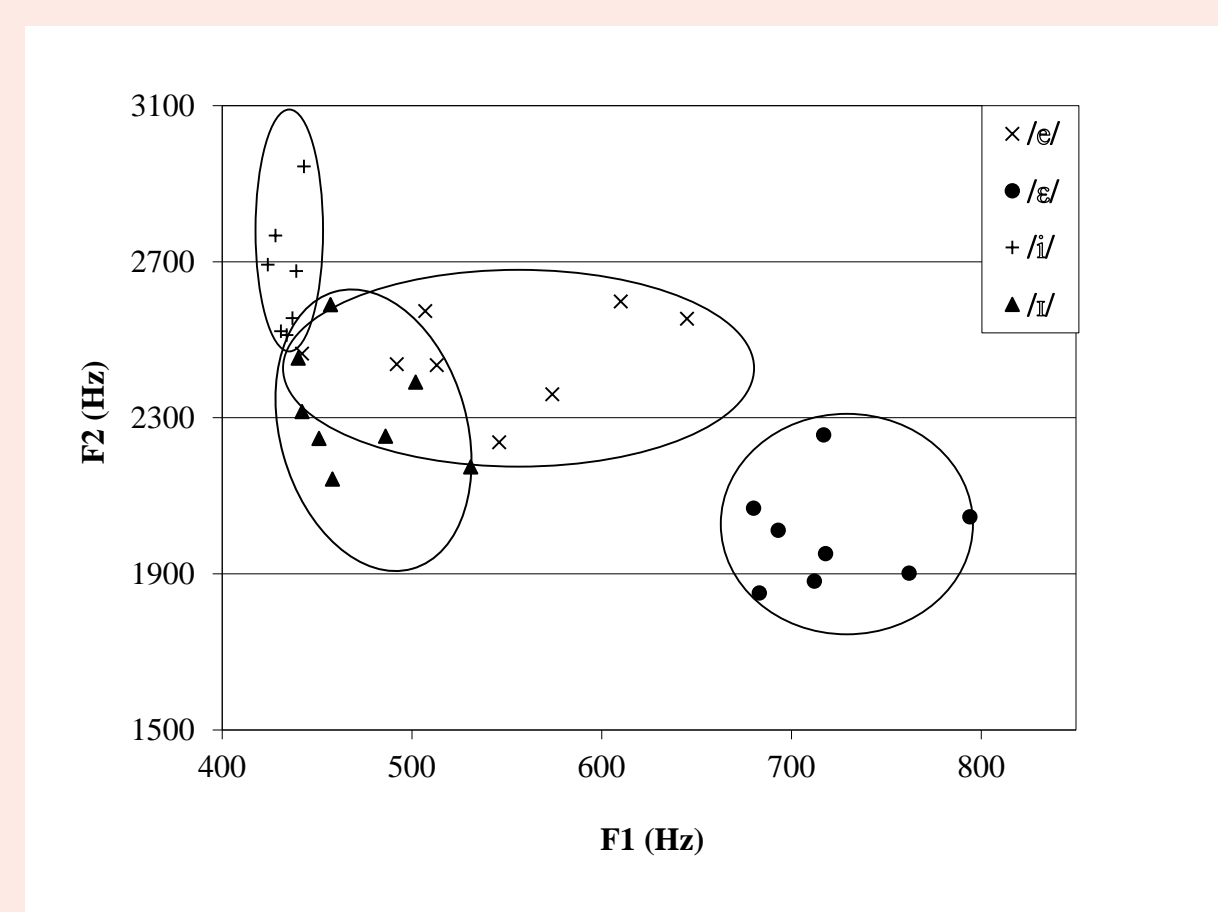## Infants' Discrimination of English front vowels
