

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

Part 1: Computational model

- Replication & Extension of Feldman et al. (2013)
- Added phonetic cues to models
 - temporal cues: duration
 - dynamic spectral cues: $\Delta F1$; $\Delta F2$; $\Delta F3$
 - Other cues: f_0 , $F3$ & $F4$
- Re-ran distributional and interactive models on different subset of cues
- Evaluation
 - Number of learned vs. real categories
 - F-score (0 – worst; 1 – perfect)
- Every Interactive model outperforms its distributional counterpart

Part 1: Modeling RESULTS

Real categories in the input = 12

Cues	Distributional Models	Interactive Models
Model 1: F1, F2 (Feldman et al. 2013)	8 categories; F-score: 0.40	12 categories; F-score: 0.65
Model 2: F1, F2, F3, duration	8 categories; F-score: 0.46	12 categories; F-score: 0.76
Model 3: F1, F2, F3, dur., $\Delta F1$, $\Delta F2$	11 categories; F-score: 0.71	12 categories; F-score: 0.90
Model 4: F1, F2, F3, dur., $\Delta F1$, $\Delta F2$, $\Delta F3$	11 categories; F-score: 0.73	12 categories; F-score: 0.92

Model performance distinguishing vowel pairs (proportion correct)

Vowel pairs	Low-dimension Distributional Model (Feldman et al)	Low-dimension Interactive Model (Feldman et al)	High-dimension Distributional Model	Effect sizes Cohen's <i>d</i>	
				Mono. English	Bilingual
/e/ - /ε/	0.76	0.95	0.96	1.06	0.61
/i/ - /ɪ/	0.68	0.85	0.90	0.83	0.44
/e/ - /ɪ/	0.57	0.71	0.98	0.22	0.17

Chance!

