Copyright

by

Christina Elke Gildersleeve-Neumann

2001

The Dissertation Committee for Christina Elke Gildersleeve-Neumann certifies that this is the approved version of the following dissertation:

CONSTRAINTS ON INFANT SPEECH ACQUISITION: A CROSS-LANGUAGE PERSPECTIVE

Committee:

Barbara L. Davis, Supervisor

Randy L. Diehl

Peter F. MacNeilage

Thomas P. Marquardt

Marleen Haboud Ortega

Elizabeth D. Peña

CONSTRAINTS ON INFANT SPEECH ACQUISITION: A CROSS-LANGUAGE PERSPECTIVE

by

Christina Elke Gildersleeve-Neumann, M.A., B.A.

Dissertation

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Doctor of Philosophy

The University of Texas at Austin

August 2001

Dedication

To Jonathan, without whom this dissertation

would not have been possible, interesting, or worth it

Acknowledgements

This dissertation would not have been possible without the guidance and support of many. My heartfelt thanks to each of you, especially those mentioned below.

I would like to thank the members of my dissertation committee for their encouragement and intellectual input: Barbara Davis, Peter MacNeilage, Thomas Marquardt, Elizabeth Peña, Marleen Haboud Ortega, and Randy Diehl.

At the University of Texas, my deepest gratitude is extended to Barbara Davis, who has been my adviser and mentor since I entered graduate school. What I have learned from her both professionally and personally is immeasurable. I feel very fortunate to have her as my supervisor and friend. Peter MacNeilage has also provided encouragement and advice throughout my graduate career and has been central to my development as an academic. Thank you to Tom Marquardt for his continual professional guidance as well as financial support.

I gratefully thank my colleagues in Ecuador who supported me throughout this project. Particular thanks to Marleen Haboud Ortega, who introduced me to and shared my interest in the Quichua-speaking community. Her advice, contacts, and

continued interest in my project have been invaluable. Fernando Garcés provided much needed expertise on the phonology of Ecuadorean Quichua and on the Quichua speakers of the Zumbagua region. Fabian Potosí taught me much of the Quichua I know, and conducted reliability on adult Quichua for me. Thank you to the Salesian priests in Zumbahua who provided shelter, food, and perspective during my data collection. And of course, thank you to Daniel Guanotuña, who tirelessly assisted me throughout data collection, providing both linguistic and cultural translation, as well as the means to community participation in Michacalá.

A special thank you to the families of the children in this study as well as to the community of Michacalá, who welcomed me into their homes without hesitation. And thanks to the children themselves, who went on vocalizing, despite my tape recorders and microphones.

Thanks to all my friends who have encouraged and listened so much throughout the years. Particular thanks to Kathy Jakielski, who conducted the English reliability, Lisa Redford, who conducted the Quichua infant reliability, and Deborah von Hapsburg, who contributed numerous ideas.

I am deeply grateful to my parents, Kaethe and George, and siblings, Walter and Alison – for their patience and interest in my studies, and continued emotional and intellectual support throughout. Lastly but most importantly, I'd like to thank

my family, Jonathan, Simona, and Elijah, who have lived and breathed this project for too long, two of you since the day you were born!

CONSTRAINTS ON INFANT SPEECH ACQUISITION:

A CROSS-LANGUAGE PERSPECTIVE

Publication No._____

Christina Elke Gildersleeve-Neumann, Ph.D.

The University of Texas at Austin, 2001

Supervisor: Barbara L. Davis

This study explored the relative contributions of child-internal production factors and perceptual influences from the ambient language on early speech-+ acquisition. Research has suggested that both articulatory complexity and perceptual distinctiveness impact a language's phonetic inventory; however, the ways these two properties interact during speech acquisition is not well understood. Quichua, spoken in Highland Ecuador, differs from English in many phonological properties. Babbling and early words of seven Quichua-learning infants between 9 and 16 months at the onset were followed longitudinally for 6 months. They were compared to the babbling and early words of English-learning infants and to Quichua and English adult speech samples.

Production factors predominated in the babbling and early words of the Quichua infants. The infants' productions in the two language environments were

more similar than the Quichua infants' speech productions were to the Quichua adult language models. Infants from both language environments primarily produced coronal stops and nasals, lower left quadrant vowels, simple consonant-vowel syllables, one-syllable utterances, as well as similar predicted intrasyllabic consonant-vowel co-occurrence and intersyllabic consonant-consonant and vowel-vowel variegation patterns.

Evidence of ambient language influences was apparent in consonant and vowel inventories and utterance length in the older infants. Dorsals, fricatives, and affricates occurred more frequently, and labials and liquids occurred less frequently in Quichua than English-learning infants. Quichua infants also produced more low vowels in late babbling and more two- and three-or-more syllable words. These findings all mirror Quichua properties. In addition, the Quichua infants' lower level of word use and shorter babbling length appear to reflect cultural influences. These findings indicate that child-internal production factors, ambient language influences and cultural norms must all be considered in an attempt to understand early speech acquisition.

Many of the production patterns observed in the infants' utterances also occurred in the adult ambient language, although not to the same extent as in the infants. Based on the parallel findings in infants and adults, it appears that production-based factors are a principle underlying factor in babbling and first words, and are so basic to the production mechanism that they are retained to a lesser extent in modern languages.

Table of Contents

List of Tables xvi

List of Figures xvii

CHAPTER 1: INTRODUCTION 1

CHAPTER 2: REVIEW OF THE LITERATURE 5

PERCEPTION AND PRODUCTION IN SPEECH ACQUISITION 5

RELATIONSHIP BETWEEN PRODUCTION AND PERCEPTION 7

INFANT PERCEPTUAL ABILITIES 10

INFANT PRODUCTION PATTERNS 13

The Frame Dominance Hypothesis 16

RESEARCH ON AMBIENT LANGUAGE INFLUENCES DURING ACQUISITION 20

Prosody and Tone 22

Production Properties of Prosodic and Tonal Information 23

Listener-Perception of Prosodic Information 26

Prosody and Tone Summary 29

General Segmental, Syllabic and Word Information 30

Continuity Between Babbling and First Words 30

Segmental Information 33

Syllable and Word Shapes 42

Segmental, Syllable, and Word Shape Summary 46

Intrasyllabic and Intersyllabic Patterns 47

Intrasyllabic Consonant-Vowel Co-Occurrence and Intersyllabic Consonant and Vowel Variegation Patterns 47

Anterior-Posterior Variegation Patterns 55

Intrasyllabic and Intersyllabic Patterns Summary 57

ECUADOREAN QUICHUA 61
General Segmental Information 62
Phonetic Inventory 62
Syllable and Word Shapes 65
RESEARCH HYPOTHESES 66
Hypothesis 1 – General Inventory Information: 68
Hypothesis 2 – Intra-syllabic Information: 69
Hypothesis 3 – Inter-syllabic Reduplication and Variegation Constraints: 69
CHAPTER 3: METHODOLOGY 71
Subjects and Data Collection Procedures 72
Quichua Infants 72
English-Learning Infants 74
Adults 75
Data Analysis 76
Transcription 76
The Data Set 78
Reliability 81
Quichua Infants 81
English-Learning Infants 84
Quichua and American Adults 84
Data Analysis 85
Consonant Place 86
Consonant Manner 87
Vowels 87
Statistical Analysis 87
CHAPTER 4: RESULTS 89
General Syllabic and Segmental Information 90
Consonants 90

Consonant Place 90
Consonant Place in Quichua and English 90
Consonant Place in Quichua Infant Babbling and Words 91
Consonant Place in Quichua Adults and Quichua Infants 92
Consonant Place in Quichua and English-Learning Infants 94
Consonant Place Summary 97
Consonant Manner 98
Consonant Manner in Quichua and English 98
Consonant Manner in Quichua Infant Babbling and Words 99
Consonant Manner in Quichua Adults and Quichua Infants 100
Consonant Manner in Quichua and English-Learning Infants 102
Consonant Manner Summary 104
Vowels 105
Vowel Front/Back Patterns 105
Vowel Front/Back Patterns in Quichua and English 105
Vowel Front/Back Patterns in Quichua Infant Babbling and Words 106
Vowel Front/Back Patterns in Quichua Adults and Quichua Infants 107
Vowel Front/Back Patterns in Quichua and English-Learning Infants 109
Vowel Front/Back Patterns Summary 111
Vowel Height 112
Vowel Height in Quichua and English Adults 112
Vowel Height in Quichua Infant Babbling and Words 113
Vowel Height in Quichua Adults and Quichua Infants 114

Vowel Height in Quichua and English-Learning Infants 115
Vowel Height Summary 118
Consonant-Vowel (CV) Ratio 118
CV Ratio in Quichua and English 118
CV Ratios in Quichua Infant Babbling and Words 119
CV Ratios in Quichua Adults and Infants 120
CV Ratios in Quichua and English-Learning Infants 121
CV Ratios Summary 122
Word Length Patterns 123
Word Length Patterns in Quichua and English 123
Word Length Patterns in Quichua Infant Babbling and Words 124
Word Length Patterns in Quichua Adults and Quichua Infants 125
Word Length Patterns in Quichua and English-Learning Infants 126
Word Length Patterns Summary 129
Intrasyllabic Information 130
Consonant-Vowel (CV) Co-occurrence 130
CV Co-occurrence Patterns in Quichua and English 131
CV Co-occurrence Patterns in Quichua Infant Babbling and Words 132
CV Co-occurrence Patterns in Quichua Adults and Quichua Infants 132
CV Co-Occurrence Patterns in Quichua and English-Learning Infants 133
CV Co-Occurrence Summary 135
Intersyllabic Information 136
Consonant Reduplication and Variegation 136
Consonant Reduplication vs. Variegation and Types of Variegation in Quichua and English 136

Consonant Reduplication vs. Variegation and Types of Variegation in Quichua Infant Babbling and Words..... 138

Consonant Reduplication vs. Variegation and Types of Variegation Quichua Adults and Quichua Infants 139

Consonant Reduplication vs. Variegation and Types of Variegation in Quichua and English-Learning Infants.... 142

Consonant Reduplication vs. Variegation and Types of Variegation Summary..... 146

Vowel Reduplication and Variegation 148

Vowel Reduplication vs. Variegation and Types of Variegation in Quichua and English 148

Vowel Reduplication vs. Variegation and Types of Variegation in Quichua Infant Babbling and Words..... 150

Vowel Reduplication vs. Variegation and Types of Variegation in Quichua Adults and Quichua Infants 152

Vowel Reduplication vs. Variegation and Types of Variegation Quichua and English-Learning Infants..... 154

Vowel Reduplication vs. Variegation and Types of Variegation Summary..... 158

Anterior-Posterior Patterns..... 159

Anterior-Posterior Patterns in Consonant-Vowel-Consonant Productions (CVCs) 160

Anterior-Posterior Patterns for CVCs in Quichua and English..... 160

Anterior-Posterior Patterns for CVCs in Quichua Infant Babbling and Words..... 161

Anterior-Posterior Patterns for CVCs in Quichua Adults and Quichua Infants..... 161

Anterior-Posterior Patterns for CVCs in Quichua and English-Learning Infants..... 162

Anterior-Posterior Patterns for CVCs Summary 163

Anterior-Posterior Patterns in Consonant-Vowel-Consonant-Vowel Productions (CVCVs)..... 164

Anterior-Posterior Patterns for CVCVs in Quichua and English 164
Anterior-Posterior Patterns for CVCVs in Quichua Infant Babbling and Words 165
Anterior-Posterior Patterns for CVCVs in Quichua Adults and Quichua Infants 166
Anterior-Posterior Patterns for CVCVs in Quichua and English-Learning Infants 167
Anterior-Posterior Patterns for CVCVs Summary 168

CHAPTER 5: DISCUSSION 169
Theoretical Framework 171
Frame Dominance 171
Dynamic Systems 174
Culture 176
Findings 178
Production Factors 178
CV Co-Occurrence Patterns 179
Reduplication/Variegation Patterns 182
Consonant Vowel Ratios 189
Ambient Language Influences 192
Consonant Inventory 192
Vowel Inventory 194
Utterance Length Patterns 196
Conclusion 203
Bibliography 208
Vita 222

List of Tables

Table 2-1: Highland Ecuadorean Quichua Consonant Place & Manner Categories 64

Table 3-1: Quichua Infant Characteristics 73

Table 3-2: English-Learning Infant Characteristics 75

Table 3-3: Babbling and Words for Quichua Infants by Age Group and Total .. 79

Table 3-4: Babbling and Words for English-Learning Infants by Age Group and Total 80

Table 3-5: Quichua and English Adults Total Words and Syllables 81

Table 3-6: Quichua Infant Transcription Reliability 83

Table 4-1: Observed to Expected CV-Co-Occurrence in Quichua & English .. 131

Table 4-2: Observed to Expected CV Co-occurrence in Quichua Adults & Infants 133

Table 4-3: Observed to Expected CV Co-Occurrence in Quichua & English-Learning Infants' Babbling 134

Table 4-4: Observed to Expected CV Co-Occurrence in Quichua & English-Learning Infants' Words 135

List of Figures

Figure 4-1: Consonant Place in Quichua & English 91

Figure 4-2: Consonant Place in Quichua Adults & Infants..... 93

Figure 4-3: Consonant Place in Quichua & English-Learning Infants' Babbling 95

Figure 4-4: Consonant Place in Quichua & English-Learning Infants' Words ... 96

Figure 4-5: Consonant Manner in Quichua & English 98

Figure 4-6: Consonant Manner in Quichua Adults & Infants 101

Figure 4-7: Consonant Manner in Quichua & English-Learning Infants' Babbling 103

Figure 4-8: Consonant Manner in Quichua- & English-Learning Infants' Words 104

Figure 4-9: Vowel Front/Back Patterns in Quichua & English..... 106

Figure 4-10: Vowel Front/Back Patterns in Quichua Adults & Infants 108

Figure 4-11: Vowel Front/Back Patterns in Quichua & English-Learning Infants' Babbling 110

Figure 4-12: Vowel Front/Back Patterns in Quichua & English-Learning Infant's Words 111

Figure 4-13: Vowel Height in Quichua & English..... 113

Figure 4-14: Vowel Height in Quichua Adults & Infants 114

Figure 4-15: Vowel Height in Quichua & English-Learning Infants' Babbling . 116

Figure 4-16: Vowel Height in Quichua and English-Learning Infants' Words... 117

Figure 4-17: CV Ratios in Quichua & English 119

Figure 4-18: CV Ratios in Quichua Adults & Infants 120
Figure 4-19: CV Ratios in Quichua & English-Learning Infants' Babbling 121
Figure 4-20: CV Ratios in Quichua and English-Learning Infants' Words 122
Figure 4-21: Word Length Patterns in Quichua & English 124
Figure 4-22: Word Length Patterns in Quichua Adults & Infants 126
Figure 4-23: Utterance Length in Quichua & English-Learning Infants' Babbling 128
Figure 4-24: Word Length Patterns in Quichua & English-Learning Infants' Words 129
Figure 4-25: Consonant Reduplication and Variegation in Quichua & English . 137
Figure 4-26: Consonant Variegation Patterns in Quichua & English 138
Figure 4-27: Consonant Reduplication and Variegation in Quichua Adults & Infants 140
Figure 4-28: Consonant Variegation Patterns in Quichua Adults & Infants 141
Figure 4-29: Consonant Reduplication and Variegation in Quichua & English-Learning Infants' Babbling 143
Figure 4-30: Consonant Variegation Patterns in Quichua & English-Learning Infants' Babbling 144
Figure 4-31: Consonant Reduplication and Variegation in Quichua & English-Learning Infants' Words 145
Figure 4-32: Consonant Variegation Patterns in Quichua & English-Learning Infants' Words 146
Figure 4-33: Vowel Reduplication and Variegation in Quichua & English 149

Figure 4-34: Vowel Variegation Patterns in Quichua & English..... 150
Figure 4-35: Vowel Reduplication and Variegation in Quichua Adults & Infants..... 152
Figure 4-36: Vowel Variegation Patterns in Quichua Adults & Infants..... 153
Figure 4-37: Vowel Reduplication and Variegation in Quichua & English-Learning Infants' Babbling..... 155
Figure 4-38: Vowel Variegation Patterns in Quichua & English-Learning Infants' Babbling 156
Figure 4-39: Vowel Reduplication and Variegation in Quichua & English-Learning Infants' Words..... 157
Figure 4-40: Vowel Variegation Patterns in Quichua & English-Learning Infants' Words 158
Figure 4-41: Anterior-Posterior Patterns for CVCs in Quichua and English..... 161
Figure 4-42: Anterior-Posterior Patterns for CVCs in Quichua Adults & Infants..... 162
Figure 4-43: Anterior-Posterior Patterns for CVCs in Quichua & English-Learning Infants' Babbling..... 163
Figure 4-44: Anterior-Posterior Patterns for CVCVs in Quichua & English..... 165
Figure 4-45: Anterior-Posterior Patterns for CVCVs in Quichua Adults & Infants..... 166
Figure 4-46: Anterior-Posterior Patterns for CVCVs in Quichua & English-Learning Infants' Babbling..... 167

CHAPTER 1: INTRODUCTION

The present study explores the relative contribution of production factors and ambient language perceptual influences in early speech acquisition. Previous research has suggested that production and perception influences are interconnected in adult languages (Lindblom, 1992), with a constant interplay between achieving perceptual distinctiveness at minimal articulatory displacement determining the phonological composition of a language. However, the extent to which these factors are interconnected during early speech acquisition is not well understood.

This study represents the first longitudinal analysis of early speech acquisition in a non-Indo-European language to address the potential role of perceptual influences from ambient language input versus child internal production factors. These factors are explored by comparing infant babbling and early word productions of Quichua-learning infants to infant babbling and early word productions of English-learning infants. Both are compared to ambient language influences found in Quichua and American English phonology.

