Nature's distributional-learning experiment: Infants' input, infants' perception, and computational modeling

Benders, A.T.

Publication date
2013

Citation for published version (APA):

General rights
It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

Disclaimer/Complaints regulations
If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: https://uba.uva.nl/en/contact, or a letter to: Library of the University of Amsterdam, Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.
**CONTENTS**

1 Introduction: Nature’s Distributional-Learning Experiment  
1.1 Introduction  
1.2 Nature’s distributional-learning experiment  
1.3 The BiPhon model and comparison to other theories and frameworks  
1.4 Dutch /a/ and /a:/  
1.5 Part I) investigate the acoustic properties and the auditory distributions of the phonemes in the infants’ environment  
1.6 Part II) investigate infants’ perception of the same phonemes  
1.7 Part III) explain infants’ speech-sound perception from infants’ input distributions through distributional learning simulated in a computational model  
1.8 Comparison to previous work  
1.9 Summary

2 All mommy does is smile! Dutch mothers’ realization of speech sounds in infant-directed speech expresses affect, not didactic intent  
2.1 Introduction  
2.1.1 Didactic vowel space enhancement in IDS  
2.1.2 Affective vowel formant increase in IDS  
2.1.3 Testing didactic and affective changes in Dutch IDS  
2.1.4 Summary of study objectives  
2.2 Method  
2.2.1 Participants  
2.2.2 Procedure and Equipment  
2.2.3 Coding  
2.2.4 Acoustic measurements  
2.2.4.1 Vowels  
2.2.4.2 The fricative /s/  
2.2.4.3 Pitch  
2.2.5 Exclusion and Analyses  
2.3 Results  
2.3.1 Vowel space: Area  
2.3.2 Vowel space: Formant frequencies  
2.3.3 The fricative /s/  
2.3.4 Pitch characteristics  
2.4 Conclusion and Discussion  
2.5 Appendix: Details of the analysis  
2.5.1 Vowels
3 Learning phonemes from multiple auditory cues: Dutch infants’ language input and perception

3.1 Introduction
3.1.1 Distributional learning of phoneme categories
3.1.2 Infants’ perception of vowel quality and duration
3.1.3 Dutch /a/ and /a:/
3.1.4 Summary of study objectives

3.2 Study 1: /a/ and /a:/ in Dutch infant-directed speech
3.2.1 Method
3.2.1.1 Materials
3.2.1.2 Data preparation
3.2.1.3 Analysis
3.2.2 Results
3.2.3 Discussion

3.3 Study 2: Dutch infants’ perception of /a/ and /a:/
3.3.1 Method
3.3.1.1 Participants
3.3.1.2 Stimuli
3.3.1.3 Procedure
3.3.1.4 Preparation of looking-time data and analysis
3.3.2 Results
3.3.3 Discussion

3.4 General Discussion
3.5 Summary

4 Dutch infants’ sensitivity to the combination of vowel quality and duration in a speech sound categorization paradigm

4.1 Introduction
4.1.1 Infants’ sensitivity to vowel duration and vowel quality
4.1.2 Methods to study infants’ phoneme representations

4.2 Method
4.2.1 Subjects
4.2.2 Sound stimuli
4.2.3 Visual stimuli
4.2.4 Set-up and procedure
4.2.5 Analysis plan

4.3 Results
4.3.1 RT analysis
4.3.1.1 Adults – RT analysis
4.3.1.2 Infants – RT analysis
5 Explaining Infants’ Phoneme Perception from the Distributions in Infant-Directed Speech: Two Distributional-Learning Models 95
5.1 Introduction 96
5.2 The distributions of /a/ and /a:/ in Dutch infant-directed speech 98
5.3 Dutch infants’ perception of /a/ and /a:/ 101
5.4 A computational-level model to link input and perception: Incremental Mixture-of-Gaussians model 103
   5.4.1 The Mixture-of-Gaussians model 103
   5.4.2 Distributional learning 103
   5.4.3 Evaluation of the MoG modeling 104
5.5 MoG modeling of distributional learning 106
   5.5.1 Results 2-cue-with-ρ MoG 108
   5.5.2 Results 2-cue-no-ρ MoG 108
   5.5.3 Results 1-cue-F2 MoG and 1-cue-duration MoG 110
   5.5.4 Discussion 112
5.6 A neural network model to link input and perception: Emergent categories in symmetric neural networks 114
   5.6.1 The neural network architecture 115
   5.6.2 Activity spreading 115
   5.6.3 Distributed categories and categorical perception 117
   5.6.4 Distributional learning 119
   5.6.5 A NN architecture for two input dimensions 120
   5.6.6 Evaluation of the NN modeling 121
5.7 NN modeling of distributional learning 124
   5.7.1 Results: 2-cue NN 125
   5.7.2 Results: 1-cue-F2 NN and 1-cue-Duration NN 126
   5.7.3 Discussion 126
5.8 Discussing the NN modeling of distributional learning 127
   5.8.1 Understanding the dynamics of learning with two input layers 129
   5.8.2 The acquisition of enhanced perceptual contrast 132
   5.8.3 The absence of a representation of auditory distance 133
5.8.4 Learning with a lexicon to acquire the status of specific cue combinations 135
5.9 General Discussion 136
5.10 Summary 138
5.11 Appendix A: The mathematical definition of the MoG 139
5.12 Appendix B: The mathematical definition of the NN 142

6 Discussion and Conclusion: Evaluating nature’s distributional-learning experiment 145
6.1 Summary of the study aims 146
6.2 Summary of the empirical results:
   Similarities between infants’ input and perception 146
6.3 Evaluating the role of computational models:
   Tools or theories? 147
6.4 Investigating infants’ input:
   Against data reduction 149
6.5 Investigating infants’ phoneme perception:
   Overt behavior and attention allocation 150
6.6 Conclusion 152

Bibliography 153

Summary in English 175
Samenvatting in het Nederlands 185
Curriculum Vitae 195