Part 2: Infants' discrimination of English front vowels

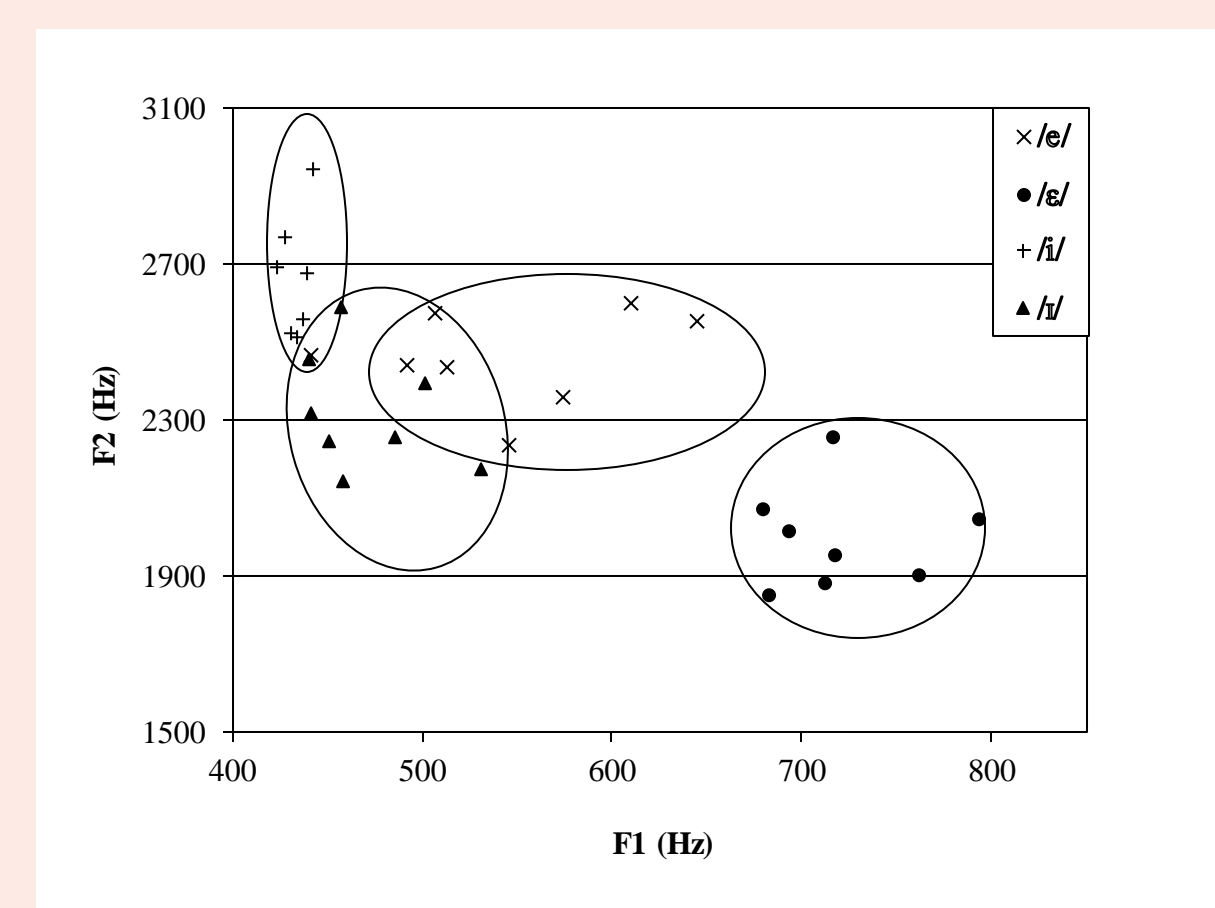


Figure 1: F1 & F2 at vowel steady state

- Stimuli produced by 8 female talkers from 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

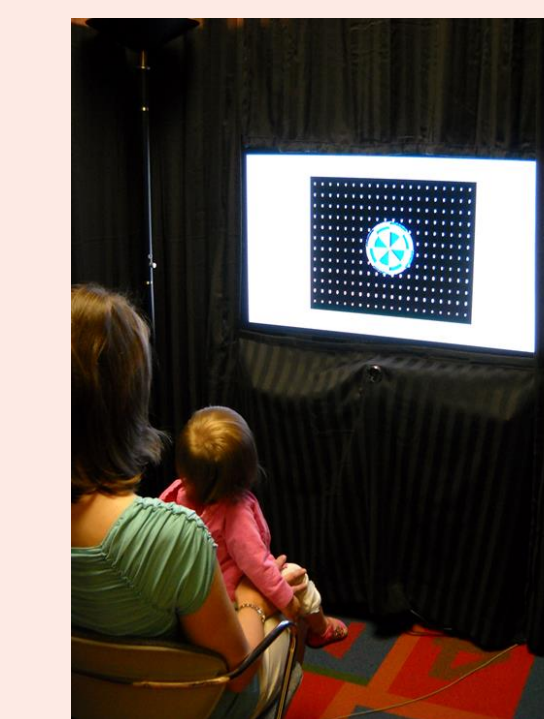
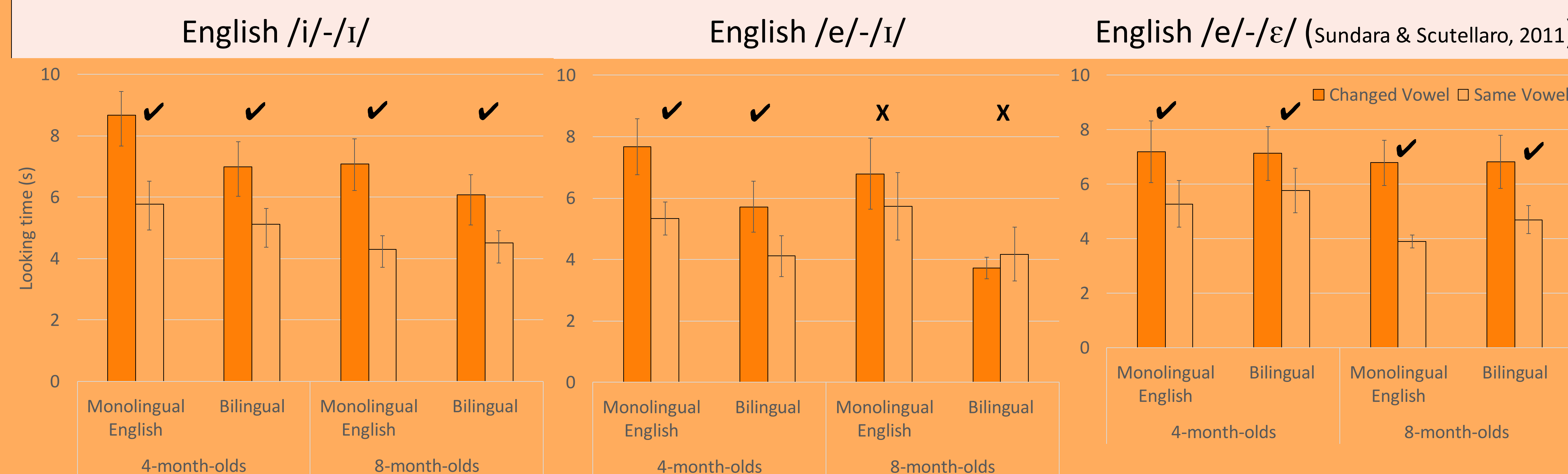