Seven Quichua-learning infants between the ages of 9 and 16 months at the onset of the study were followed longitudinally for approximately six months. Their babbling data are divided into three age groups: 9 to 13 months, 13 to 17 months, and 17 to 22 months. Their babbling and early word utterances are compared to available data on six American English-learning infants (Davis & MacNeilage, 1995, Davis, MacNeilage, & Matyear, in press). In addition,

connected speech samples of seven adult Quichua speakers and seven adult English speakers were collected for comparison, to determine language differences. The adult samples are also compared to infant Quichua vocalizations, to analyze for ambient language influences.

Phonological differences between Quichua, spoken in Highland Ecuador, and English motivated this study. Preliminary analysis determined that Quichua and English differ in segmental and syllabic features. Quichua has more dorsals, fricatives, and affricates, and fewer labials and liquids, than English. In contrast to English, Quichua has only three vowels and is primarily composed of multisyllabic words and simple consonant-vowel syllable shapes.

The roles of production and perception were tested in this cross-language study by evaluating predicted patterns of the frame dominance hypothesis. MacNeilage and Davis (1990, 1993) have proposed the frame dominance hypothesis to explain production constraints during early speech acquisition. This perspective predicts intrasyllabic dependencies between vowels and consonants produced by mandibular open-close rhythmic cycles (‘frames’) with little independence of active articulators such as the tongue or velum during speech-like movements. This lack of independence is also expected intersyllabically. From a frame dominance perspective, independent control of sub-syllabic elements is not predicted to be present in babbling or in first words of infants in any language environment, regardless of the frequency of consonants and vowels and combinations in the adult target language.

To examine the roles of production and perception factors in early speech acquisition, this study tested three hypotheses. Production constraints were predicted to predominate over perceptual influences from the ambient language environment for 1) segmental inventories of consonants and vowels and utterance shapes, 2) intrasyllabic, and 3) intersyllabic patterns.

Results showed that the majority of sounds and sound patterns in Quichua infants are more similar to patterns in English-learning infants than they are to the ambient language. Utterance shapes, intrasyllabic patterns, and intersyllabic patterns did not significantly differ from those observed in English-learning infants. Consonant and vowel inventories in the younger Quichua infants were similar to the inventories of English-learning infants. However, ambient language influences were observed in the consonant and vowel inventories of the older infants. In addition, frequency of word production and length of babbling utterances appeared to reflect societal norms.

The majority of the findings support MacNeilage and Davis' frame dominance hypothesis, suggesting that production factors predominate in early speech acquisition. However, limited ambient language influences were apparent in Quichua infant babbling and words. The results of this study are explained from a dynamic systems' perspective to understand the interconnectedness of perception and production in early speech acquisition. Dynamic systems provides an important metaphor for understanding how heterogeneous components are interconnected in complex biological systems. The findings that social influences affect speech acquisition are explained from a Vygotskyan perspective,

suggesting that the children's motivation to communicate with others in their culture is also a guiding force during speech acquisition.

In addition to the findings on speech acquisition, findings for Quichua are similar to those found for English, suggesting that production factors are also important in explaining adult languages. This study shows that production patterns in the form of frame dominance prevail in the organization of adult languages studied thus far. Thus intrasyllabic and intersyllabic patterns resulting from articulatory complexity are shown to predominate in early speech acquisition and to continue in languages, although weakened somewhat due to the need for perceptual distinctiveness.

CHAPTER 2: REVIEW OF THE LITERATURE

PERCEPTION AND PRODUCTION IN SPEECH ACQUISITION

To understand the nature of infant speech acquisition, it is necessary to explore various contributing factors as well as the relative importance of each. Two primary factors proposed as contributing to speech acquisition are production and perception. An early hypothesis of Roman Jakobson (1968/1941) suggested that perceptual factors play the predominant role in the unfolding of speech contrasts in acquisition. Recent data-based research refutes his claims of a universal sequence of development of phonemic contrasts across infants and languages. In contrast, data suggest that production constraints within the child limit and may guide the development process (Davis & MacNeilage, 1995a; Locke, 1983; Oller, Wieman, Doyle, & Ross, 1976; Stark, 1980). However, some research suggests that characteristics of babbling and early words differ systematically in children from different language environments, suggesting that the ambient language may play an important role in early development (e.g., Boysson-Bardies & Vihman, 1991; Levitt & Aydelott-Utman, 1992).

Speech acquisition research emphasizing the primary importance of production influences suggests that highly similar production patterns in sounds and sound combinations will be found in infant babbling and early words across different language environments. Perceptual influences of the ambient language environment are not considered to be as central in early speech acquisition as are production constraints. In contrast, ambient language-oriented research suggests

that there are differences in babbling and early words in infants from diverse language environments, indicating that the perceptual influence from the ambient language plays a significant role in speech acquisition. From this perspective, individual differences in children and across languages are relatively more emphasized, based on the influence of the local environment as well as each child's response to the ambient environment.

It is principally through longitudinal studies of speech acquisition in varied language environments that appropriate and testable means of assessing the relative contributions of perception and production factors will be found, as well as understanding how and when each influences the acquisition process. To determine the relative importance of production and perception influences during acquisition, it is necessary to compare babbling and early words of infants from diverse language environments. Languages studied must differ in segmental and syllabic composition so that questions of perception and production influences can be appropriately assessed. Research suggesting general production characteristics for speech acquisition has been conducted primarily on English-learning infants. These findings need to be replicated on infants from varied language environments to assess the generality of patterns proposed based on studies of English.

The current study provides longitudinal data from infants during the babbling and early word period to evaluate the relative role of production and perception during this period of speech acquisition. Phonetic properties of babbling and early words in seven infants and seven adult speakers from a

Quichua language environment were evaluated and compared to English-learning infants and to English. The phonemes and syllable structure of Quichua and English differ in many ways. The goals of this study were 1) to determine the generality of previously hypothesized production characteristics, based on infants in Indo-European language environments, to these Quichua infants, and 2) to evaluate potential ambient language influences from the Quichua language environment in babbling and early word productions.

An overview of the relationship between production and perception in adult languages is provided to give a context for exploring acquisition. A description of a production constraint model (MacNeilage & Davis 1990, 1993) that forms a framework for this dissertation is reviewed. Then a review of the research on speech production as it applies to production constraints and ambient language influences is provided for the purpose of establishing what kinds of acquisition data are available for evaluating the findings in this study. Phonetic and phonological properties of Quichua are discussed. Finally, three research hypotheses that predict production constraints during speech acquisition will be presented.

RELATIONSHIP BETWEEN PERCEPTION AND PRODUCTION

Lindblom (1992) has argued that in languages, and to some extent in infant vocalizations, perception and production influences are inextricably connected. According to Lindblom, perception and production play an interactive role in the selection of consonants and vowels in any language, with a balance

between perception and production resulting in maximal perceptual distinctiveness at minimal articulatory cost (Lindblom & Maddieson, 1988).

This equilibrium of perceptual distinctiveness and ease of production is suggested as being the determining factor in the phonemes found in any given language. There are roughly 5,000 languages in the world (Maddieson, 1984), with the average number of consonants per language 20 to 25, and the average number of vowels typically five (Maddieson, 1984). Some languages contain as few as 6 and some as many as 95 consonants (Lindblom & Maddieson, 1988). Importantly, the majority of the phonemes in diverse languages are highly similar – oral and nasal stop consonants and the vowels /i, a, u/ (Lindblom, 1986; Lindblom & Maddieson, 1988).

While perceptual distinctiveness is always paramount, achieving distinctiveness is accomplished with as little articulatory complexity as possible. Lindblom and Maddieson maintain that the components of an expanded consonant or vowel inventory are determined by phonetic content in the form of articulatory complexity (Lindblom & Maddieson, 1988). They define consonants as “basic,” “elaborated,” and “complex,” depending on the number of articulatory movements and the articulatory displacement necessary to produce them. Consonants that comprise the majority of the world's languages are "basic," requiring simple articulator movement (Maddieson, 1984). Basic consonants are often the only consonants in languages with small consonant inventories. Consonant inventory size appears to be the primary selection constraint, with larger consonant inventories showing greater articulatory complexity in order to

achieve sufficient perceptual contrast. Only as consonant inventories increase in size are "elaborated" consonants added to inventories. "Complex" consonants appear in languages with the largest consonant inventories. Languages containing complex consonant inventories build these inventories from a core of basic sounds rather than developing novel movement patterns, thus utilizing already mastered articulatory movement patterns for expanding the inventory (Lindblom, 1992).

Lindblom and Maddieson's (1988) findings suggest that in adult languages there is interplay between perception and production that determines a language's phonological inventory. But according to Lindblom (1992), in infant productions during early acquisition, a lack of motor control results in constrained babbling and first word phonetic inventories, as a result of production difficulty for the infant. Lindblom also suggests that due to this difficulty, phonetic inventories in babbling and first words will be highly similar cross-linguistically.

As evidence, basic sounds characterize both the majority of the sounds in the world's languages and the sound qualities that first emerge in babbling and continue to characterize first word productions (Lindblom, 1992). Lindblom proposes that the infant is equipped with a system oriented to speech production, whereby the infant does not need to rely on cognitive abilities for the emergence of speech (Lindblom, 1990). Productions will remain similar until the infant has gained greater motor control, regardless of emerging ambient language specific perceptual abilities.

The sounds less frequent in early infant vocalizations involve control of the back of the tongue–dorsal consonants and back vowels, and articulatorily more complex manners of articulation, including fricatives, liquids, and affricates (Gildersleeve-Neumann, Davis, & MacNeilage, 2000). To eventually master articulatorily-more-difficult sounds, an infant is hypothesized to increase speech production abilities by developing new routines using the phonetic information already familiar from previous productions.

In summary, perception and production both appear to be factors determining the sounds that comprise adult languages. But this is not clearly the case during speech acquisition. As will be discussed, research based primarily on English infants, and to some extent on infants in Indo-European languages environments, suggests that sounds in babbling and early words are highly similar, likely due to the production constraints during speech acquisition.

INFANT PERCEPTUAL ABILITIES

To determine the relative roles of perception of ambient language differences versus production influences in infant speech acquisition, it is necessary to understand initial constraints and abilities as well as those developed in the first few months of life.

Research suggests that perceptual abilities relative to the basic properties of the auditory system are developed early in life. By the 28th week of gestation, infants are receiving auditory input (Pujol, Lavigne-Rebillard, & Uziel, 1991). In the womb, infants receive a lowpass filtered speech signal, thus providing general

prosodic information, such as language-specific intonation patterns, long before birth (Querleu, Renard, Boutteville, & Crepin, 1988).

As a result of the prenatal auditory processing, newborn infants have a sensitivity to prosodic features that will potentially aid them in discriminating their ambient language from other languages during the first year (Jusczyk, 1992). Newborns can discriminate native from nonnative languages (Moon, Cooper, & Fifer, 1993), as well as nonnative languages from rhythmically different language families (Mehler et al., 1988, Mehler and Christophe, 1994, cited in Werker & Tees, 1999). And even at this early age, infants prefer sounds of their ambient language to those of an unfamiliar language. By one month of age, infants discriminate syllables differing in a single consonant or vowel property, such as place, manner, backness, height, or voicing (Eimas, 1975; Eimas, 1974; Jusczyk, 1977; Levitt, Jusczyk, Murray, & Carden, 1988; Trehub, 1976). These categorical discrimination abilities have been characterized as universal, regardless of the particular phonemic contrasts in the infants' ambient language environment.

Infants are born with the ability to contrast sounds and sound combinations from any language, making it possible for them to learn the language of whichever language environment they are born into. These are abilities not found in adult speakers, whose perceptual discrimination skills are primarily available for native language discrimination. Consequently, infants must lose their ability to distinguish all sounds, instead focusing on those necessary to learn the ambient language. This non-native language perceptual

loss occurs during the second half of the infant's first year. Werker and colleagues (Werker & Lalonde, 1988; Werker & Tees, 1983; Werker & Tees, 1984) have explored this loss of discrimination for non-native language contrasts. Their findings suggest that non-phonemic perceptual distinctions the infant was capable of at 6 months are lost between 10 and 12 months of age. This loss may occur as early as six months of age for non-phonemic vowel contrasts (Polka & Werker, 1994) and as early as four and one-half months of age for language-specific prosodic cues (Jusczyk et al., 1992). Best (1988) and Werker (1992) suggest that the infant’s general perceptual reorganization happens at the point when the infant is beginning to comprehend and sometimes produce words. In contrast, the infant's general pre-phonemic sensitivity is well suited for learning whichever language surrounds her.

This perceptual reorganization reflecting native language perceptual categories occurs at the same time as infants are beginning to perceive and produce their first words. Recent findings by Stager and Werker (1997) show that infants at 14 months pay less attention to phonetic details of words than at 8 months. Werker explains this "loss" as an increased sensitivity to the native language syllabic characteristics, allowing the infant to represent and pay attention to native language forms. Werker and colleagues have suggested that a loss in understanding of non-ambient language perceptual distinctions occurs concurrent with a functional reorganization in the child, one in which the child shifts from focusing on specific sound differences to a focus on lexical meaning (Werker & Tees, 1999). The word-learning situation imposes many new demands

on infants' attention. For this reason, during the early first word period, there may be less emphasis on encoding all the information that could be received from the acoustic signal–information that the infant was attuned to earlier (Jusczyk, 1992).

In summary, infants are born with auditory abilities that provide a building block for learning language-specific phonemic categories. During the first year of life, they become more familiar with the ambient language, preferring phoneme categories initially and then higher-order prosodic and syntactic structure as familiarity with the language increases. By the onset of first words, infants have lost the ability to discriminate non-native sounds, appearing more adultlike in their emphasis on the sounds of their ambient language.

Perception research provides ample evidence to indicate that infants discriminate and prefer the sounds of their ambient language to those from other languages by the point of first word learning. These findings imply that if indeed infants are producing similar sounds in babbling and early words, it is not because they cannot discriminate the differences. The next section explores production research to understand the similarities and differences in infant production patterns cross-linguistically.

INFANT PRODUCTION PATTERNS

A perspective emphasizing speech acquisition as motor skill acquisition provides a basic rationale for the common constrained production patterns observed in babbling and first words of infants in languages which have been frequently described (Locke, 1983). The relative contribution of production

constraints to acquisition must be viewed within the context of neuro-anatomical changes and maturation. This knowledge is important for understanding how anatomical and physiological development may motivate vocalizations observed in the first year of life.

At birth, neuro-anatomical limitations affect the range, frequency, and types of vocalizations the infant produces. One limitation is a relatively large tongue that is completely contained in the oral cavity (Kahane, 1988). Initially, tongue control is primarily of the extrinsic muscles, necessary for gross tongue movements such as sucking and swallowing, and not of the intrinsic tongue muscles, necessary for the fine tongue precision of speech sounds (Fletcher, 1973). By 18 months, the posterior one-third of the tongue has descended into the pharyngeal cavity, reducing its relative proportion in the oral cavity (Kahane, 1988). Simultaneously, the infant's intrinsic tongue muscles are gradually developing, expanding tongue movement from gross motor movements of elevation, depression, and lateralization, which have predominated since birth, to fine motor control, such as tongue-tip raising and lowering, and narrowing or flattening the tongue. Tongue musculature development occurs concurrent with rapid tongue tip growth (Fletcher, 1973). By 24 months of age, anatomical structures and physiological capabilities needed to produce speech sounds are relatively developed. These include the shape of the oral cavity, tongue size, placement, and control, greater lip musculature control, separation of the oral and nasal cavities, descent and relative shape change of the larynx resulting in the separation of the oral and nasal cavities, the eruption of teeth, and better

coordination of the respiratory, laryngeal, and articulatory systems (Bosma, 1975; Fletcher, 1973; Kahane, 1988; Kent, 1981).

As a result of underdeveloped anatomical structures and physiological capabilities during the first 18 months of life, sound production is proposed as being constrained. These constraints exist regardless of the ambient language characteristics of the infant, resulting in universally-shared production characteristics in infants' early vocalizations (Buhr, 1980; Davis & MacNeilage, 1995a; Kent, 1992; Locke & Pearson, 1992; MacNeilage & Davis, 1990; Oller & Eilers, 1982; Thevenin, Eilers, Oller, & Lavoie, 1985).

Production constraints during development have been broadly predicted. Using radiographs, Kent (1981) has found that the vowels typically produced by infants–front and central vowels–are produced with a fixed tongue shape-jaw relationship, with differences in jaw height sufficient to result in perceived differences in vowel quality. He noted that early back vowels are likely produced without labial movement, thus resulting in vowels that would not likely be perceived by English listeners as back vowels, due to their lack of a phonemic equivalent in English.

Grillner (1981, 1985) has suggested that the repetition of established motor patterns is necessary to construct new motor routines. In studies of frogs with transected spinal cords, decorticated cats, and lamprey central nervous systems, Grillner has found that new motor routines develop in a hierarchical fashion to replace damaged ones, with simpler patterns underlying more complex

patterns. Grillner states that only when a movement pattern has become automatic can it develop into more complex patterns.

Hodge (1989) compared spontaneous CV utterances of 7 1/2 to 9 1/2 month old infants to imitated CV utterances produced by 3 year old, 5 year old, 9 year old children and adult speakers acoustically. She found that the relationship between the first and second formants in these CVs suggested that younger children were producing CV utterances in babbling with more mandibular than lingual movement, whereas older children and adults produced CVs with relatively greater lingual than mandibular movement.

Nittrouer (1989) measured formant frequencies in /ə/ + fricative + vowel productions in three year old, five year old, and seven year old children, as well as in 10 adults. She found that by age 3, the children were opening and closing the vocal tract in an adult-like manner. However, tongue movements in these productions were constrained by the particular consonant-vowel context until age seven.