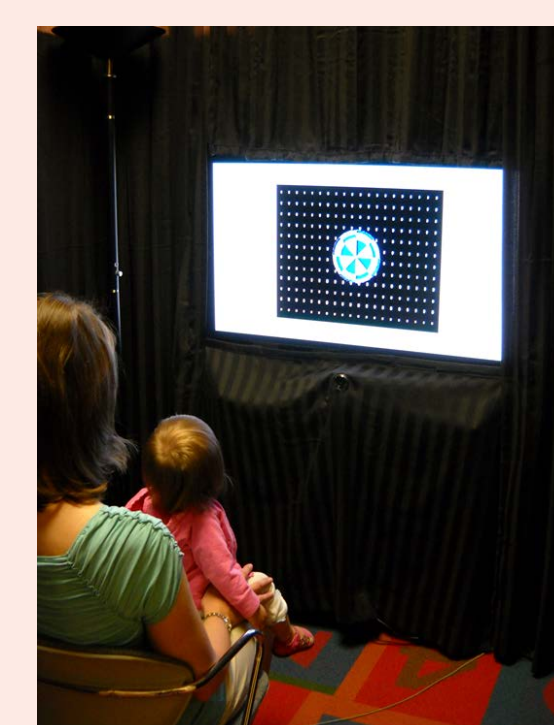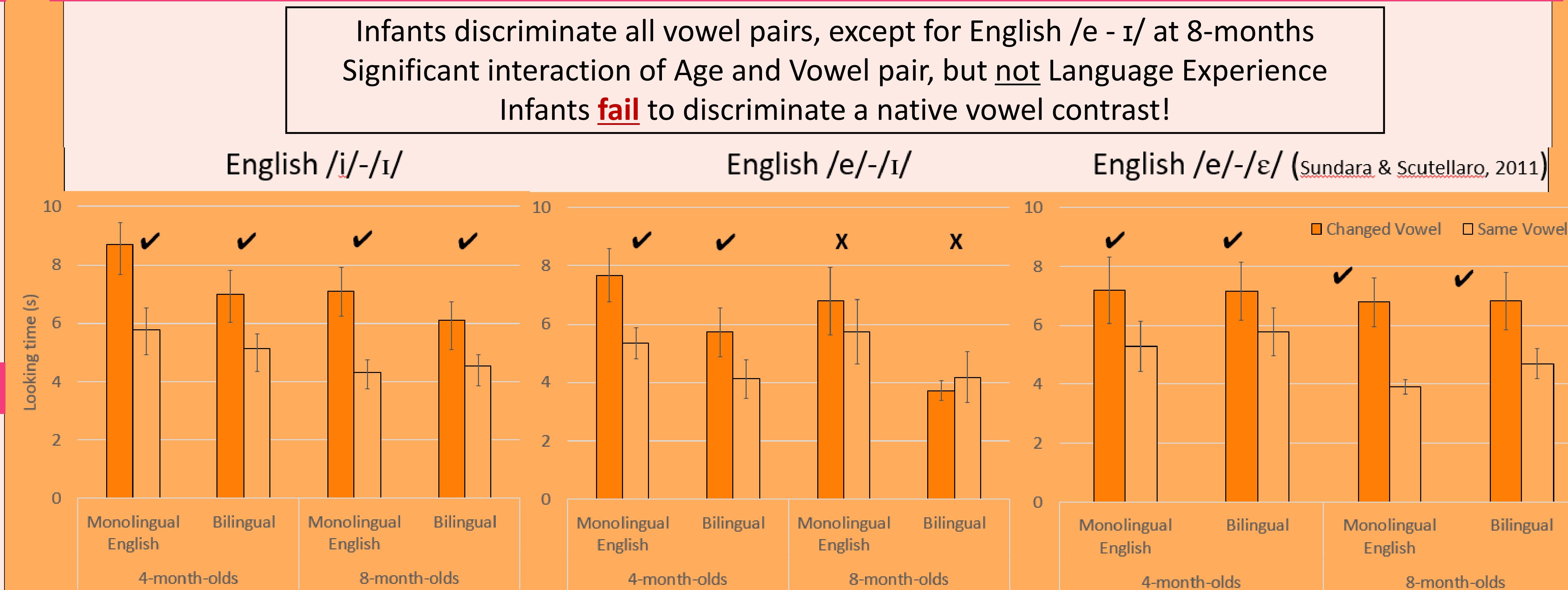
Figure 1: F1 & F2 at vowel steady state

