

Distribution-Based Learning of Phonemic Contrasts: Native Speakers of English Learning Arabic Pharyngealization Contrasts

Shaun Matthews
Rachel Hayes-Harb
University of Utah

DLLS Symposium, BYU
March 10, 2006



Overview

- Background
 - Acquisition of novel phonemic contrasts
 - Distributional learning
 - Pharyngealization contrasts
- Experiment (with preliminary results)
- Future directions

Background

- How do language learners determine the phonemic inventory of the language to be learned?

Background

- Traditional account
 - Phonemic contrasts learned via knowledge of minimally contrastive word pairs (lexical contrast)
 - e.g. /p/ and /b/ are contrastive in English as shown by the minimal pair [□] → [◆] and [ʔ] → [◆]
 - *lexical contrast-based learning*

Background

- Problem!
 - L2 input does not contain sufficient minimal pairs for learners to learn phonological categories from lexical contrast-based learning alone!
 - Infants show learning of L1 native phoneme inventories *months* before they have been shown to discern differences in relevant minimal pairs' meaning (Maye et al. 2002)

Background

- More recent account
 - Phonemic contrasts also learned via observation of the distribution of acoustic information
 - *distribution-based learning*

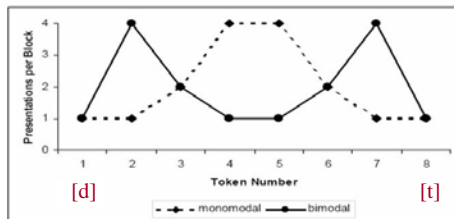
Distribution-Based Learning

- Learner uses information about the distribution of speech tokens in the input to learn a contrast
 - Contrastive dimensions: two *distinct* clusters of speech tokens along relevant acoustic dimensions
 - Non-contrastive dimensions: single cluster of speech tokens along relevant acoustic dimensions

Maye (2000)

- Tested ability of adult English speakers to learn a novel phonemic contrast between [d] and unaspirated [t] word-initially
- Used two training distributions:
 - *Monomodal* (non-contrastive dimension)
 - *Bimodal* (contrastive dimension)

Maye (2000)



Maye (2000)

- Subjects trained with a Bimodal distribution exhibited more accurate discrimination of the two endpoint tokens than did subjects trained with a Monomodal distribution

Additional Studies

- Maye et al. (2002) showed this effect in infants
- Hayes-Harb (2003) also replicated the effects of distribution-based learning in a comparison between its efficacy and that of lexical-contrast-based learning

Use of Manipulated Tokens

- For all of these studies, ideal sets of tokens, evenly spaced along the continuum of interest, were created synthetically by modifying natural tokens
- Synthetic speech is more difficult to process than natural speech (Duffy & Pisoni, 1992)
- How might the use of unmodified natural speech tokens impact distribution-based learning?

Question 1

- Can distribution-based learning results be replicated with natural speech tokens?
- Hypothesis: Previous results with respect to distribution-based learning can be replicated with natural speech tokens

Arabic Pharyngealization Contrasts

- Previous studies have examined only voicing contrasts
- If distribution based learning is a general mechanism, it should apply to *any* contrast found in natural language

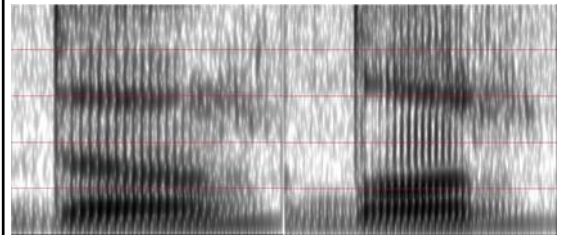
Arabic Pharyngealization Contrasts

- Arabic contrasts “plain” plosives [t, d] with their “emphatic” counterparts having a secondary, pharyngeal articulation [tˤ, dˤ]
- A primary acoustic cue for this contrast is a drop in the following vowel’s F2 onset value (Card, 1983; Al-Masri & Jongman, 2004)

Arabic Pharyngealization Contrasts

[dar] 🗨️

[dˤar] 🗨️



Question 2

- Can distribution-based learning results be replicated with Arabic pharyngealization contrasts?
- Hypothesis: Previous results with respect to distribution-based learning can be replicated with this contrast