The Frame Dominance Hypothesis

MacNeilage and Davis have proposed the Frames then Content theory as a production system oriented account for speech acquisition (for a thorough discussion of this theory, see MacNeilage, 1998). According to this functionalist theory, speech evolved from the human ability to place segmental "content" elements into syllabic "frames." These frames are mandibular oscillations, or simple close/open movements of the jaw, accompanied by phonation. Frames are

proposed to have evolved from movement patterns necessary for sucking, licking, and chewing. In speech, these close/open movements of the jaw result in consonants when the jaw is closed and vowels when the jaw is open. "Content," or individual consonants and vowels, are the result of tongue movements independent from jaw movement in sequences, resulting in a variety of consonant and vowel combinations.

Davis and MacNeilage suggest that during speech acquisition, the serial organization of babbling and early words is dominated by these frames (Davis & MacNeilage, 1990; MacNeilage & Davis, 1993). Content, in the form of independent consonants and vowels, does not appear until much later in speech acquisition. Frame dominance results from the inability to separately control the jaw and other articulators, such as the tongue, lips, and jaw in serial movement sequences during speech. The other articulators are predicted to remain in a neutral position throughout the vocalization, or to maintain the position they have assumed prior to the onset of the vocalization. For this reason, consonants and vowels are assumed to be highly interdependent within and across strings of syllables. The favored types of syllables, resulting from mandibular oscillation and unplanned preplacement of the tongue, are for front (coronal) consonants to co-occur with front vowels, back (dorsal) consonants to co-occur with back vowels, and labial consonants to co-occur with central vowels (both labial and central sounds requiring neutral tongue placement).

Frame dominance also predicts intersyllabic (intercyclic) regularities in the form of constrained consonant-vowel-consonant-vowel patterns across

syllables (MacNeilage & Davis, 1990). When consonants and vowels differ across syllables, variegation is predicted to be primarily a result of degree of mandibular oscillation and not of active tongue, lip, or palate movement. Thus, consonants separated by a vowel are predicted to differ in manner, or degree of mandibular constriction, rather than place, or tongue placement. And vowels across syllables are predicted to differ in vowel height, or jaw opening, rather than front-back dimension, or tongue front-back placement.

A reduction in frame dominance, resulting in separate control of consonants and vowels within syllables (intrasyllabically), and in separate control of consonants and vowels across syllables (intersyllabically), is considered to begin once the infant develops independent control of the tongue and velum from the mandible during movement sequences. At that point, segmental "content" elements can emerge, demonstrated by segments that are not characterized by proximity of successive articulatory positions (e.g., dorsal consonant–front vowel associations, such as /ki/, and variegated multi-syllabic syllable productions showing consonant place changes, such as /kɑtɑ/, or vowel front-back changes, such as /kuki/). However, this independent control of sub-syllabic elements is not predicted in concurrent babbling or in the first words of infants in any language environment.

MacNeilage and Davis predict that the first step away from frame dominance and towards segmental independence occurs in an infants' early words, in the form of anterior-posterior patterns (Davis, MacNeilage, & Matyear, in press; MacNeilage, Davis, Kinney, & Matyear, 2000a; MacNeilage, Davis,

Matyear, & Kinney, 2000b). It is proposed that infants produce words with variegated CVCV shapes by producing the first of the two consonants more anterior in the mouth, typically using labial-coronal patterns, since dorsal consonants are infrequent in early utterances. They propose that this configuration results from the relatively easier movement necessary to produce a labial consonant–a simple close movement during a mandibular cycle with no active tongue placement. Coronal and dorsal consonants, on the other hand, require an additional tongue movement for their production. Utterances that show initial place variegation begin with a more anterior place of articulation for the first consonant than for the second, typically in a labial-coronal consonant sequence (Davis et al., in press; MacNeilage et al., 2000a; MacNeilage et al., 2000b). The initial labial consonant may be produced without active tongue or lip involvement, perhaps because of the functional load involved in simultaneously initiating respiratory, phonatory and articulatory activity for an utterance. Once the utterance is initiated, an additional articulatory movement can be made. The second consonant in the disyllabic production is typically a coronal consonant, as production primarily requires the addition of tongue blade movement to the mandibular cycle. Because of the limited production of dorsals in infants studied thus far, this anterior-posterior prediction has primarily been investigated with labials and coronals. It is of interest to investigate whether this anterior-posterior labial-coronal pattern extends to preferences for initiating words with labial and coronal consonants over dorsal consonants or whether a more general labial-lingual pattern will result.

According to the frame dominance view, babbling and early speech in any ambient language environment will be subject to these production constraints, regardless of the frequency of consonants and vowels and combinations in the language. However, the majority of research on frame dominance has been conducted in English. Cross-language research investigated only infants in Indo-European language environments (Boysson-Bardies, 1993; Davis, MacNeilage, Gildersleeve-Neumann, & Teixeira, 1999a; Teixeira & Davis, submitted; Zlatic, MacNeilage, Matyear, & Davis, 1997). Acquisition of adult-like speech production abilities in languages other than English may show early emergence of target phones and combinations not predicted, instead of those predicted by this general production-constraint model. Additional cross-language comparisons are essential to evaluate the generality of the frame dominance predictions in describing the nature of early speech acquisition.

RESEARCH ON AMBIENT LANGUAGE INFLUENCES DURING ACQUISITION

Our knowledge and understanding of the infant speech acquisition process has greatly increased since Jakobson's proposal that sounds in babbling and first words are discontinuous and that sounds in words are perceptually motivated rather than constrained by production characteristics (1968/1941). Yet the majority of current research has been conducted with monolingual English-learning children. While this research has provided a general understanding of the acquisition of speech during the first few years of life, the emphasis on

English as the basis for assertions regarding general infant acquisition patterns may be misleading.

An infant develops within a language community, surrounded by mature speakers of a language. While core research findings suggest that consistent vocal patterns in babbling and early speech reflect production constraints, very few languages are represented in these findings, and not all languages have the same phonemic structure. Some languages have more frequent use of vowels and consonants that emerge later in the speech acquisition of English-learning infants, or contain vowel and consonant production characteristics not exploited by English for phonemic contrast. For example, the Mayan language Quiché has more frequent use of /tʃ/ than English (Pye, Ingram, & List, 1987); German has the vowel /œ/ and Spanish the consonant /ɣ/, both of which are not phonemic in English. Many languages have a more limited, or a more complex, syllable structure than English. Without in-depth research on children from a variety of language environments, generalities regarding speech acquisition patterns may not be valid, as children acquiring diverse languages may demonstrate differing acquisition patterns reflecting specific ambient language influences.

Children eventually develop the ability to produce all phonemes, syllable shapes, and sequential patterns of their ambient language, typically by about 4 or 5 years of age. At some point during the speech acquisition process, ambient language characteristics influence what the infant perceives and produces. However, it has not been established when these influences on production may

occur, as cross-language research on speech acquisition is limited, especially between the ages of 12 and 24 months.

A review of available information exploring phonetic constraints and ambient language influences in speech acquisition follows. This information is divided into three sections. First, background information on cross-linguistic studies of prosody and tone is presented. Information on phonemes, syllable, and word shapes follows. Finally information on intersyllabic and intrasyllabic production constraints is reviewed. Each section will present findings on babbling and first words. The weaknesses and strengths of individual studies will be noted, especially as they reflect on the design of the proposed cross-language study.

Prosody and Tone

While prosody and tone analysis are not within the scope of this study, ambient language influences on prosody are present prior to the onset of babbling and highlight the importance cross-language research has had on understanding perceptual effects on speech acquisition. Available cross-language research has suggested that the effect of the ambient language may first be observed in the prosody of the infant’s vocal productions, while language-specific tonal information appears later.

Ambient language effects on prosody are studied in two ways. Production studies compare prosodic qualities in the utterances of infants from different language environments. Perceptual studies ask adult listeners whether infants'

utterances sound different from each other or whether they "sound like" their ambient language.

Production Properties of Prosodic and Tonal Information

Levitt and colleagues have provided a body of research on cross-language differences in prosodic development. Whalen, Levitt & Wang (1991) examined differences between French and English infants in use of fundamental frequency and pitch contours. In 156 two- and three-syllable reduplicative babbling strings of five French and five English-learning infants (5 to 13 months), the French infants showed significantly more rising intonation and less falling intonation than the English infants. These differences in intonation reflect adult syllable contours of the two languages and supporting the notion of the ambient language effect on early prosodic development. Levitt and Wang (1991) examined final-syllable lengthening, (greater in French than English), timing of non-final syllables (equally timed in French), and the average number of syllables per utterance (more in French) in these same infants. The infants' babbling showed ambient language characteristics: a significantly higher percentage and greater magnitude of final-syllable lengthening, more reduplicative babbles that were four or more syllables in length, and more regularly timed non-final syllables in the French infants. Levitt (1993) investigated prosodic differences in these French and English-learning infants from 7 to 11 months of age. She observed non-significant tendencies toward language-specific duration and pitch characteristics such as varying syllable duration in English but not French and longer final

syllables in French. However, Levitt and colleagues' findings are weakened by grouping of data across age ranges, not permitting analysis of changes in intonation characteristics during the first year, or specific information on when language-specific effects may have occurred. Also, only 15 utterances were analyzed per infant. Data from the infants were pooled for statistical analyses so it is difficult to determine if individual infant differences were greater than cross-language differences.

Prosodic characteristics of disyllabic vocalizations were analyzed for language effects in two English and two French children (Vihman, DePaolis, & Davis, 1998). Twenty vocalizations at the 0-word, 4-word, 15-word, and 25-word points for infants from 9-18 months of age were analyzed. Early mastery was predicted for prosodic parameters whose natural manifestations are supported by the stress system of the ambient language (final lengthening in French, joint increase in pitch and amplitude on the first syllable in English). Results supported the model for final lengthening in the French infants but showed varied amplitude and pitch values in the English infants during this period.

Language-specific pitch contour and vowel durations were analyzed acoustically in babbling and words of four French and four Japanese 18-month-olds (Hallé, Boysson-Bardies, & Vihman, 1991). For the French infants, rising pitch contours and final syllable lengthening predominated, whereas falling fundamental frequency contours and absence of final lengthening were found for the Japanese children, tendencies congruent with adult prosody in the two languages.

The acquisition of tone was studied in four Cantonese children from 14 to 24 months (So & Dodd, 1995). There are nine phonemic tones in Cantonese. All four children had acquired (75% correct usage) all nine tones by the age of two. Most vowels were also mastered by the age of two. The authors suggested that tones are acquired early (relative to consonants and vowels) because of their importance in distinguishing meaning in Cantonese.

The earliest cross-language studies of tone were diary studies, collected without the assistance of audio recordings. Diary studies are particularly subjective and unreliable when analyzing prosody. Nevertheless, some early studies on the acquisition of tone are noteworthy. Tuaycharoen (1978) transcribed the babbling of a Thai child in her home environment from 3 to 5½ months of age. She noted that the infant's utterances did not exhibit any tonal information. Variation of tone and pitch were described as very similar to an English infant of the same age. These findings were similar to those of Clumeck (reported in Tuaycharoen, 1978), who kept a diary of the utterances of a Mandarin infant. Both researchers noted anecdotally that meaningful tone changes were not evident until first words emerged, suggesting that this lexical quality did not appear earlier than lexical information in non-tonal languages. Chao (1976, reported in Hallé & Boysson-Bardies, 1996) provided a diary study of his 28-month old granddaughter, raised in a Mandarin environment. Chao's findings concur with Tse, who analyzed tonal information from a 22-month old Chinese learner. Both noted that tone accuracy occurred earlier than segmental accuracy in Chinese. While these studies need to be replicated with acoustic analysis, the

researchers had linguistic training and spoke tone languages, suggesting that their findings may give a generally valid picture comparable to early diary studies of segmental information. Thus, available findings on tone languages suggest lack of meaningful control of lexical pitch contours until the emergence of words, but the ability to produce tones accurately before mastering vowel and consonant phones.

Listener-Perception of Prosodic Information

This second body of infant prosody research–adult listener perception of ambient language differences in infants' utterances–is conducted by asking adults to deduce an infants' ambient language by listening to audio recordings of infant vocalizations from a variety of language environments.

A number of adult listener studies have not found support for ambient language effects in prosody. Atkinson, MacWhinney & Stoel (1969, cited in Locke, 1983; see also Thevenin et al., 1985) presented tapes of American, Chinese, and Russian infants babbling at approximately 5, 10, and 16 months of age to adult American listeners. These listeners were able to identify English versus non-English ambient language environments of the infants correctly 57% of the time, or at a level not much greater than chance. Olney & Scholnick (1976) played two 15-second recordings of the babbling of one Chinese and one American infant, each at 6, 12, and 18 months of age, to adult American listeners. They also were not able to discriminate language background at a level

significantly above chance. Both findings were interpreted to indicate the lack of language-specific prosodic information in babbling.

Thevenin and colleagues (1985) examined the ability of adult English and adult bilingual Spanish-English speakers to discriminate babbling of English-learning from Spanish-learning infants longitudinally (Thevenin et al., 1985). They asked 20 adult judges (10 English, 10 bilingual English/Spanish) to identify the language background of seven Spanish and seven English infants, grouped between 7 to 10 and 11 to 14 months of age. Adults listened to eight randomly selected canonical babbling strings from each of the 14 infants, each one- to three-seconds long. Adult judges were unable to identify language background significantly above chance level, suggesting ambient language influences were insignificant. The authors found that bilingual and monolingual judges showed consistently different patterns of judgment with regard to particular infants and utterances. Judges appeared to be influenced by their language background, even though this influence did not lead to greater success in ambient language identification overall. However, the short length of the language samples may have negatively impacted perceptual evaluation of prosodic information.

Dinger and Blom (1973) reported on adult listener ability to discriminate infants growing up in different ambient language environments. Fifty Dutch and 50 American adults were asked to identify the language background of two Dutch and two American babies at approximately 8, 10, 12, 15, and 18 months of age. The authors found that listeners could first accurately discriminate the ambient language of the babbling infants at one year of age, and that accuracy of

discrimination increased at older ages. Unfortunately, words were not excluded from the 90-second samples, thus making it possible that the correct language discrimination was based on lexical items and not language-specific segmental or prosodic characteristics.

Boysson-Bardies and colleagues asked French adults to determine if infants audiotaped at 6, 8, and 10 months of age were French (Boysson-Bardies, Sagart, & Durand, 1984). Four of the infants were French, two were Arabic, and two were Chinese. Forty native French adults heard four 15-second babbling sequences from each infant. At 6 months of age, the listeners were correct in determining language environment 55%, at 8 months, 74%, and at 10 months, 53%. When all three possible ambient language choices were available to the listeners, correctness of judgments did not change greatly, remaining at chance levels for the 6- and 10-month old infants. Twelve French phoneticians also listened to the segments. Their success rate was slightly higher, but followed the same trend of identifying the 8-month olds correctly more often. Boysson-Bardies concluded that there is an early ambient language influence on the metaphonological characteristics of babbling and that listeners received clues from the intonational cues of canonical babbling of the 8-month old infants. She suggested that the chance correct identification of 10-month olds was due to primary cues being segmental, and that segmental information did not differentiate ambient language environment. Her findings suggest that segmental information in the babbling of 10-month-olds is highly similar and not discriminable cross-linguistically.

Prosody and Tone Summary

Studies of ambient language effects on prosody in infants' utterances provide conflicting results. At some point between 5 and 12 months, acoustical analysis suggests potential ambient language influences on prosody. From an early age, infants appear to pay attention to and match the prosodic qualities of the language they hear in their ambient language environment (Dinger & Blom, 1973; Hallé et al., 1991). These findings are supported by perceptual studies, suggesting that infants discriminate ambient language prosody from nonnative prosodic information (Jusczyk, Luce, & Charles-Luce, 1994; Jusczyk, Cutler, & Redanz, 1993). However, at seven to eight months, when canonical babbling appears and infants show loss in attention to nonnative perceptual information, adult listeners in the majority of studies have not been able to identify ambient languages of infants at a rate greater than chance. These findings suggest that the perceptual abilities of the infants are not reflected in their babbling productions. Available research on tonal languages indicates that pre-linguistic babbling may not show contrastive tonal information related to ambient language characteristics, yet infants in a tone language environment produce some ambient language tones in babbling, demonstrating potential ambient language influences on their babbling. Studies-to-date suggest that ambient language prosodic characteristics may be observed in infants earlier than segmental and syllabic qualities, although methodological considerations in all these studies reduce the strength of the effects proposed.

General Segmental, Syllabic and Word Information

Continuity Between Babbling and First Words

The continuity of babbling and first word stages was one of the first questions explored in the study of infant speech acquisition. From a phonetic/functional perspective, speech is like any motor skill and evolves as the infant gradually develops control of the speech mechanism. Words and babbling require the same motor patterns, and are likely to be subject to similar production constraints.

Grégoire was one of the first child researchers to show an interest in babbling as a way of understanding speech acquisition. He suggested that babbling and word stages are continuous. He also thought that environmental influences could be observed in early babbling. While he did not have the opportunity to conduct crosslinguistic research to confirm or disprove his theories, studies of his two children, and the proposed influences of their native French on their babbling, led him to assert that as early as the cooing stage, a child's language environment influences vocalizations.

Jakobson argued that infant babbling and first words were discontinuous, and therefore found babbling not of interest in the study of speech development (1968/1941). Pre-linguistic babbling was hypothesized as containing "articulations which are never found within a single language," including, "palatalized and rounded consonants, sibilants, affricates, clicks, complex vowels…" (pg. 21). However, when words emerged, non-phonemic contrasts

were not distinguished, according to Jakobson. An infant's sound repertoire was proposed to be extremely limited, slowly developing in complexity through the unfolding of a universal sequence of perceptually-based phonological oppositions, reaching phonemic complexity of the ambient language by three to four years of age.

Brown (1958) rejected Jakobson's notion that infants babbled similarly cross-linguistically. Like Grégoire, Brown suggested that the babbling of infants would "drift" towards their ambient language before the onset of first words, reflecting the adult language in types and frequency of sounds produced. He proposed that perceptual information available regarding the ambient language would be reflected in infant output.