Figure 2: Set-up

- Stimuli by 8 female talkers (Hillenbrand Corpus)
- Visual Habituation Procedure
  - Completely infant-controlled
  - 50% decline in looking time, 3-trial window
  - Habituation condition counterbalanced
    - Vowels produced by 4 talkers
  - Test trials: vowels by 2 new talkers / category

Data to be modeled: RESULTS on infants' discrimination of English front vowels (n=280)

Infants discriminate all vowel pairs, except for English /e - ɪ/ at 8-months
Significant interaction of Age and Vowel pair, but not Language Experience
Infants **fail** to discriminate a native vowel contrast!

English /i/-/ɪ/   English /e/-/ɪ/   English /e/-/ɛ/ (Sundara & Scutellaro, 2011)

Extending the Bayesian Model of Feldman et al., (2013)

- Model comparisons include F1, F2, F3; Δ F1, Δ F2, Δ F3; duration
  - Simulated 5000 word vocabulary
- Every Interactive model outperforms its distributional counterpart
  - Learns 12/12 categories; with near perfect discriminability
  - Also outperforms infants !

High-dimension Interactive models **fail** to capture the **rank order** of difficulty of contrasts at either 4- or 8-months.

Vowel Pairs	Effect sizes 4-mo-olds (Cohen's d)	Effect sizes 8-mo-olds (Cohen's d)
/e - ɛ/	0.39	0.80
/e - ɪ/	0.62	0.10
/i - ɪ/	0.64	0.65

Only **one** distributional model captures the **rank order** of difficulty of contrasts at 4-months. Includes – **F1, F2, F3 & duration**
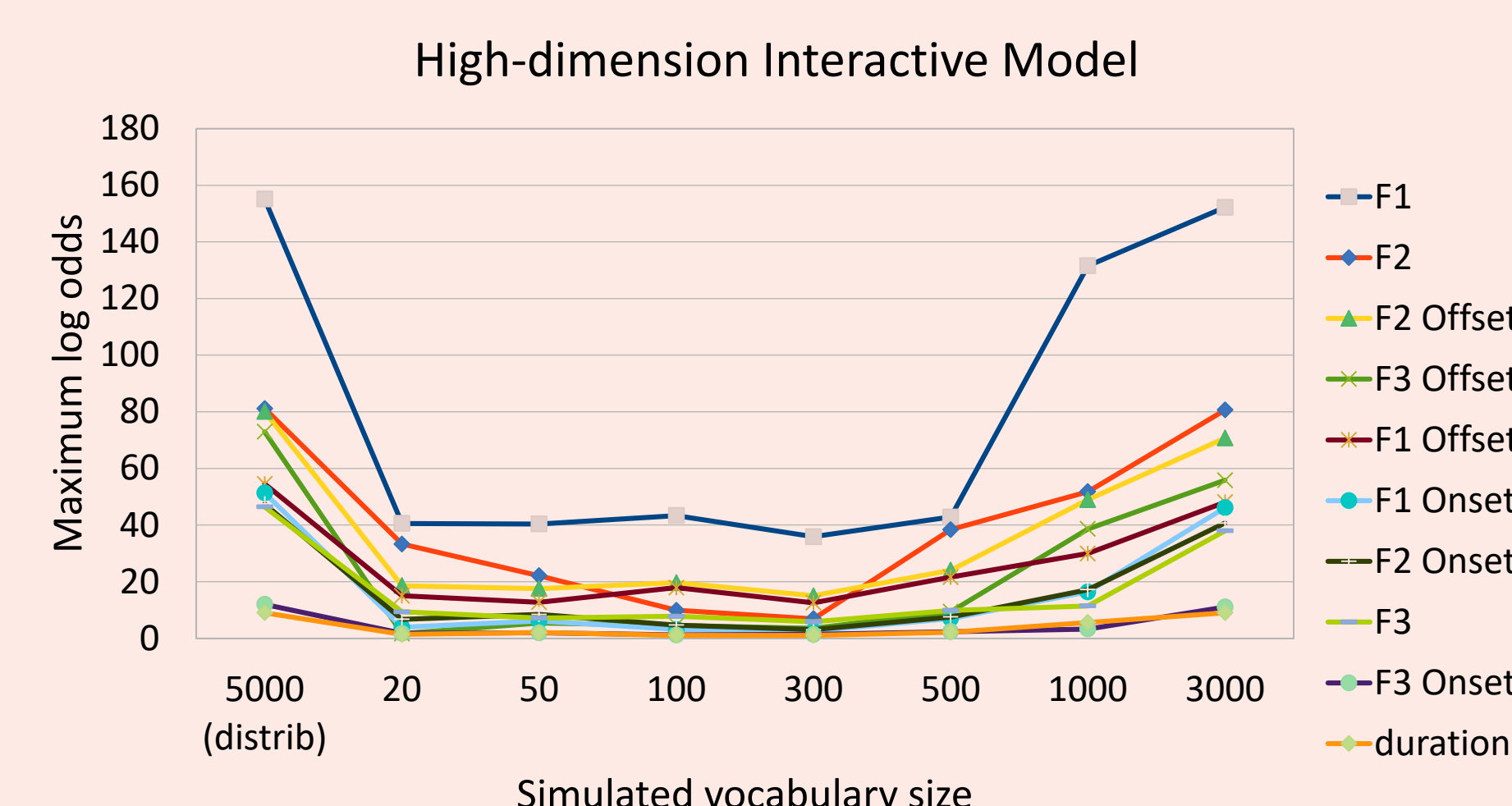
Only a low-dimension interactive model captures rank order of difficulty of contrasts at 8-months