Study Overview

- We recreated the general format used in Maye (2000) and Hayes-Harb (2003)
- Three experimental groups:
 - Monomodal (M)
 - Bimodal (B)
 - No-Training (NT) control group
- Tests administered in a sound-attenuated booth using DMDX software

Subjects

- All subjects were native speakers of English exclusively
 - Bimodal Group (N=8)
 - Monomodal Group (N=9)
 - No-Training Group (N=9)

Experiment Overview

- Practice Test
- Training Phase
- Test Phase

Training Phase

- Subjects listened to target and filler stimuli
 - Training Phase Sample: 🗣️
- Distribution of target stimuli determined by training group

Training Stimuli

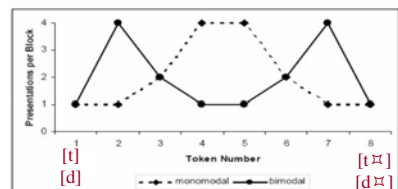
- A native speaker of Saudi Arabic produced [t, d, tʰ, dʰ] in three vowel contexts: [_ar], [_ir], and [_ur]
 - The same speaker also produced filler stimuli
- Measurements of voice-onset time and vowel formant onset values were taken for all tokens of [t, d, tʰ, dʰ]

Training Stimuli

- F2 onset ranges created for both of the contrasts in each of the three vowel contexts
- Ranges divided into 8 equidistant, ideally spaced points
- Actual tokens chosen to most closely match the idealized values

Training Stimuli

- These tokens were used to create Bimodal and Monomodal training blocks for each vowel context



Training Procedures

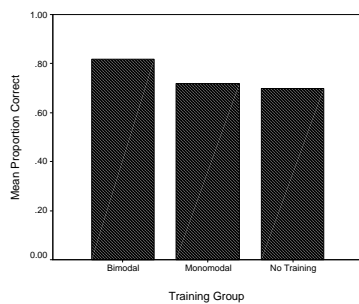
- Subjects listened to four sets of training stimuli, separated by a break after each
 - In order to maintain focus, subjects were asked to mark a check sheet for each token heard
- Each set contained 96 contrast-relevant tokens and 96 filler tokens
- 784 tokens total; ~25 minutes of training

Test Phase

- Test tokens divided into five conditions:

Token Condition	Example Pair	Correct Response
Experimental Different	[da ₁] vs. [dʰa ₂]	'different'
Experimental Same	[da ₁] vs. [da ₁]	'same'
Filler Identical	[la _a] vs. [la _a]	'same'
Filler Same	[la _a] vs. [la _b]	'same'
Filler Different	[la _a] vs. [ma _a]	'different'

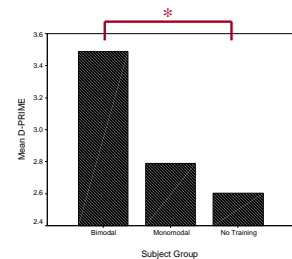
Results: Proportion Correct



Results: D-Prime

- Analysis using ANOVA
- Bimodal group significantly more likely to discriminate endpoint tokens than the No-Training group ($p < .05$)

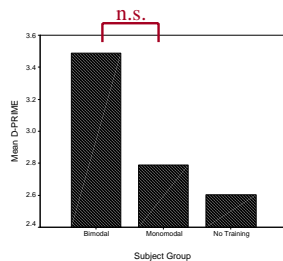
→ *Support for Training Effect of Bimodal Group*



Results: D-Prime

Difference between Bimodal and Monomodal groups not (yet) significant, but is similar to findings in previous studies

- Low statistical power
- More subjects needed



→ *Encouraging Preliminary Pattern*

Findings

- Replicated previous findings with respect to the effect of Bimodal training relative to No-Training
- Effect of Bimodal training relative to Monomodal training, though, is not significant at this point

Conclusions

- Results so far are promising
- More subjects are needed!

Future Directions

- Several follow-up studies are planned
 - Increasingly naturalistic stimuli and settings (e.g. stimuli embedded in natural conversation)

Thank You!

- Acknowledgments
 - Zac Rasmussen, Jennifer Mallory, Erin Larsen, study subjects
- Please contact us with any questions/comments:
 - Shaun_Matthews@hotmail.com
 - Hayes-Harb@linguistics.utah.edu