Locke (1983) disagreed with Brown, Grégoire, and Jakobson. Locke asserted that babbling would not drift towards the infant's ambient language before first words. Locke proposed that during the period of babbling and first words, vocalizations would be highly similar cross-linguistically, and would be composed of limited sound categories. Locke's (1983) compilation of data from 15 languages representing 124 infants was the first large assembly of cross-language data. He found that the phonetic inventory of infant speech in different ambient language environments reflects universal production tendencies. For example, his collection of babbling samples demonstrated that the phones of infant babbling at 11 to 12 months had remarkable similarities. In Locke's analysis, 95% of consonant phones in babbling at 11 to 12 months were /p, t, k, b, d, g, m, n, w, j, h, s/.

Subsequent studies of infants in English environments have confirmed Locke's assertions about continuity between babbling and first words. Oller, Wieman, Doyle & Ross (1976) compared consonant productions in babbling of five 6 to 8 month old American English infants to those of five 12 to 13 month olds in first words. They found that all infants showed a propensity for unaspirated stops, final devoicing, fewer initial fricatives than initial stops, and more final fricatives than stops. Infants in both periods produced more apical (tongue front) than dorsal consonants. Vihman and colleagues (Vihman, Ferguson, & Elbert, 1986; Vihman, Macken, Miller, Simmons, & Miller, 1985) analyzed parallels in babbling and first words in nine American English-learning infants from 9 to 17 months of age. They found similarities in vocalization length (primarily monosyllabic), consonant inventory (stops, nasals, labials, and dentals) and sequential complexity (virtual nonexistence of consonant clusters) in the babbling and first words of infants both within and across time periods studied. Like Oller et al's findings, Vihman's findings also strongly support the notion of continuity in sound productions through earliest periods of speech acquisition.

Thus, current research on acquisition of babbling and first words has not supported Jakobson’s assertion of discontinuity. The types of sounds and sequences found in babbling appear to form the phonetic substrate for first words and are consistent within and across infants.

Grégoire's (1937, cited in Boysson-Bardies, 1999) assertion that babbling demonstrates environmental influences continues to warrant examination. The major studies of babbling and first words in English have formed a foundation for

our understanding of speech acquisition. They are typically larger in scale than existing crosslinguistic studies. Also, the volume and variety of English-based studies have served to provide us with a general understanding of speech acquisition. However, to determine whether babbling and words differ for children in varied language environments in ways that reflect the ambient language requires further in-depth studies in new languages.

Segmental Information

In addition to establishing continuity between babbling and early words, Locke's 1983 study suggested that infants in a variety of language environments primarily produce coronal and labial stop and nasal consonants in babbling. This result has been confirmed in subsequent research on infants from English and other language environments.

Kent and Bauer (1985) studied the babbling vocalizations of five American English-learning infants at 12 months of age. They confirmed Locke's (1983) finding that most consonant productions were labial and apical stops and nasals. They also suggested that most vowels produced in babbling were in the lower left quadrant of the vowel space (low- and mid- central and front vowels).

Stoel-Gammon (1985) proposed that the same sound qualities are present in babbling and first words. In her study of 34 American English-learning infants from 9 to 24 months of age, word-initial consonants were primarily voiced anterior stops, nasals, and glides. Velar consonants and voiceless fricatives were not common in words until 24 months of age. When the sounds present in the

phonetic inventory of over 50% of her infants are compared with Locke's 1983 data, all sounds in babbling were present in first words except for /j/. In addition, Stoel Gammon's data found initial /f/ and final /ɹ/ in first words.

Davis and MacNeilage (1990) analyzed vowel and consonant inventories in the first words of one infant recorded weekly from 14 to 20 months of age. The infant's vowel inventory in unstressed syllables in disyllabic words was determined to be similar to that reported for babbling – a preponderance of vowels in the lower-left quadrant. Monosyllabic productions showed greater vowel variety, although many vowels in monosyllabic words were also characterized as central vowels. Consonants were typically oral and nasal stops and glides. In a subsequent study of the babbling of one infant recorded weekly from seven to twelve months of age, Davis and MacNeilage (1994) noted that the most frequent consonants were labial and alveolar stops, nasals, and glides, and that the most frequent vowels were mid- and low-front. Davis and MacNeilage (1995a) found similar consonant and vowel repertoires from the onset of babbling through the onset of first words in six infants. MacNeilage, Davis and Matyear (1997) compared stop, nasal, and glide use and vowels in words and concurrent babbling in four infants followed longitudinally into first words who had participated in the earlier study of babbling (Davis & MacNeilage, 1995a). They found an increase in the use of labials relative to velar consonants in first words in three of the four infants. The diversity of vowels increased, with infants producing more high vowels and back vowels than in babbling.

Crosslinguistic research has found similarities in consonant and vowel inventories to those of English-based studies. Oller and Eilers (1982) analyzed obstruent voice onset time, consonant and vowel inventory, and stress patterns in infant babbling of eight 8 to 14 month-old infants each from English- and Spanish-language environments. Results showed that in spite of ambient language differences, infants in both language environments produced predominantly CV (consonant-vowel) syllables composed of stops, nasals, and glides, with voiceless, unaspirated plosive consonants. Very few liquids and fricatives were produced by either English- or Spanish-speaking infants. Vowels showed some ambient language influences, with English-learning infants producing a wider variety of vowels, reflecting the larger English vowel inventory, and suggesting that the infants' vowel productions were influenced, however minimally, by English characteristics. The trend towards use of vowels of the ambient language suggests that vowels may show language-specific influences earlier than consonants. Statistical analyses were not reported, so the strength of these trends cannot be assessed.

Eilers, Oller, and Benito-García (1984) examined the acquisition of voice onset time (VOT) in stops in words and babbling in seven English- and seven Spanish-learning infants at 8, 14, and 26 months. At 8 and 14 months, the differences in language-specific VOT phonemic categories–a long VOT lead in voiced consonants in Spanish and a long VOT lag in voiceless stops in English–were noted. At 26 months, three Spanish- and four English-learning infants

showed language appropriate VOT lag time, suggesting that by the end of the second year, infants are beginning to produce language-specific VOT properties.

Eilers et al.'s findings (1984) contradict findings of Macken and Barton (1980) on the acquisition of voicing contrast in stops in three Mexican Spanish-learning infants. Macken and Barton did not find consistent VOT distinctions between voiced and voiceless obstruents, even at thirty-nine months of age. However, the Macken and Barton study compared VOT to adult Spanish values while Eilers, Oller, and Benito-García compared differences in VOT between English- and Spanish-learning infants. These methodological differences may account for the differences in their findings, suggesting that it takes longer for utterances to consistently appear adultlike in VOT. Infants from different language environments may be moving towards their target language and thus as a group produce utterances differing in VOT.

Boysson-Bardies, Hallé, Sagart and Durand (1989) found differences in vowel formants reflecting the ambient language in babbling of 16 infants at 10 months of age, 4 each from French, British English, Chinese, and Arabic language environments. Comparing the ratio of the second formant to the first formant (F2/F1), they found French and English infants have more diffuse ratios than do Arabic and Chinese infants. These findings reflect language-specific F2/F1 ratios and suggest ambient language differences in vowels before the onset of first words. However, Boysson-Bardies reported mean values across the four infants within each language environment. These results may be misleading, as individual variation within language environments was reported to be large.

Boysson-Bardies and Vihman (1991) found general similarities with limited ambient language influences after nine months in the consonant inventories of five infants each from four linguistic environments (French, English, Japanese and Swedish). They recorded the infants twice monthly starting at nine months until the production of 25 words within a session. All infants produced more labials, dentals, and stops, although the Swedish infants produced fewer labials and slightly more dentals than the other language groups. Individual variability was relatively high, making it difficult to support general conclusions from the data reported. Boysson-Bardies and Vihman noted that in the later sessions, when infants produced 25 words per session, individual variation had decreased, suggesting that ambient language influences were greater at this point. They also noted an increase in labials in all infants' first words, which has been reported in other research (Davis et al., in press; Stoel-Gammon & Cooper, 1984). It is difficult to determine whether Boysson-Bardies' adult frequencies actually reflect those of the target languages. They were based on phonetic shapes of the adult words attempted by the infants at 18 months of age and thus may continue to reflect production constraints rather than ambient language influences characteristic of adults.

Levitt and Utman (1992) found that late in babbling–after 11 months of age–the consonant inventories of one French and one American infant diverged to more closely resemble their ambient-language environments. They perceptually and acoustically analyzed frequency and change in consonants and vowels in these infants at 5, 8, 11, and 14 months. The English-learning infant produced

more fricatives, reflecting adult English frequency of occurrence. Both infants primarily produced vowels in the lower left quadrant of the vowel space, comparable to other findings on vowels (Davis & MacNeilage, 1995a; Kent & Bauer, 1985). However, detailed acoustic analysis of second formant (F2) measurements found language-specific tendencies: the English-learning infant showed slightly higher F2 vowel values, reflecting the frequency of front vowels in English. This study suggests that only late in babbling, at approximately 15 months, are language-specific effects are seen in segmental inventories. Vowel inventories may show acoustic ambient language tendencies that are difficult to perceptually distinguish much earlier. However, no statistical analyses were conducted. All ambient language trends were descriptive. Hence it is not known if the slight trends are significant. The small number of data points analyzed per infant–approximately 15 each–weakens their findings as well.

Little evidence of ambient language effect on consonant repertoire was found in a longitudinal analysis of canonical babbling in twins growing up in a bilingual Serbian-American English environment (Zlatic et al., 1997). The infants' utterances were studied for five months after the onset of canonical babbling. These data were compared to the utterances of infants in a monolingual English environment. The only nonsignificant ambient language trend found was a greater percentage of palatal glides and nasals, both sounds frequent in Serbian, in the infants' babbling.

Ingram (1988) found that the acquisition of word-initial /v/, considered a later-emerging phone based on research in English environments, emerged earlier

in children from language environments with a greater frequency of /v/ phonemes. He reviewed the first words of single infants reared in Swedish, Estonian, and Bulgarian environments and compared them to available English data. The Swedish and Estonian infants had acquired word-initial /v/ by nineteen months. /v/ was the first fricative acquired by the Estonian infant, transcribed in the first month of analysis. The Bulgarian infant acquired word-initial /v/ by twenty months. Ingram concluded that the frequency of the phoneme /v/ in the ambient language, and not its ease of articulation, determined the order of acquisition. Ingram stated that the later use of initial /v/ in American-English infants could therefore not be attributed to production difficulty. Ingram's conclusions must be interpreted with caution, as he relied on diary studies based on parent transcriptions, which may show language-specific biases. Also, it is unclear how much information was analyzed for each infant, although it appears limited. Ingram provides no statistical analysis of his data nor does he provide detailed analysis of English, to which he compares these three languages. Nevertheless, his findings suggest that by the end of the second year of life, infants' word productions of consonants may begin to reflect ambient language influences.

Cross-language research on Quiché-learning children in Mexico has suggested that the consonants /tʃ/ and /l/ are frequently produced by 18 to 36 month olds, even though these phones are normally not yet produced in English-learning infants (Pye et al., 1987). One sample each from five Quiché infants was analyzed at 19, 24, 25, 33, and 36 months of age. The authors found a higher frequency of /tʃ/ in early words of Quiché children than in reports on American

children, paralleling the greater frequency of /tʃ/ in Quiché than in English. The liquid /l/ was also produced in greater frequency by the Quiché children than is reported for English-learning children of the same age. Substitution patterns, in which /l/ was substituted by /ɹ/ in Quiché but by /j/ in English, were also found to be language-specific. The greater frequency of /tʃ/ and /l/ in the infants' productions is considered to reflect adult frequencies of these phones and suggests that ambient language influences have resulted in productions of consonants that emerge much later in English-learning children. The authors conclude that exposure to a language is the best determinant of the phonological emergence path and that ease of articulation plays only a minor role. However, the infants in their study vary in age between 19 and 36 months at the points of comparison, and vary between 23 and 115 lexical types. It is never clear at which point during the 17-month span infants acquire the later-emerging consonants /tʃ/ and /l/. Also, Pye does not report statistical analyses or adult language target frequencies, making his conclusions difficult to generalize.

K. Davis (1995) analyzed the acquisition of voicing contrasts in 20 Hindi and 20 English children, ranging in age from 1;11 to 6;9, and divided into four age groups. She also collected data on 10 Hindi and 10 English-speaking adults to use for voicing contrast models. While English has pairs of phonemes differing in voicing only (e.g., /k/-/g/), Hindi has groups of four phonemes differing in voice onset time (e.g., /g^h/-/g/-/k^h/-k/). Davis found that acoustic differences in lag or lead time in voicing were the key components in determining the order of acquisition of the voicing contrasts–the greater the magnitude of difference in the

adult model, the earlier the contrastive productions existed in the children. Davis stated that the acquisition of phonological rule differences, such as [+] voice versus [-] voice, or [+] spread versus [-] spread distinctions, could not explain the acquisition order.

Similar suggestions for the importance of acoustical salience were made in Deuchar and Clark's (1996) study of the acquisition of voicing in an English-Spanish bilingual child, followed longitudinally from 1;7 to 2;3. At 1;11, little evidence for cross-linguistic differentiation in voicing contrasts was evident. By 2;3, voicing contrasts for both English and Spanish were being established. Contrary to the English voicing contrast, the Spanish voicing contrast in the infant did not match the adult Spanish models of lead versus lag voicing distinctions, instead showing a VOT distinction based on contrasting lag distinctions. The authors suggest that acoustical difference explains this better than phonological differences. They conclude that there is not a single phonological system for the beginning bilingual, but a lack of system in either language that develops into a dual system.

In summary, available research on infants in English and other language environments suggests that in babbling, consonants are primarily stops, nasals, and glides with few fricatives, affricates, and liquids. Labial and coronal consonants tend to be produced more frequently than dorsal consonants. Vowels are typically in the lower left quadrant: low- and mid- front and central vowels. Some ambient language tendencies for consonants and vowels have been found, typically in the relative frequency of the categories. Vowels have been found to

show ambient language tendencies earlier than consonants, perhaps as early as ten months of age.

The consonants and vowels of babbling also predominate in early words, with an increase in labials in first words noted in English and other languages studied so far. Agreement is not available on the potential effect of ambient language environment during the acquisition of first words. Limited cross-language research in this period tends to reflect the period of acquisition after the first 50 words, and suggests that ambient language influences play a significant role in speech production characteristics at this point. Findings suggest that between 19 and 36 months of age, consonant frequencies in early words may reflect frequency in the ambient language. Subtle differences in sound quality, such as voice onset time, may potentially be reflected in infant utterances by approximately two years of age.

Syllable and Word Shapes

Languages are similar in their preferences for syllables that begin with a consonant and end with a vowel (Bell & Hooper, 1978). However, phonological rules for permissible syllable complexity differ across languages. English allows for more complex consonant combinations (i.e., (CCC)V(CCCC)), while other languages, such as Quichua, a language spoken in Highland Ecuador, are primarily composed of simple consonant-vowel syllables (i.e., (CV)). In addition, Quichua and many other languages utilize primarily multisyllabic words, in contrast to the predominance of monosyllables in English. Syllable and word

shapes have been studied in English-learning infants primarily, and have received limited exploration cross-linguistically. These analyses are typically found in studies focusing on segmental properties of infant speech that also report sequential complexity and utterance shapes.

Kent and Bauer (1985), in their study of five American English-learning infants at 13 months, determined that most frequent syllable shapes in babbling were CV and CVC. Consonant clusters were rare. In one infant's babbling between 7 and 12 months of age, Davis and MacNeilage (1994) noted that approximately 50% of the infant's utterances were monosyllabic, and that both monosyllabic and multisyllabic utterances were almost exclusively composed of consonant-vowel syllable shapes. In six infants followed from the onset of babbling through onset of first words, Davis and MacNeilage found the most common syllable shape to be CV (Davis & MacNeilage, 1995a). Vihman and Ferguson noted similar syllable and word shapes in words–primarily CV and CVCV–and the virtual nonexistence of consonant clusters in first words in 10 American English-learning infants between 9 and 16 months of age at the 0-, 4-, 15-, and 25-word points (Vihman et al., 1986). They also found monosyllabic utterances to be the most common.

Oller and Eilers (1982) found similarities cross-linguistically for use of word shapes in the babbling of 16 infants, 8 each from Spanish- and English-language environments, collected between 11 and 14 months of age. Infants in both language groups produced CV syllables primarily, with few consonant cluster sequences and few final consonants observed. While the results appear

very similar in the two different language environments, Oller and Eilers did not report statistical analysis of their findings.

Boysson-Bardies, Bacri, Sagart, and Poizat (1981) found similarities in the late babbling of one French infant between 18 and 20 months of age to that of the 16 infants in Oller and Eiler's 1982 study. Like the Spanish- and English-learning babies, the French infant produced few final consonants and few consonant clusters in babbling. Boysson-Bardies did not report on syllabic length of utterances. Although her study is limited in scope, the similarities noted between French, Spanish, and English suggest strong similarities in utterance complexity in babbling.

In contrast, Levitt and Utman's (1992) descriptive study of the babbling of a French and an American English infant–each analyzed at 5, 8, 11, and 14 months–reported that the infants' syllable shapes differed slightly. Both infants produced few closed syllables, although the American infant produced slightly more, matching the higher frequency of closed syllables in English than French. The French-learning infant produced more multisyllabic utterances, reflecting French word length. However, they conducted no statistical analysis and the ambient language information was descriptive rather than quantitatively based.

The overall findings for babbling reported above have also been found in words (Piske, 1995). His study of eight monolingual German infants from twelve to twenty-four months of age found that all infants produced CV, with some CVC, word shapes. Consonant clusters were not reported to emerge in the infants' productions until late in their second year.