Figure 2: Set-up

Part 2: RESULTS on infants' discrimination of English front vowels

Monolingual & bilingual infants discriminate all vowel pairs, except for English /e/-/ɪ/ at 8-months



Modeling vs. Infant discrimination

IMPLICATIONS for Development

- At 4-months,
 - English-learning infants discriminate /e/-/ε /; /i/ - /ɪ/ & /e/ - /ɪ/
- With language experience, at 8-months,
 - English-learning infants discriminate /e/-/ε /; /i/ - /ɪ/
 - They do not discriminate /e/ - /ɪ/
- **Interactive models** outperform English-learning infants at 8-months on /e/ - /ɪ/
 - Optimal **high-dimension distributional model** also outperforms English-learning infants at 8-months
- Best fit to 8-mo-olds' discrimination data
 - **Low-dimension distributional model**

Future Directions

- Is lexical bootstrapping available at later age or for children with larger vocabularies?
 - Not till 18-months; 12- to 18-month-olds also fail to discriminate /e/ - /ɪ/
- Currently working on an interactive model that temporarily ignores (sometimes relevant) some distributional cues

REFERENCES

- Bergelson, E. & Swingley, D. (2012). At 6 to 9 months, human infants know the meaning of many common nouns. *PNAS*, 109, 3253-3258.
- Feldman, N.H., Griffiths, T.L., Goldwater, S., Morgan, J.L. (2013). A role for the developing lexicon in phonetic category acquisition. *Psych. Review*, 120(4), 751-778.
- Hillenbrand, J. et al. (1995). Acoustic characteristics of American English Vowels. *JASA* 97(5), 3099-3111.
- Maye, J. Werker, J., Gerken, L. (2002). Infant sensitivity to distributional information can affect phonetic discrimination. *Cognition*, 82, B101-B111.
- Saffran, J.R., Aslin, R.N., Newport, E.L. (1996). Statistical learning by 8-month-old infants. *Science*, 274(5294), 1926-1928.
- Sundara, M. & Scutellaro, A. (2011). Rhythmic distance between languages affects the development of speech perception in bilingual infants. *J of Phonetics*, 39(4), 505-513.
- Swingley, D. (2009). Contributions of infant word learning to language development. *Phil. Trans. Royal Soc. B*, 364, 3617-3622.

ACKNOWLEDGMENTS

Kristi Hendrickson, Anya Mancillas, Robyn Orfitelli and Victoria Mateu for help with infant recruitment and data collection.