Interactive model with only F1, F2

Figure 3. Model performance distinguishing vowel pairs

High-dimension Interactive Model

Figure 4. Contribution of different phonetic dimensions to model performance
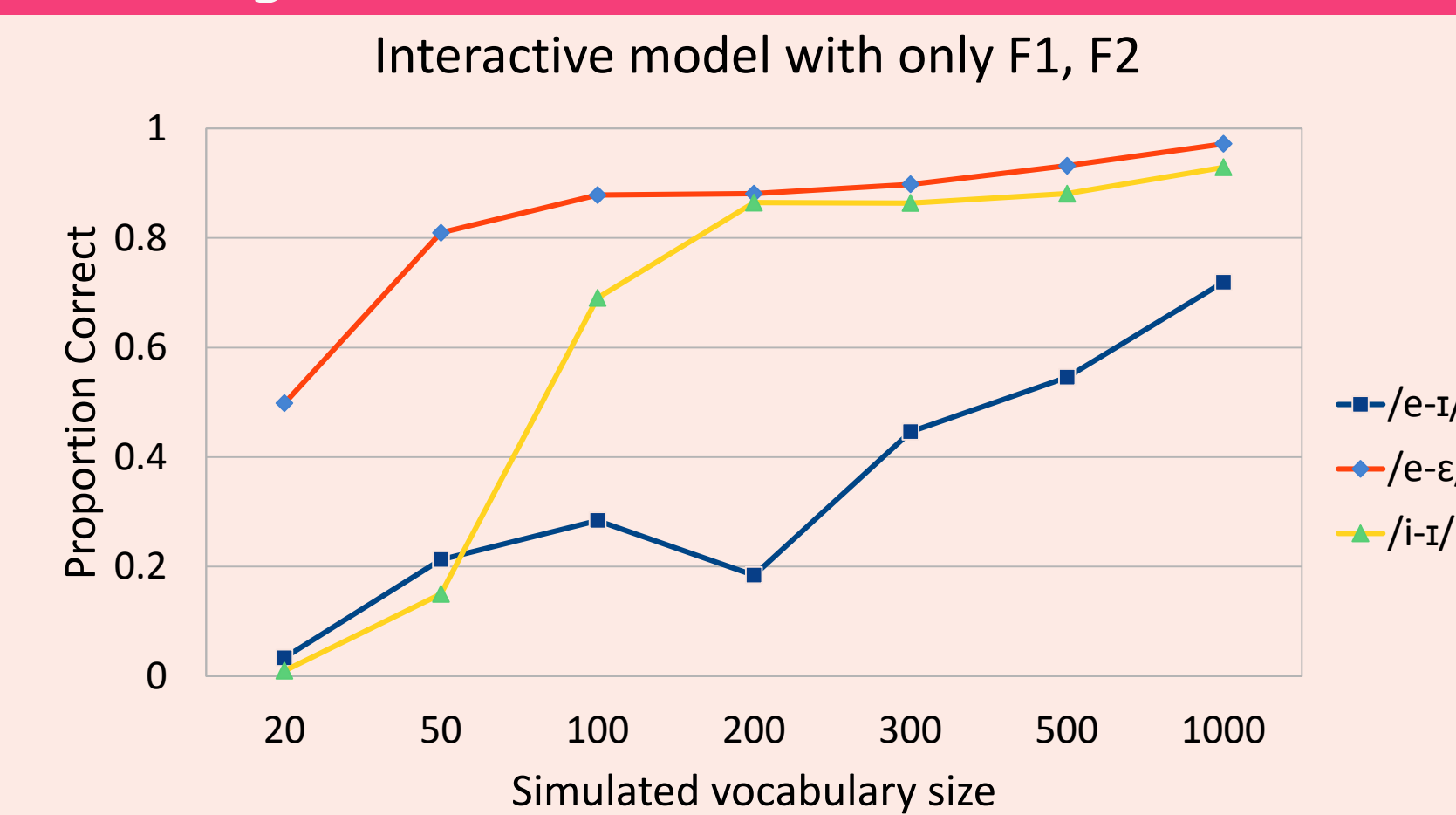
Which phonetic dimensions might the learner (temporarily) ignore? Looking inside the interactive model

Modeling vs. Infant discrimination

IMPLICATIONS for Development

- At 4-months,
  - English-learning infants discriminate all three vowel contrasts
  - Best fit: **distributional model** with access only to F1, F2, F3 & duration
- At 8-months,
  - English-learning infants discriminate /e - ɛ/, /i - ɪ/ , but not /e - ɪ/
  - Decline in discrimination observed even for native vowel pairs!
  - Best fit: **low-dimension interactive** model with access to only F1 & F2
- To mimic infant behavior, Bayesian interactive models must be able to **down weight** less informative phonetic dimensions
  - Such a model could account for developmental trajectory for native and non-native perception

Future Directions

- English-learning 12- to 17-month-olds do not distinguish /e- ɪ/. We are testing 18- to 20-mo-olds (vocabulary ~ 200+).

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