Vogel (1975) found similarities in the phonetic inventory and word shapes in the two languages of a Romanian-American English bilingual infant in a 1½-hour spontaneous speech sample. While cluster reduction and few final consonants were observed in both languages, the frequency of these phenomena differed from English to Romanian, with the infant's English utterances demonstrating more final consonant deletion and cluster reductions. Vogel proposed that this pattern resulted from the limited number of clusters and final consonants in Romanian, thus providing the infant with fewer opportunities for exposure to these patterns. She did not compare directly final consonants and clusters cross-linguistically. No statistical analysis or direct comparison to adult ambient language frequencies was conducted.

In contrast to Vogel's findings, Ingram (1981) reviewed data collected by the older sister of an Italian-American English bilingual two-year old during one session. He noted that differences in phonological processes were apparent in English and Italian. The infant produced many more multisyllabic words in Italian and fewer final consonants. He stated that these differences were actual differences based on the infant's phonological separation of the two languages and resulting phonetic differentiation. Ingram did not consider the frequency of final consonants or the relative proportion of multisyllabic words in the target language, reported no statistical information, and no adult ambient language frequencies. Unfortunately, the conflicting findings of these two studies and their small sample sizes make it difficult to draw strong conclusions regarding the effects of ambient language on utterance complexity at two years of age.

Segmental, Syllable, and Word Shape Summary

Available cross-language studies of production patterns suggest that vowels may show language-specific influences earlier than consonants, perhaps as early as 10 months of age. Consonants and syllable shapes tend to show more limited and consistent production patterns across languages. They appear to begin reflecting the ambient language later, during or after the first word stage.

Most research on babbling has revealed limited phonetic inventories relative to ambient language patterns, with few clearly documented ambient language effects (Eilers et al., 1984; Levitt & Aydelott-Utman, 1992; Locke, 1983; Oller & Eilers, 1982). Some researchers suggest that ambient language influences outweigh production constraints before the onset of first words (Boysson-Bardies et al., 1984; Boysson-Bardies & Vihman, 1991). However, most studies suggest that babbling is highly similar cross-linguistically, at least through the first year of life. Boysson-Bardies' research (Boysson-Bardies et al., 1989) suggests that vowels may show ambient language effects slightly earlier, although methodological limitations weaken her findings.

Syllable and word shapes appear to be remarkably similar during babbling and first words – typically CV shapes, with few final consonants or consonant clusters. While data on English-learning infants suggest that babbling utterances are primarily monosyllabic and disyllabic (Davis & MacNeilage, 1995a; Kent & Murray, 1982), not much information is available about the similarity in length of babbled utterances cross-linguistically. Findings suggest that articulatory

influences on speech acquisition are stronger relative to language-specific perceptual influences through the babbling period. During the first word period, syllable shapes and word length differ by the end of the second year, although these findings are not conclusive, as the data are limited in scope and differ in the strength of the ambient language influences reported (Ingram, 1981; Vogel, 1975).

In summary, limited cross-language information on the first word phonetic inventory suggests that by the end of the second year of life, the ambient language may influence segmental characteristics of infant productions. However, studies are not clear as to when this effect takes place. Also, the limited scope of research on language-specific effects lessens the generalizations from available findings.

Intrasyllabic and Intersyllabic Patterns

Intrasyllabic Consonant-Vowel Co-Occurrence and Intersyllabic Consonant and Vowel Variegation Patterns

Davis and MacNeilage's research on production constraints during speech acquisition has provided the primary information on intrasyllabic and intersyllabic patterns in babbling and first words of English-speaking infants. Their work has been replicated by others in English but has had limited exploration cross-linguistically. They predict that an infant's syllables will demonstrate frame dominance resulting from mandibular oscillation accompanied by phonation. These frames result in consonant-like sounds when the jaw is closed and vowel-like sounds when the jaw is open, with little independent tongue or lip movement.

Frame dominance has been observed in intrasyllabic consonant-vowel co-occurrence patterns. According to MacNeilage and Davis, production-based effects result in consonant-vowel interdependencies based on inertial tendencies in sequences containing consonants and vowels. In this view, the "consonants" and "vowels" are not seen as independent entities but as emergent aspects of the rhythmic jaw cycle. The result is greater-than-expected co-occurrences of coronal consonants with front vowels, labial consonants with central vowels, and dorsal consonants with back vowels.

The implications of frame dominance have also been explored by examining consonant and vowel variegation patterns intersyllabically. The frame dominance hypothesis predicts that in variegated CVCVs, changes will be in consonant manner and vowel height intersyllabically, both resulting from amplitude changes of mandibular oscillation: during the closed phase for consonants and the open phase for vowels (MacNeilage & Davis, 1990). Variegated syllables demonstrating consonant place or vowel front/back dimension changes are not predicted, as these require active tongue movement for their production.

In longitudinal studies of babbling of seven American English-learning infants, MacNeilage and Davis and colleagues (Davis & MacNeilage, 1995a; Davis et al., in press; Gildersleeve-Neumann et al., 2000; MacNeilage et al., 1997; Redford, MacNeilage, & Davis, 1997) have obtained strong evidence for five babbling sub-patterns in English-learning infants which support the Frame Dominance hypothesis. Zlatic, MacNeilage, Davis, & Matyear (1997) also found

these patterns in bilingual Serbian-American English infants. These five patterns were as follows. For consonants involving the tongue, two patterns of consonant-vowel co-occurrence have been observed: 1) consonants involving a constriction in the front region of the oral cavity (alveolar stops, nasals, and fricatives) and the glide [j] tend to co-occur with front vowels; and 2) dorsal stop consonants tend to co-occur with back vowels. Mandibular movement, with little independent contribution of tongue positioning during an utterance, may be primarily responsible for these patterns. A third pattern observed was for labial stops, fricatives, nasals, and glides to co-occur with central vowels. This pattern was described as a "pure frame" as it may involve no active contribution of any articulator other than the mandible (Kent, 1981; MacNeilage & Davis, 1990). Two other patterns were observed intersyllabically in multisyllabic utterances in variegated babbling and first words: a) vowel changes were primarily in height rather than the front back dimension, and b) consonant changes were primarily in manner (amount of constriction) rather than place. Both of these patterns are related to changes in the amplitude of the mandibular closing phase. Five predictions from the frame dominance principle have been tested in six subjects. Four of the predictions (excluding dorsals due to infrequent productions) were tested in three subjects (Davis & MacNeilage, 1995a; Davis et al., in press; MacNeilage et al., 1997). Of the 42 predictions, 34 have been confirmed at significant levels, 6 resulted in non-significant positive trends, and only 2 showed a chance association. There were no countertrends.

In a cross-language test of the Frame Dominance hypothesis, Zlatic, MacNeilage, Davis, & Matyear (1997) analyzed babbling vocalizations in fraternal twins in a bilingual Serbian/American English environment for five months. The twins' babbling was found to follow general production patterns and expected production characteristics of infants in segmental frequency, CV co-occurrence, and intersyllabic variegation patterns. The authors compared these infants' canonical babbling to the Serbian language, as well as to babbling of English-learning infants in the same developmental stage. Analyses of predicted CV co-occurrence patterns were statistically significant in syllables and variegated babbling in one infant; the second infant did not show a preferred consonant-vowel co-occurrence pattern.

Oller and Steffens (1993) analyzed change in CV co-occurrences in canonical babbling and first words of three children at 10, 12, 16, 20, and 24 months of age and one child at 10 months of age. The authors determined CV co-occurrences by dividing consonants into labial, coronal, and dorsal, and vowels into front and back places of articulation. At 10 to 12 months, dorsal consonants were produced most often with back vowels; both labial and coronal consonants occurred most frequently with front vowels. In 16 to 24 month olds, syllabic and CV co-occurrence constraints were weaker, with labials, coronals, and dorsals occurring most often with front vowels. Oller and Steffens suggested that this weakening of CV co-occurrences occurs due to maturation of speech production structures and the beginning of segmental independence. However, during the

period of first words and concurrent babbling–10 to 16 months–these infants demonstrated strong consonant-vowel co-occurrence constraints.

MacNeilage, Davis, and Matyear (1997) analyzed consonant-vowel co-occurrence patterns in stops, nasals, and glides in babbling and first words of four English-learning infants. They found the same consonant-vowel co-occurrence patterns–coronal consonants with front vowels, labial consonants with central vowels, and dorsal consonants with back vowels. Gildersleeve-Neumann, Davis, and MacNeilage (2000) found these patterns in a study of fricatives, affricates, and liquids in babbling of these same four infants. In a subsequent study of first words of ten infants, Davis, MacNeilage, and Matyear found the three CV co-occurrence patterns are as evident as they are in pre-speech babbling (Davis et al., in press). Six of these infants were participants in the babbling study reported earlier (Davis & MacNeilage, 1995b) and four were available from an unpublished dissertation study of first words (Jasuta, 1987). These findings suggest that even by the end of the single-word stage, there is little evidence to suggest that infants have developed segmental independence. In contrast, they suggest that consonants and vowels continue to be interdependent subcomponents of the close-open mandibular cycle (Davis, MacNeilage, & Matyear, 1999).

Vihman studied CV co-occurrence patterns in canonical babbling cross-linguistically and found within language differences as great as cross-language differences (Vihman, 1992). She compiled data from three studies at 4-, 15-, and 25-word sessions for ten American infants, five French infants, four Japanese infants, and four Swedish infants. A majority of the infants showed labial-central

vowel and velar-back vowel associations. Three infants tended to produce labials with vowels other than central vowels. Results were mixed for alveolar consonants and front vowels: eight infants demonstrated a positive association and seven demonstrated a negative association. However, Vihman analyzed [æ] as a central vowel. In contrast, [æ] is more often considered a front vowel. Thus, it is difficult to evaluate her results for alveolar consonant-vowel co-occurrences with the results of her analysis.

Boysson-Bardies (1993) analyzed CV co-occurrence in a cross-language babbling study of five infants each in French, American English, Swedish, and Yoruba language environments at 10 months of age. She proposed that the infants' interactions with the ambient language rather than child internal production factors were more important in determining CV co-occurrences in canonical babbling. Output patterns of infants during babbling begin to reflect ambient language effects as early as ten months of age, according to Boysson-Bardies. To determine ambient language influences, she compared the infants' CV patterns to the targets for those lexical items. She found labial-central vowel associations in English, French, and Yoruba infants and for Swedish infants in the initial syllable. American infants most often produced front vowels with labial consonants. Front vowels were produced with dental consonants in English, Swedish, and French in the initial syllable. In French and Swedish, dental consonants co-occurred more often with front vowels, an association Boysson-Bardies interpreted as showing influence of the frequency of dental-front vowel co-occurrences in the Swedish and French languages. Yoruba infants were found

to produce dentals with central vowels most frequently. Velar consonants were produced most often with central vowels in English and Swedish and with front vowels in Yoruba. Boysson-Bardies also suggested that intersyllabic consonant and vowel variegation patterns show ambient language influences in frequency in the babbling and first words of infants. However, individual trends in production patterns within infants in specific languages varied widely in this study, making Boysson-Bardies' generalizations for the language group debatable. In addition, Boysson-Bardies' defined ambient language tendencies by the patterns in the targets for the words that the infants produced rather than to general patterns in the ambient language. The subset of words attempted by infants may show strong lexical effects and may not reflect ambient language patterns accurately.

Zmarich and Lanni (1999) studied consonant-vowel co-occurrence patterns in babbling and first words of one Italian infant between 10 and 16 months of age. Using impressionistic and acoustic analyses, they found two of the three predicted CV co-occurrence patterns from 10 to 12 and from 14 to 16 months of age: labial consonants with central vowels and coronal consonants with front vowels. Dorsals occurred most often with central vowels from 10 to 12 months of age, and with front vowels from 14 to 16 months of age.

Teixeira and Davis (submitted) analyzed CV co-occurrence patterns between the onset of first words and three years of age for two children in a Brazilian-Portuguese environment. They looked at early (12 to 23 months) and late (24 to 36 months) word acquisition periods and compared the children's utterances to frequencies of sounds in Brazilian Portuguese based on dictionary

data and adult speech samples, as well as sound frequencies in words used by children reported on the Brazilian Portuguese version of the MacArthur Communicative Development Inventory (CDI). One of the two children showed all predicted CV co-occurrence patterns during both time periods, while the second showed the predicted dorsal-back combinations only. The authors stated that production-oriented characteristics are predominant during development, but the relative role of perceptual influences from the ambient language environment was found to be evident in the greater frequency of dorsal consonants and in the greater frequency of multisyllabic utterances, matching Brazilian Portuguese characteristics.

Intersyllabic consonant and vowel variegation patterns have also been found to characterize first words (Davis et al., in press). In a pooled analysis of first word patterns in ten infants, intersyllabic consonant manner changes occurred at a rate of 2.5 greater than that expected by chance. For vowels, 9 of 10 infants could be individually analyzed statistically. Eight out of 9 infants produced significantly more height than front/back vowel variegation; the ninth infant demonstrated a nonsignificant trend towards greater front-back than height variegation. As a group, height variegation occurred at a rate 7 times that expected by chance.

Studies of reduplication and variegation patterns from a phonetic perspective are extremely infrequent. A few studies have analyzed reduplication and variegation patterns from a phonological perspective. Both Vihman (1978) and Macken (1993) describe consonant harmony as a phonological pattern in

which the initial consonant of the second syllable in a word assimilates the phonological properties of the initial consonant in the word. Vihman has also referred to this pattern as a melodic pattern (1992), in which infants use a well-established melodic organization existing in their word repertoire to produce new words. Neither Vihman nor Macken explore phonetic or motor skill explanations for these patterns, instead relying on cognitive properties to explain them.

Anterior-Posterior Variegation Patterns

MacNeilage and Davis and colleagues (MacNeilage & Davis, 1999a; MacNeilage et al., 1997; MacNeilage et al., 2000b) have proposed that the place in which increase in consonantal aspects of sequential complexity may first be observed is in disyllabic first word productions. However, this movement toward more complexity still appears to be governed by production factors in the tendency for infants to produce disyllabic words with variegated consonants by producing the first of the consonants at the labial place and the second consonant more posterior in the mouth. This pattern is typically manifested as a labial-coronal sequence of consonants and is likely a result of beginning with the simple mandibular closure necessary to produce the labial and following with an additional tongue movement for the more posterior coronal or dorsal consonant.

In first words, Davis et al (in press) found that labial-coronal patterns accounted for 44% of all variegated patterns in disyllabic early words of ten English-learning infants. Labial-dorsal patterns were also preferred to dorsal-labial patterns in these infants. However, no preference for coronal-dorsal or

dorsal-coronal patterns was found. Thus infants primarily produced words by initiating with a labial closure and then moving the tongue.

In a review of seven reports involving infants from five different language communities, 21 of 22 infants demonstrated a labial-coronal preference (MacNeilage et al., 2000a). Included in this review was data from Levelt, who found that labial consonants were the preferred first consonant in 11 infants learning Dutch (Levelt, 1994). Analysis of the first words of Czech-learning infants (reported in Locke, 1983) showed that labial consonants were the most-frequently produced initial consonant, whereas coronal consonants were most frequent word-medially.

Teixeira and Davis (submitted) looked at labial-coronal patterns in words of two 12-36 month old children learning Brazilian-Portuguese. Labial-coronal patterns were the predominant variegated pattern in their disyllabic word utterances.

While information is limited, labial-coronal patterns appear to predominate in the first instances of place variegation in multisyllabic words of languages. This labial-coronal pattern has also been found in a dictionary analysis of 10 languages, in which 9 of the 10 languages showed significantly more labial-coronal than coronal-labial sequences (MacNeilage, Davis, Kinney, & Matyear, 1999). The related findings in early words to those in diverse languages suggest a strong sequential pattern for labial-coronal consonants in disyllabic productions.

Thus recent research on intrasyllabic consonant-vowel co-occurrence and the relative importance of manner variation and height variation in intersyllabic consonant and vowel variegation patterns respectively largely confirms predictions of frame dominance based on rhythmic mandibular oscillations accompanied by phonation. Within syllables in both babbling and words, consonants and vowels appear to be interdependent shown by greater-than-expected co-occurrences of consonant-vowel sequences in which the tongue occupies the same place in the oral cavity. Intersyllabic variegation patterns in babbling and early words show greater-than-expected changes in consonant manner than place and vowel height than front/back placement. In addition (though this was not predicted from frame dominance), in early words with changes in consonant place of articulation, the pattern is overwhelmingly labial-coronal. This pattern suggests that infants begin words with no active tongue placement and then move the blade of the tongue for the second closure phase of the cycle. The majority of this research has been conducted on English-learning infants. Crosslinguistic studies have been smaller in scale. They do not include comparisons to CV co-occurrence or variegation patterns for adults in the language environment. To determine the generality of these patterns, it is important to provide in-depth information from diverse language environments.

Intrasyllabic and Intersyllabic Patterns Summary

While studies of speech acquisition of infants in English environments have provided us with a general understanding of the babbling and early word periods, crosslinguistic studies are necessary to determine whether the results are

general or specific to English. There has been some exploration of speech acquisition in other language environments; however it is limited and has, for the most part, not been conducted in non-Indo-European language environments. Yet infants must eventually speak the language around them. At some point in time they will acquire the sound qualities and segmental patterns necessary for their ambient language. Thus additional cross-language studies of speech acquisition can provide us with critical information on the potential effects of cultural influences, evident in incorporation of ambient language characteristics unique to a given language. Alternatively, a production constraint view predicts common production tendencies in infants across languages regardless of ambient language characteristics. This search for universal production tendencies versus unique paths for infants in varied ambient environments also touches on potential early influences of cognitive and lexical effects that may be considered specific to individual infants. Additional cross-linguistic studies are essential to determining the generality of results based primarily on English and limited studies of Indo-European languages.

Cross-language studies suffer from various methodological difficulties. Many consist of small samples and limited subject pools (Boysson-Bardies et al., 1981; Ingram, 1981; Levitt & Aydelott-Utman, 1992; Tuaycharoen, 1978; Vogel, 1975). Others are limited by reporting: group means when individual infants' production patterns vary widely (Boysson-Bardies et al., 1989), group data for infants over a large age range (Levitt & Wang, 1991; Pye et al., 1987), solicited rather than natural speech productions (Krueger, 1995; Thevenin et al., 1985),

information collected from diary studies (Ingram, 1981; Ingram, 1988; Teixeira & Davis, submitted), and cross-language infant comparisons for infants at markedly different stages of acquisition (Boysson-Bardies et al., 1981). In addition, the definition of ambient language influences can differ. For example, Boysson-Bardies and Vihman (1991) used adult phonetic shapes of word targets for infants at 18 months to determine ambient language influences, although targets of words attempted by infants may also reflect production constraints.

The current study attempts to avoid limitations of previous cross-language studies, particularly by analyzing quantitatively the language environments of the infants. This approach allows statistical comparison of the babbling and words of infants to both their language environment and infants from another language environment to assess ambient language perceptual influences and general production constraints observed. Infants in this study have been matched for age cross-linguistically. Analysis of the infants' utterances is divided into early, middle, and late babbling ages to note any changes over time. Statistical procedures are used that take into account individual differences and group trends.

In spite of the shortcomings of available cross-language studies, an important method for measuring ambient language influences on the characteristic productions of babbling and first words is to study infants in different language environments with segmental and/or syllabic differences that provide means for evaluating both production constraints and ambient language perceptual influences. If perceptual factors play a crucial role in instantiating patterns observed, one would anticipate early influence of the ambient language. This

would result in different phones and phone sequences in the babbling and words of infants raised in different language environments, with a greater increase in frequency of segments, sequential complexity, and syllable shapes particular to the infant's ambient environment. In contrast, if production abilities motivate the sound qualities of early speech acquisition, we would predict similar babbling and first word productions regardless of the ambient language environment, including similarities in manner, type and frequency of phones, syllable and word shapes, as well as intrasyllabic and intersyllabic constraints.

Assessment of the potential role of production constraints in infant utterances requires an analysis of segmental and syllabic properties of the ambient language. The current study includes analysis of phonological properties of adult Quichua and comparison of these properties to American English. It also includes collection and analysis of pre-speech babbling, first words, and concurrent babbling of Quichua infants. Quichua infant productions are compared across infants within the language environment as well as being compared to Quichua language characteristics. In addition Quichua and American English-learning infant babbling and first words are compared.

In contrast with previous studies, this study employed a larger corpus of data gathered at closely spaced sampling points for seven infants to characterize production patterns and potential ambient language effects in babbling and early speech of Quichua infants. Data from individual infants were analyzed for each infant and for the group, so that individual differences could be distinguished from group trends.

ECUADOREAN QUICHUA

Quechua (Quichua in Ecuador) is most widely known as the language of the former Incan civilization in South America. As with many indigenous languages, the geographical and cultural separation of Quechua-speaking communities from each other has led to numerous and widely varying dialects. There are a variety of dialects of Quechua spoken throughout Perú, Ecuador, Argentina, Colombia, and Bolivia (Torero, 1983), and many different dialects spoken within Ecuador. In some cases, phonological and lexical properties of Ecuadorean Quichua differ between neighboring communities (Orr, 1978).

This study is of Ecuadorean Quichua spoken in the rural highland community of Michacalá in the province of Cotopaxi. Michacalá is a remarkably isolated community of 200 people, requiring two hours of travel by foot from the closest village, which is a two-hour bus ride from the closest city of 20,000 people. Many of the community members, particularly the women, have never ventured further than a two-hour walking radius of their home. The majority of the adult community and almost all of the women have received no schooling and are completely illiterate. This isolation from others and from standardized schooling has resulted in a dialect of Quichua with phonetic properties particular to this community only.

There have been few studies of the phonology of Ecuadorean Quichua (Cerrón-Palomino, 1987; Cotocachi, 1998; Garcés, 1996; Moya, 1987), and no studies of speech acquisition in Quichua. To understand the segmental, syllabic,

and word-level properties of Quichua, one aspect of this study included description of Quichua production characteristics in the Michacalá community. This analysis provides a comparison with infant Quichua learners in this community as well as with characteristics of English. To better understand the phonological properties of Quichua, limited speech samples from four Quichua-speaking adults were collected and a Quichua-Spanish dictionary (Ministerio de Educación y Cultura, 1982) was analyzed. Results from this preliminary analysis as well as information from the literature on Quichua are presented below. A brief description of how this information applies to known information on speech acquisition is provided.

General Segmental Information

Phonetic Inventory

Pilot data on frequency and types of consonant and vowel productions of adult Quichua from the Imbaburan province in Ecuador, as well as Quichua dictionary inventories (Ministerio de Educación y Cultura, 1982) were collected. These findings were compared to known phonological frequency characteristics of American English (Mines, Hanson, & Shoup, 1978).

The Quichua phonemic consonant inventory is shown in Table 2-1, indicating the place and manner of each consonant. In addition to the phonemes shown in Table 2-1, the voiced unaspirated stops /ɓ, d, ɠ/, the voiced fricatives /β, ð, ɤ/, the aspirated stops /p^h, t^h, k^h/, and occasionally the voiceless ejectives /p’, t’, k’/ are produced as allophones of the voiceless aspirated phonemes

/p, t, k/. Also, [x, ɤ] are frequently produced as variants of [k], and [ŋ] is typically produced instead of [n] in final position (Cotocachi, 1998; Garcés, 1996; Lombeida-Naranjo, 1976; Moya, 1987; Torero, 1972). Preliminary analysis of Quichua consonants showed a greater frequency of affricate, nasal, and dorsal consonants and a slightly greater frequency of fricatives than in English. Fewer labial, coronal, and liquid consonants were observed in Quichua than in English. During the babbling and first word periods, fricatives and affricates, and dorsals are described as being infrequent (Boysson-Bardies & Vihman, 1991; Davis & MacNeilage, 1995a; Locke, 1983; Oller & Eilers, 1982; Stoel-Gammon, 1985). Labial consonants are reported to increase in the production of first words (Boysson-Bardies & Vihman, 1991; MacNeilage et al., 1997; Stoel-Gammon & Cooper, 1984). If ambient language influences productions in first words, one would anticipate an increase in the frequency of phones particular to the infant's language environment. Quichua infants would be more likely to produce fricatives, affricates, nasals, and dorsals than English-learning infants. In contrast, if production constraints predominate, fewer later-emerging Quichua phones, such as fricatives, affricates, and dorsals would be produced by the Quichua infants, matching American English infants' babbling and first words in these properties, regardless of the frequency of these phonemes in Quichua.

Table 2-1. Highland Ecuadorean Quichua Consonant Place & Manner Categories

	PLACE					
MANNER	**LABIAL**	**CORONAL**				**DORSAL**
	Labial	**Dental**	**Retroflex**	**Palato-alveolar**	**Palatal**	**Velar**
STOP	**p**	**t, ɾ**				**k**
NASAL	**m**	**n**				**ŋ**
GLIDE	**w**	**j**				
LIQUID		**l**			**ʎ**	
FRICATIVE		**z, s**	**ʂ**	**ʃ, ʒ**		**x**
AFFRICATE		**ts**		**tʃ**		

The phonemic vowel inventory of Highland Ecuadorean Quichua is composed of /i, a, u/. The vowels /ɛ/ and /o/ are produced as allophones of the vowels /i/ and /u/ respectively, particularly in words borrowed from Spanish.

A preliminary comparison of Quichua and English vowel inventories suggests a greater frequency of central vowels and a lower frequency of front vowels in Quichua than in English. While less is known about acquisition of vowels, available data suggest that infants first produce low- and mid- front and central vowels (Davis & MacNeilage, 1994; Davis & MacNeilage, 1995a; Kent & Bauer, 1985). If the language environment were a primary motivating factor in early speech, infants in Quichua environments would produce primarily high-front, low-central, and high-back vowels. In contrast, if early vowel inventories were the result of general production constraints, infants in Quichua environments would primarily produce low- and mid- front and central vowels, of which only one, /a/, occurs in Quichua.

Syllable and Word Shapes

Phonological rules of Quichua permit syllable shapes composed of minimally a vowel nucleus optionally abutted by consonant syllabic margins ((C)V(C)) (Cerrón-Palomino, 1985; Lombeida-Naranjo, 1976). These phonological rules for syllable shapes allow consonant clusters in medial position of words only. English syllable shapes are much more complex. English words can include three consonants in initial position and up to four consonants in final position (i.e., (C(C(C(V)C)C)C)C) (MacKay, 1987).

A preliminary analysis of Quichua and English syllable shapes and word types was conducted to determine the length of utterances and the phonotactic distribution of consonants. Quichua was found to have a markedly greater frequency of two-syllable and three-or-more syllable words than English (86% for Quichua spontaneous speech samples, 98% for Quichua dictionary samples, 22% for English dictionary samples).

Quichua is an agglutinative language (Ministerio de Educación y Cultura, 1982). Many grammatical markers are attached to root words rather than existing as individual words (as in English). For example, Quichua words such as *huahua* /wawa/ (baby) and *ñaña* /ñaña/ (girl), are rarely used in their root forms. Instead, they are almost always produced with added grammatical function, such as *huahuaca* (the baby), *ñañapacca* (the girl's) *huahuapash ñañapashca* (the baby and the girl), *ñañamantami* (from the girl, with added emphasis), *huahuacamaccunatami* (to the baby's caregivers). These grammatical markers are

meaningless if they are not included with a word, much as the English plural “s” exists only as part of a word.

A large proportion of English-speaking infants' first words are one-syllable in length (Davis & MacNeilage, 1990; Davis et al., in press). If word length in English is a result of general production constraints, first words of Quichua infants will also be predominantly one-syllable. However, if ambient language perceptual influences play the major role in word length, the longer average word length in Quichua will result in longer first words in the Quichua-learning infants.

In summary, segmental and syllabic characteristics of Quichua make the exploration of infant Quichua acquisition important for a greater understanding of speech acquisition. Quichua has more fricatives, affricates, dorsals, and fewer liquids, as well as a simpler phonotactic structure and a greater frequency of multisyllabic utterances than English. Analysis of intrasyllabic and intersyllabic constraints in adult languages has been limited. In-depth comparison of these patterns in Quichua and English infants as well as the Quichua and English language information will provide information on the general nature of these patterns across languages as well as a further test of the Frame Dominance hypothesis in acquisition.

RESEARCH HYPOTHESES

The goal of this study is to describe production patterns for segments and sequences in babbling and first words of Quichua infants. These patterns will be

compared with patterns described for English-learning infants. Infant patterns will be compared with language characteristics for English and Quichua. Relative frequency is used as the metric of analysis to assess the role of production effects versus perceptual influences from the ambient language in this period.

To explore these questions, three aspects of speech acquisition were investigated in babbling and in first words: a) *general phonetic information* (consonant and vowel inventories and frequencies, consonant-vowel ratios, and word length patterns); b) *intrasyllabic patterns* of consonant-vowel co-occurrences; and d) *intersyllabic patterns* for variegation, reduplication, and anterior-posterior place change. The results of this research will allow evaluation of productions of Quichua-learning infants relative to patterns predicted by the production constraint hypothesis, the Frame Dominance hypothesis (MacNeilage & Davis, 1990), which has been largely tested on English-learning infants (Davis & MacNeilage, 1990; Davis & MacNeilage, 1994; Davis & MacNeilage, 1995a; Davis et al., in press). The larger question of this study concerns the relative extent to which babbling and first words are influenced by perceptual influences from the ambient language that depart from production based patterns observed for English infants.

This research was guided by the following hypotheses. The majority of the hypotheses assume that general production characteristics are the primary factors guiding early speech acquisition, with ambient language perceptual influences playing a relatively minor role.

Hypothesis 1 – General Inventory Information:

Babbling and first words of Quichua-learning infants will be limited in phonetic inventory, syllable, and word shapes.

a) Consonants: The babbling and first words of Quichua-learning infants will contain a greater percentage of consonants produced at labial and coronal place of articulation, and stop, nasal, and glide manner of articulation. A lower percentage of dorsal place of articulation and fricative, affricate, and liquid manner of articulation will be found, consistent with patterns for English infants, rather than a higher frequency of consonants produced at the dorsal place of articulation and a lower frequency of consonants produced at the labial place of articulation, as well as a higher frequency of fricative and affricate and a lower frequency of liquid manners of articulation, consistent with Quichua;

b) Vowels: Vowels present in babbling and first words will be those in the lower left quadrant of the vowel space, consistent with patterns for English-learning infants, rather than only containing high-front, low-central, and high-back vowels, consistent with Quichua;

c) Simple CV syllable shapes will predominate in the babbling and first words of Quichua-learning infants consistent with patterns

for English infants. The Quichua-infants' syllable shapes will be even simpler than Quichua, which consists of less complex syllable shapes than English;

d) Babbling and first word utterances of Quichua infants will be predominantly one- and two-syllables in length, while first words will tend toward one syllable long utterances consistent with patterns in English-learning infants, rather than a majority of multisyllabic utterances, consistent with Quichua.

Hypothesis 2 – Intrasyllabic Information:

Intrasyllabic combinations of consonants and vowels present in babbling and first words of Quichua infants will exhibit constraints similar to those observed in English-learning infants. Specifically, babbling and first words will be composed of a significantly greater percentage of intrasyllabic combinations reflecting production constraints, consisting of labial consonants with central vowels, coronal consonants with front vowels, and dorsal consonants with back vowels.

Hypothesis 3 – Intersyllabic Reduplication and Variegation Constraints:

The intersyllabic consonant-consonant and vowel-vowel patterns present in multi-syllabic babbling and first words of Quichua infants will be similar to patterns for English-learning infants. Specifically, multi-syllabic babbling and first words in Quichua will consist of a significantly greater percentage of vowel

and consonant intersyllabic pairs reflecting height rather than front/back changes for vowels and manner changes rather than place changes for consonants. As production complexity increases during the acquisition of first words, disyllabic utterances demonstrating changes in consonant place of articulation will more frequently be anterior to posterior sequences: labial-coronal or labial-dorsal, rather than posterior to anterior sequences: coronal-labial, dorsal-labial.

CHAPTER 3: METHODOLOGY

All data collection specific to this study took place in Ecuador during a six-month period. The Quichua infant and adult samples were collected in the village of Michacalá, located in the Andean highlands at 14,000 feet above sea level. Michacalá has a population of approximately 600 people. All inhabitants speak Quichua as their first language, approximately 83% of the adult males and 10% of the adult females also speak Spanish (Hess, 1992).

In Michacalá formal education is limited. While Michacalá has had a primary school since 1972, few children attend. In 1992, only 47% of males and 7% of females reported having attended school, and only 3% of males and 0% of females reported having completed the 6th grade (Hess, 1992).

Infants are raised and cared for primarily by their mother, with siblings and other relatives assisting. Small infants are with their mother 24 hours a day, carried on her back in a sling while she works. Once the infants are introduced to solid food, female siblings and relatives share in the care of the infants. Children as young as four are often responsible for their younger sibling's care, although they are typically within their mother's earshot at all times.

There is little vocal interaction between children and adults. Adults do not view themselves as encouraging linguistic development in children. In interviews, the mothers of the infants in this study took little credit for language emergence in their infants, stating that infants begin to speak "when they're ready, when they're big, when it's time, by themselves, by listening to adults, by

imitating animals, by talking to other children." Even though the introduction of the author, her assistant, and the technological equipment to the homes led to an increased focus on the children and their use of language, the speech acquisition period observed in Michacalá is one of frequent listening, frequent gestural communication with other children, but little direct encouragement of conversational attempts until words are present.

Data collection was conducted with a research assistant whose first language is Quichua. He lives in a neighboring village where he is attending the local college. He is also the principal teacher in Michacalá and has relatives there, and is thus a very highly respected figure in Michacalá. It was through his connections and important role in the community that this study was made possible. The research assistant aided in setup of equipment and served as cultural and linguistic translator throughout the data collection portion of this study.

SUBJECTS AND DATA COLLECTION PROCEDURES

Quichua Infants

Seven infants were selected for this study. The infants were located by community referral through the research assistant. All infants were in the babbling or early word stage of acquisition at the beginning of the study according to parent report. All infants were developing normally according to parental information on infant expressive and receptive language knowledge, as well as informal administration of the DOCT (Davis Observational Checklist for

Texas), (Davis, 1991), a parent interview screening instrument of communication acquisition. All infants had normal hearing based on sound field hearing testing. Hearing and speech and language acquisition were informally monitored throughout the data collection period to ensure continued normal development. Quichua infant characteristics are shown in Table 3-1.

Table 3-1. Quichua Infant Characteristics

Infant	**Gender**	**# Sessions**	**Age at Beginning of Study**	**Age at End of Study**
Adelaida	F	7	1;3	1;7
Edison	M	8	0;9	1;2
Fabian	M	8	1;3	1;8
Lourdes	F	8	1;3	1;8
Marisa	F	8	0;9	1;2
Miriam	F	7	1;1	1;6
Silvio	M	7	1;5	1;10

Data collection included babbling and first words. Each infant was observed, audio recorded, and transcribed by the author. The infants' utterances were audio recorded approximately every three weeks for an hour. Seven to eight sessions were obtained for each infant. Data collection took place in the home of the infant the majority of the time; one session was conducted in the school classroom. During each session, the infants interacted normally with whomever was present. Typically the mother, a few family members, the author, and her research assistant were present. The author and the research assistant participated

in the environment in an informal manner. All attempts were made to keep the environment as natural as possible.

A Marantz PMD-201 portable analog tape recorder was used to collect all data. A Sony wireless microphone was clipped to the infant's clothing to maximize clear acoustic signals. A wireless transmitter was placed on the infant's back in an apron. A receiver was attached to the Marantz to ensure high quality audio recording.

English-Learning Infants

Six infants being raised in monolingual American English homes provided the comparison data for this study. The data for these infants are from the University of Texas at Austin Speech Acquisition Database. Information on data collection for these infants is reported in previous studies (see Davis & MacNeilage, 1995a; Davis et al., in press; MacNeilage et al., 1997). Characteristics for the English-learning infants particular to the present study are shown in Table 3-2.

Table 3-2. English-Learning Infant Characteristics

Infant	Gender	# Sessions	Age at Beginning of Analysis	Age at End of Analysis
C	F	20	0;9	1;3
N	M	37	0;9	1;10
P	M	38	0;9	1;10
R	F	35	0;9	1;10
S	F	20	0;9	1;9
W	M	17	0;9	1;3

English-learning infants were audio recorded on a weekly basis from the onset of babbling through the emergence of first words. At that point, infants were audio taped on a bi-weekly basis. All recordings were collected in the infant's home environment while they participated in normal daily activities. An ATW-20 digital audio tape recorder was used to collect all data. An Audiotechnika ATW-1031 microphone was clipped to their shoulder. A wireless transmitter was placed in a fanny pack on their back. Additional information on data collection for these infants is available in previously published research (Davis & MacNeilage, 1995a).

Adults

Hour-long structured conversational interviews were collected from seven Quichua adults and seven American adults. Each interview included identifying information, a narrative, and expository information. 75 utterances were randomly selected for transcription. All fourteen adult participants were taped

and transcribed by the author. The Quichua adults were the mothers of the seven infants in this study. Their speech samples were collected in the home environment. The American adults were located through the English-speaking community in Ecuador. Five were female and two were male. All spoke Standard American English. Their speech samples were collected in home or work environments.

All adult speech samples were recorded on the Marantz PMD-201. The adults also used the transmitter and receiver as well as the Sony wireless microphone to ensure sound fidelity for transcription.

DATA ANALYSIS

Transcription

For infant transcription, broad International Phonetic Alphabet (IPA) symbols with diacritics for infant speech were employed (Bush et al., 1973). These supplemental symbols include vowel lengthening, aspiration, rounding, syllabification, palatalization, velarization, as well as those describing vocal quality (salivary, etc.). Only comfort state vocalizations were transcribed. No vocalizations not determined to be words or babbling were analyzed in this data set. The beginning and end of each utterance was determined by a period of silence on either side as well as intuition of the researcher (Davis & MacNeilage, 1995a; Oller & Lynch, 1992). For adult speech samples, broad IPA transcription was used.

Words were defined by researcher judgment on what is a word, using criteria outlined by Vihman and McCune (1994). This includes information on determinative context, parental identification, vocalization phonetic shape, and relation of the token to the infant's other tokens. Parent report aided in determining the meaningfulness of words.

It proved more difficult to define words for Quichua infants than for English-learning infants for many reasons. Lack of metalinguistic skill of the Quichua mothers, absence of cultural emphasis on word identification in infants, the author's limited knowledge of Quichua, and absence of prior research of typical first words in Quichua infants were complicating factors. Thus words were only identified when there was no doubt about their meaning in the communicative context. This is one of the reasons that Quichua infants produce fewer words than their English-learning peers.

The author transcribed the Quichua infant data and all adult data. The author is a fluent speaker of English, Spanish, and German, who has basic knowledge of Quichua and French. This varied language background provided a wide phonetic base for transcription.

All infant and adult data were entered for computer analysis into the software Logical International Phonetic Programs (LIPP), (Oller, 1990), specifically designed for infant vocalization analysis but also valid for adult speech analysis. LIPP analysis included phonetic inventory, consonant-vowel ratios, word length patterns, CV co-occurrence patterns, reduplication and variegation patterns, and labial-coronal-dorsal patterns for CVCs.

The Data Set

53 sessions were analyzed for the Quichua infants and 167 sessions were analyzed for the English-learning infants. Infant data were divided into babbling and words for analysis. Canonical babbling was selected for analysis according to the criteria reported by Davis and MacNeilage (Davis & MacNeilage, 1995a). Babbling data were analyzed two ways: Total Babbling and Babbling by Age Group (9-13 months, 13-17 months, 17-22 months). The age group analyses were conducted to assess developmental trends. Because of the limited word data for Quichua infants, words were analyzed for the overall 9 to 22 month period. The babbling and word data analyzed for the Quichua and English-learning infants by age group are shown in Tables 3-3 and 3-4 respectively. Total number of syllables and words for all Quichua and American English adult data analyzed are shown in Table 3-5.

Table 3-3. Babbling and Words for Quichua Infants by Age Group and Total

INFANT	AGE GROUP	# SESSIONS	# BABBLING UTTERANCES	# WORDS
Edison	9-13	6	823	0
	13-17	2	572	0
	Total	8	1,395	0
Marisa	9-13	6	1,318	9
	13-17	2	682	1
	Total	8	2,000	10
Lourdes	13-17	3	633	0
	17-22	5	1,420	12
	Total	8	2,053	12
Adelaida	13-17	1	70	0
	17-22	6	723	83
	Total	7	793	83
Miriam	9-13	1	15	0
	13-17	4	603	9
	17-22	2	558	6
	Total	7	1,176	15
Fabian	13-17	2	224	0
	17-22	6	1,332	83
	Total	8	1,556	83
Silvio	17-22	7	1,349	5
	Total	7	1,349	5
TOTAL	9-13	13	2,156	9
	13-17	14	2,784	10
	17-22	26	5,382	189
	TOTAL	53	19,295	411

Table 3-4. Babbling and Words for English-Learning Infants by Age Group and Total

INFANT	AGE GROUP	# SESSIONS	# BABBLING UTTERANCES	# WORDS
C	9-13	15	2,332	252
	13-17	5	761	362
	Total	20	3,093	614
N	9-13	11	484	0
	13-17	14	697	128
	17-22	12	470	473
	Total	37	1,651	601
P	9-13	13	418	7
	13-17	11	395	45
	17-22	14	576	362
	Total	38	1,389	414
R	9-13	13	1,175	20
	13-17	13	959	947
	17-22	9	877	1,204
	Total	35	3,011	2,171
S	9-13	10	661	0
	13-17	9	1,133	25
	17-22	1	84	87
	Total	20	1,878	112
W	9-13	9	794	0
	13-17	8	1,237	6
	Total	17	2,031	6
TOTAL	9-13	71	5,864	279
	13-17	60	5,182	1,513
	17-22	36	2,007	2,126
	Total	167	13,053	3,918

Table 3-5. Quichua and English Adults Total Words and Syllables

LANGUAGE	ADULT	TOTAL NUMBER OF	
		SYLLABLES	WORDS
Quichua	1	1,635	595
	2	1,769	722
	3	1,803	824
	4	1,474	618
	5	1,761	676
	6	1,451	619
	7	1,786	740
	TOTAL	**11,679**	**4,794**
English	1	1,444	1,111
	2	1,574	1,138
	3	1,615	1,184
	4	1,486	1,070
	5	1,320	1,019
	6	1,972	1,405
	7	1,632	1,268
	TOTAL	**11,043**	**8,195**

Reliability

Quichua Infants

A trilingual English/French/Spanish phonetician with extensive training in infant transcription re-transcribed 10% of the Quichua infant data. Point-to-point agreement was calculated for each infant and for the entire group and is shown in Table 3-6.

While point-to-point reliability provides the total disagreement between transcribers, it assumes an "all-or-none" segmental relationship and does not capture the multidimensionality of transcription (Jakielski, 1998). Point-to-point

reliability provides little information on the nature of transcriber disagreement. To better understand how transcription differed, reliability for the various dimensions of segments analyzed in this study was determined. Consonants were compared by place and manner and vowels were compared by height and front/back dimension. Results for these comparisons are shown in Table 3-6. Differences in transcription limited to voicing for consonants and tense/lax distinctions for vowels were not analyzed.

Many researchers compare stops, nasals, and glides only when determining transcription reliability for early speech acquisition (e.g., Davis & MacNeilage, 1995a). For comparative purposes, consonant reliability for stops, nasals, and glides only was computed and is also shown in Table 3-6.

Table 3-6. Quichua Infant Transcription Reliability

	RELIABILITY		
	GROUP AVERAGE	INDIVIDUAL RANGE	
		Highest (Infant)	Lowest (Infant)
TOTAL	65.5%	74.4% (Marisa)	60.9 % (Edison)
ALL CONSONANTS	75.7%	86.9% (Marisa)	62.6% (Lourdes)
STOP/NASAL/GLIDE	81.3%	90.7% (Silvio)	65.6% (Lourdes)
VOWELS	55.3%	60.1% (Fabian)	50.5% (Edison)
CONS - MANNER	86.1%	92.2% (Adelaida/Marisa)	73.3% (Lourdes)
CONS - PLACE	80.4%	85.7% (Silvio)	75.4% (Fabian)
VOW - HEIGHT	73.4%	79.3% (Marisa)	60.4% (Miriam)
VOW - FRONT/BACK	67.2%	78.4% (Fabian)	61.7% (Edison)

Extensive effort was made to locate a secondary transcriber who was Quichua-speaking. Two Ecuadorean linguistics' professors attempted the task. However, after extensive training in phonetic transcription of babbling and early speech, it was determined that their skills for transcribing non-Spanish or non-Quichua phonemic data were unreliable. Neither of these people spoke a language with more than five vowels and their attempts to transcribe vowels outside of their 5-vowel space were highly unsuccessful.

English-Learning Infants

Point-to-point reliability for the English-learning infants has been previously reported (Davis & MacNeilage, 1995a; Davis et al., in press; MacNeilage et al., 1997). Stops, nasals, and glides were used to determine consonant reliability. Consonant reliability averaged 76.8%, and ranged from 63% to 83%. Vowel reliability averaged 44.8% and ranged from 33% to 69%. Detailed information on the transcription reliability can be found in the studies mentioned above.

Quichua and American Adults

An Ecuadorean professor at the Salesian University in Quito who had extensive training in the transcription of adult Quichua conducted transcription reliability for the Quichua adults. 10% of the adult utterances were randomly selected for re-transcription. Average total reliability was 93.5%, and ranged from 91.2% to 95.6% by adult. Average total reliability for consonants was 93.3% and ranged from 90.6% to 96.5%. Average total reliability for vowels was 93.7% and ranged from 92.4% to 96.0%.

An English-speaking phonetician conducted transcription reliability for the American adults. 10% of the adult utterances were randomly selected for re-transcription. Average total reliability was 96.9% and ranged from 94.8% to 99.0% by adult. Average total reliability for consonants was 97.6% and ranged from 95.7% to 98.8%. Average total reliability for vowels was 95.8% and ranged from 90.6% to 99.4%.

Data Analysis

For each question, the following analyses were conducted. First, the adult languages were compared to determine ambient language influences. Then the Quichua infant data (babbling by age group, total babbling, and total words) were analyzed to determine if significant patterns existed within the infants, or whether individual differences were greater. Subsequently, the following comparisons to the Quichua infant utterances were made as appropriate: 1) Quichua infant babbling (by age group and total) to adult Quichua; 2) Quichua first words to adult Quichua; 3) Quichua infant babbling (by age group and total) to American English-learning infant babbling; 4) Quichua infant first words to American English-learning infant first words. To ensure equal value for each participant, weighted averages were used in all comparisons.

The three hypotheses and their subanalyses are listed below. Following their listings are analysis procedures that were particular to certain analyses.

Hypothesis 1: General Information

a) Consonant Place of Articulation

b) Consonant Manner of Articulation

c) Vowel Front/Back Dimension

d) Vowel Height

e) Ratio of Consonants to Vowels

f) Word Length

Hypothesis 2: Intrasyllabic Patterns

a) Consonant Place-Vowel Front/Back Dimension Co-Occurrence

Hypothesis 3: Intersyllabic Patterns

a) Consonant Reduplication and Variegation in CVCV (…) Utterances

b) Vowel Reduplication and Variegation in CVCV (…) Utterances

c) Anterior-Posterior Patterns in CVC Utterances

d) Anterior-Posterior Patterns in CVCV (…) Utterances

Consonant Place

Consonants were divided into groups for place of articulation analysis: labial, coronal, dorsal, and glottal. Labial consonant phonemes and allophones involve lip contact in closure. They include but are not limited to /ɓ, p, m, w, β, ɸ, v, f /. Consonants analyzed as coronals are those involving articulatory contact of the anterior portion of the tongue and include /n, ñ, ð, θ, z, s, dz, ts, ɮ, ʒ, ʃ, dʒ,tʃ, l, ɹ̪, j̪, ç, ʎ/. Dorsal consonants are made with articulatory contact of the posterior portion of the tongue and include /g, k, ŋ, x. ɣ, ɴ, ʀ, ʕ/. Glottal consonants are those made in the laryngeal region with no tongue involvement and include /h, ʔ/.

All analyses in which place of articulation for consonants was addressed only included labial, coronal, and dorsal consonants. These analyses were consonant place, CV co-occurrence, consonant variegation and reduplication, and

anterior-posterior patterns. Glottal consonants were included in analyses of consonant manner.

Consonant Manner

Consonants were divided into the following manner categories for preliminary analysis: stops, nasals, glides, fricatives, affricates, liquids, trills, implosives, ejectives, clicks, and nonpulmonics. The latter four categories were infrequent and were not included in the final analyses.

Vowels

Vowels were divided into front, central, and back places of articulation for the analyses of vowel front/back dimension and into high, mid, and low categories for vowel height.

Statistical Analysis

All analyses in this study were categorical. The statistical significance of differences within the Quichua infant groups or between language or age groups for the questions within the three hypotheses was determined using either Generalized Estimating Equations (GEE) (McCullagh & Nelder, 1989) or Hierarchical Generalized Linear Modeling (HGLM) (Bryk & Raudenbush, 1992).[1] For all statistical tests, an a priori significance level of .05 was adopted.

[1] GEE is an extension of Generalized Linear Models (the base of ANOVA or regression) that has been adapted for categorical data. It allows a mean of a population to be estimated through a nonlinear link function that transforms the data into binomial or multinomial

In general, HGLM was used for all across group comparisons and GEE was used for all within group comparisons. Exceptions were the use of GEE for all analyses of CV co-occurrence patterns, which have two dependent variables and cannot be analyzed using HGLM. In addition, if an analysis could not be conducted in HGLM because of analysis limitations, it was then attempted in GEE.

---

measurements. It is specifically used for repeated measures analysis with categorical outcomes. It is conducted using the GENMOD procedure in the computer program SAS. Results are reported as Chi-square values. Significance levels are shown for main effects.

HGLM is an adaptation of the generalized linear model for hierarchical or clustered data of a categorical nature (Kreft & de Leeuw, 1998). HGLM incorporates higher level variables, taking the hierarchical structure of the data into account and making it possible to incorporate variables from all levels (e.g., Level 1: Repeated observations over time, Level 2: Child, Level 3: Language). It provides separate regression lines for all data at each level, with regression coefficients of 1st level regressed on a 2nd level explanatory variable. It breaks error terms down for each level and is useful in looking at between group variation. The main difference between HGLM and GEE is the treatment of data as clustered or nested data in HGLM and as repeated measures in GEE. Thus the error term in GEE is more of a population average, with a single regression line for the group, whereas the error term in HGLM is divided by level, with regression lines for each value analyzed.

CHAPTER 4: RESULTS

The results are divided into three sections. General segmental and syllabic analyses are presented first, followed by intrasyllabic analyses, and intersyllabic analyses. Findings are presented in the following format:

First, adult Quichua (QA) and adult English (EA) are compared. Infant Quichua (QI) group patterns for babbling and words are described, as well as individual patterns which differ from group patterns. The QI data are then compared to QA results. Finally, QI findings are compared to English infant (EI) data to determine if QI patterns of production are similar to infants of similar age from a different language environment.

QI babbling data were analyzed for the entire period and for three age groups: 9 to 13 months, 13 to 17 months, and 17 to 22 months. The majority of the findings were the same for the entire babbling period and the separate age groups. Age group results are discussed in detail if they differ from the findings for the entire babbling period. Because of the limited number of tokens, infants' first words were only analyzed for the entire period.

GENERAL SYLLABIC AND SEGMENTAL INFORMATION

Consonants

Total consonants analyzed for each group were as follows: QA–13,801, EA–16,401, QI: Babbling–14,832, QI: Words–334, EI: Babbling–27,989, EI: Words–5,689.

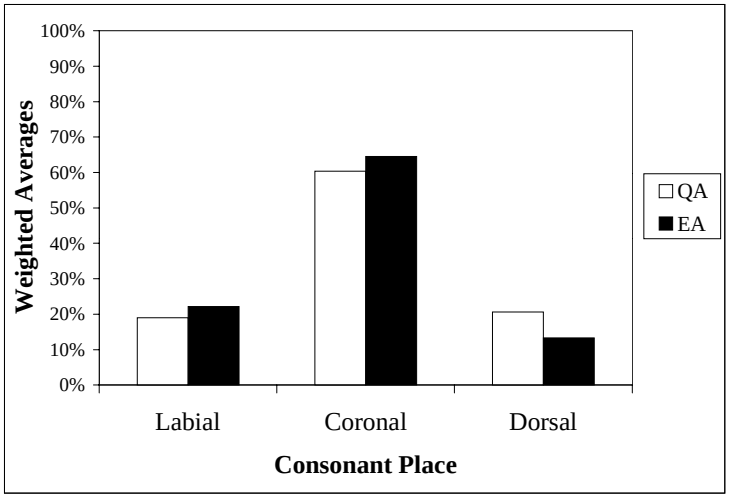
Consonant Place

Consonant Place in Quichua and English

Figure 4-1 compares place across language environments. QA averaged 19% labial, 60% coronal, and 21% dorsal; EA averaged 22% labial, 65% coronal, and 13% dorsal. All place differences were significant[1]– a greater frequency of dorsals in Quichua and a greater frequency of labials and coronals in English account for the differences.

[1] QA to EA: Labials: $t = 3.626$, DF = 12, $p = 0.004$; Coronals: $t = 5.946$, DF = 12, $p < 0.001$; Dorsal: $t = 12.367$, DF = 12, $p < 0.001$)

Figure 4-1. Consonant Place in Quichua & English



Consonant Place in Quichua Infant Babbling and Words

Babbling:

In QI, significant patterns for place were observed.[1] Coronals were most frequent (66%), followed by labials (22%), then dorsals (12%).

Words:

In QI words, group trends were for frequent coronal production (67%), followed by approximately equal frequencies of labials (17%) and dorsals (16%). However, differences between infants varied widely and patterns for place were not significant.[2] Two Quichua infants produced only coronal consonants and two

[1] QI Babbling: X^2 = 94.42, DF = 2, p = 0.0001
[2] QI Words: X^2 = 0.39, DF = 2, p = 0.8211

produced mainly coronals in words, while one infant preferred labials and one infant preferred dorsals.

Consonant Place in Quichua Adults and Quichua Infants

Babbling:

In QI babbling and words, place patterns were compared to QA patterns. Results are shown in Figure 4-2. In babbling, significant differences between QI and QA for place were found for dorsals but not for coronals or labials.[1] Both QA and QI produced coronals most frequently (QI: 66%, QA: 60%). Labials were second in frequency in QI and third in QA (QI: 22%, QA: 19%). As a group, QI produced significantly fewer dorsals (QI-12%, QA-21%) than QA. These same patterns were observed when comparing QA to QI from 13 to 17 months of age and from 17 to 22 months of age.[2] 9 to 13 month old QI differed from the group in producing not only significantly fewer dorsals but also significantly more labials than QA (QI: 33%, QA: 19%).[3]

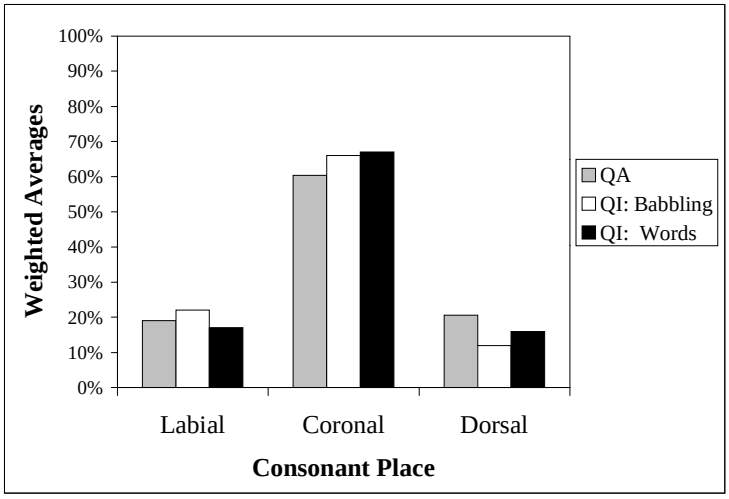
---

[1] QI Babbling to QA: Labials: $t = 0.249$, DF = 12, $p = 0.807$; Coronals: $t = 1.269$, DF = 12, $p = 0.229$; Dorsal: $t = 3.341$, DF = 12, $p = 0.006$

[2] QI 13-17 Months to QA: Labials: $t = 0.415$, DF = 11, $p = 0.686$; Coronals: $t = 1.650$, DF = 11, $p = 0.127$; Dorsals: $t = 3.513$, DF = 11, $p = 0.005$; QI 17-22 Months to QA: Labials: $t = 0.867$, DF = 10, $p = 0.407$; Coronals: $t = 1.093$, DF = 10, $p = 0.300$; Dorsals: $t = 2.790$, DF = 10, $p = 0.020$

[3] QI 9-13 Months to QA: Labials: $t = 8.258$, DF = 9, $p < 0.001$; Coronals: $t = 0.816$, DF = 8, $p = 0.438$; Dorsals: $t = 11.092$, DF = 9, $p < 0.001$

Figure 4-2. Consonant Place in Quichua Adults & Infants



Words:

Place patterns did not significantly differ when comparing QI words to QA.[1] As a group, QI produced words containing coronals (67%), labials (17%), and dorsals (16%). QA also primarily produced coronals (60%), as well as almost equal frequencies of labials (19%) and dorsals (21%). In QI words, individual differences were found, with 4 infants preferring coronals, one preferring dorsals, and one preferring labials.

[1] QI Words to QA: Labials: t = 0.390, DF = 11, p = 0.704; Coronals: t = 0.342, DF = 11, p = 0.739; Dorsals: t = 0.290, DF = 11, p = 0.777

Consonant Place in Quichua and English-Learning Infants

Babbling:

For the entire babbling period, QI and EI place patterns differed significantly for labials and coronals but not for dorsals.[1] While the order of frequency did not differ across language environments (coronals > labials > dorsals), the QI overall babbling pattern showed a lower frequency of labials (QI: 22%, EI: 38%) and a higher frequency of coronals (QI: 66%, EI: 51%) than EI. No group differences were found for dorsals, which occurred 12% of the time in both Quichua and English. Figure 4-3 compares QI and EI place patterns in babbling.

Some age group effects were found for QI and EI place patterns. In the 9 to 13 month age group, no significance differences were found between language groups.[2] In the 13 to 17 month groups, QI and EI differed significantly in labial and coronal place of production,[3] with QI producing fewer labials (QI: 20%, EI: 42%) and more coronals (QI: 70%, EI: 48%) than EI. From 17 to 22 months of age, QI and EI differed significantly in production of labials and dorsals,[4] with QI producing fewer labials (QI: 24%, EI: 44%) and more dorsals (QI: 13%, EI: 8%) than EI in this age category. While all five QI showed an increase in dorsals, two of the five produced more dorsals than labials (Fabian produced 19% dorsals and

---

[1] QI to EI Babbling: Labials: $t = 2.563$, DF = 11, $p = 0.027$; Coronals: $t = 2.862$, DF = 11, $p = 0.016$; Dorsals: $t = 0.230$, DF = 11, $p = 0.823$

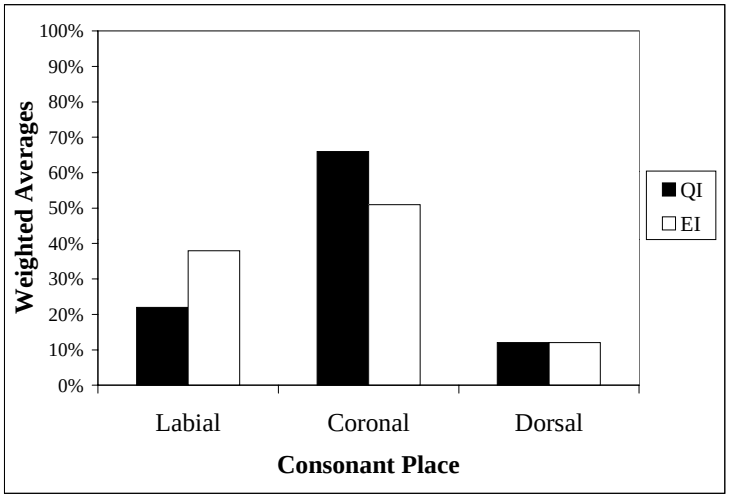
[2] QI to EI 9-13 Months: Labials: $t = 0.455$, DF = 7, $p = 0.662$; Coronals: $t = 1.055$, DF = 7, $p = 0.327$; Dorsals: $t = 0.398$, DF = 7, $p = 0.702$

[3] QI to EI 13-17 Months: Labials: $t = 2.494$, DF = 10, $p = 0.032$; Coronals: $t = 2.863$, DF = 10, $p = 0.017$; Dorsals: $t = 0.353$, DF = 10, $p = 0.731$

[4] QI to EI 17-22 Months: Labials: $t = 2.968$, DF = 7, $p = 0.022$; Coronals: $t = 2.490$, DF = 7, $p = 0.041$; Dorsals: $t = 2.318$, DF = 7, $p = 0.031$

15% labials; Silvio produced 22% dorsals and 12% labials). In contrast, EI produced equal or fewer dorsals during the 17 to 22 month period than during the 13 to 17 month period. From 17 to 22 months, three of 4 EI showed the group pattern for coronal consonant preference, although R produced more labials (52%) than coronals (38%).

Figure 4-3. Consonant Place in Quichua & English-Learning Infants' Babbling



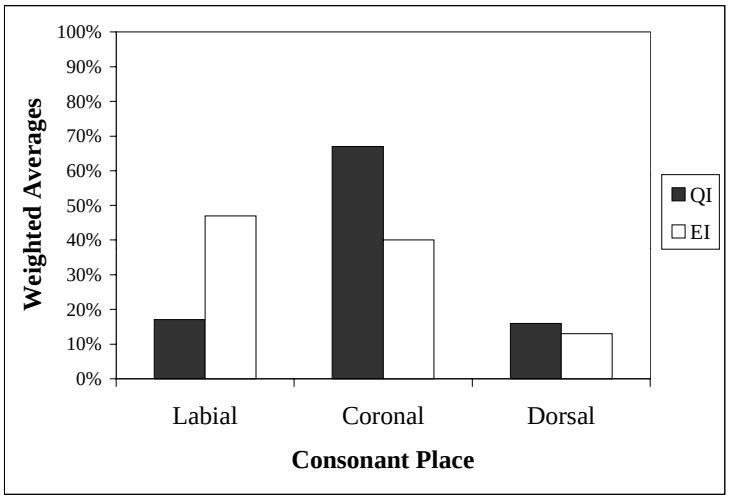
In summary, place patterns in babbling changed between 9 and 22 months of age in both language environments. Infants in the 9 to 13 month age groups did not show significantly different place preferences from one another, infants in the 13 to 17 month age groups showed some significant differences, primarily in the lower frequency of labials and the greater frequency of coronals in QI. Infants in the 17 to 22 month age group produced consonants that more closely matched

their Quichua and English language environments: QI produced fewer labials and more dorsals than EI.

Words:

For words, place patterns are shown in Figure 4-4. QI produced coronals most frequently (67%), followed by labials (17%) and dorsals (16%). EI overwhelmingly preferred labials in words, (47%), followed by coronals (40%), and dorsals (13%). The difference in labial production in QI and EI words was significant.[1]

Figure 4-4. Consonant Place in Quichua & English-Learning Infants' Words



[1]QI to EI Words: Labials: t = 3.052, DF = 10, p = 0.013; Coronals: t = 1.526, DF = 10, p = 0.158; Dorsals: t = 0.605, DF = 10, p = 0.558

Consonant Place Summary

Differences in place patterns in Quichua and English were found. QA produced significantly fewer labials and coronals and significantly more dorsals than EA.

In QI babbling, group place patterns were most frequent production of coronals, followed by labials and dorsals. In QI words, no significant group pattern was found, although coronals were preferred.

In babbling, QI produced significantly fewer dorsals than QA. In addition, QI from 9 to 13 months of age produced significantly fewer labials than QA. In words, no significant differences were found between QI and QA: the preference for coronals followed by labials and dorsals was found in both.

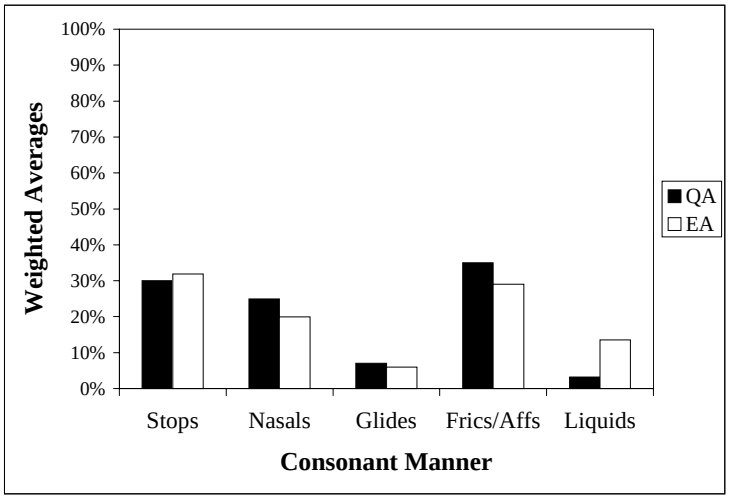
In babbling, QI produced significantly fewer labials than EI. In addition, there were differences by age. 9 to 13 month old QI and EI did not significantly differ in place frequency, from 13 to 17 months of age, QI produced significantly fewer labials and more coronals, and from 17 to 22 months of age, QI produced significantly fewer labials and more dorsals. In words, QI produced significantly fewer labials than EI.

Consonant Manner

Consonant Manner in Quichua and English

Figure 4-5 compares manner in QA and EA. QA differed from EA in that QA produced significantly more fricatives and affricates (QA-35%, EA-29%), nasals (QA: 25%, EA: 20%) and fewer liquids (QA: 3%, EA: 14%).[1]

Figure 4-5. Consonant Manner in Quichua & English



[1] QA to EA: Stops: t = 2.423, DF = 12, p = 0.032; Nasals: t = 3.532, DF = 12, p = 0.005; Glides: t = 2.015, DF = 12, p =0.067; Fricatives & Affricates: t = 11.465, DF = 12, p < 0.001; Liquids: t = 15.021, DF = 12, p < 0.001

Consonant Manner in Quichua Infant Babbling and Words

Babbling

For QI babbling, group manner patterns were significant,[1] and included most frequent production of stop consonants (47%), followed by fricatives and affricates (27%), nasals (15%), glides (10%), and liquids (2%).

Words

In QI words, a lack of convergence occurred when analyzing early-developing consonants (stops, nasals, and glides, or EDC) statistically. While stops were most frequent in 3 of the 6 Quichua infants who produced words, nasals were most frequent in the other three, perhaps leading to the lack of statistical convergence for EDC. As a group, EDCs in QI words were primarily stops (42%, ranging from 11% to 82%), followed by nasals (34%, ranging from 0% to 79%) and glides (4%, ranging from 0% to 8%). Later-developing consonants (fricatives, affricates, and liquids, or LDC) did show significant patterns, indicating similarities in production of LDCs across infants.[2] Fricatives and affricates were produced 20% and liquids were produced 2%.

---

[1] QI Babbling: *EDC*: X^2 = 126.23, DF = 2, p = 0.0001, *LDC*: X^2 = 76.61, DF = 2, p = 0.0001
[2] QI Words: X^2 = 15.79, DF = 2, p = 0.0004

Consonant Manner in Quichua Adults and Quichua Infants

Babbling

A comparison of QA and QI manner is shown in Figure 4-6. QA and QI babbling differed in the frequency of stops, glides, and fricatives and affricates; QA and QI babbling did not differ in the frequency of nasals or liquids.[1] Stops were significantly more frequent in QI babbling than they were in QA (QI: 47%, QA-30%). Glides were also produced more frequently by QI than QA (QI: 10%, QA: 7%). Fricatives and affricates were significantly more frequent in QA than in QI babbling (QI: 27%, QA: 35%).

Age-specific differences in QI babbling manner patterns compared to QA were found.[2] The 9 to 13 month olds and the 13 to 17 month olds differed from the overall QI babbling pattern by producing significantly fewer nasals than QA. All three age groups did not differ significantly from QA in glide production due to variability within the age groups.

---

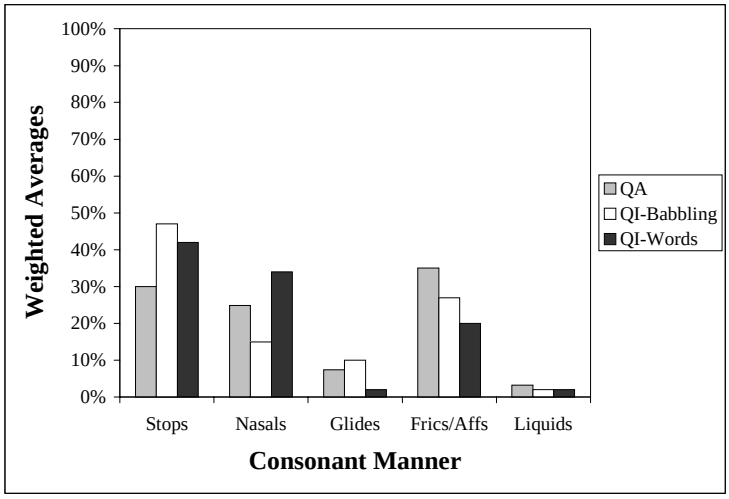
[1] QI Babbling to QA: Stops: $t = 6.858$, DF = 11, $p < 0.001$; Nasals: $t = 2.070$, DF = 11, $p = 0.062$; Glides: $t = 3.035$, DF = 11, $p = 0.012$; Fricatives & Affricates: $t = 4.373$, DF = 11, $p = 0.001$; Liquids: $t = 0.718$, DF = 11, $p = 0.488$

[2] QI 9-13 Months to QA: Stops: $t = 5.717$, DF = 8, $p < 0.001$; Nasals: $t = 6.129$, DF = 8, $p < 0.001$; Glides: $t = 2.092$, DF = 8, $p = 0.069$; Fricatives & Affricates: $t = 3.324$, DF = 8, $p = 0.012$; Liquids: $t = 2.248$, DF = 8, $p = 0.054$; QI 13-17 Months to QA: Stops: $t = 4.339$, DF = 11, $p = 0.001$; Nasals: $t = 2.960$, DF = 11, $p = 0.014$; Glides: $t = 1.170$, DF = 11, $p = 0.267$; Fricatives & Affricates: $t = 3.180$, DF = 11, $p = 0.009$; Liquids: $t = 1.694$, DF = 11, $p = 0.118$;
QI Babbling to QA: Stops: $t = 7.224$, DF = 9, $p < 0.001$; Nasals: $t = 0.762$, DF = 9, $p = 0.465$; Glides: $t = 2.045$, DF = 9, $p = 0.071$; Fricatives & Affricates: $t = 7.729$, DF = 9, $p < 0.001$; Liquids: $t = 0.677$, DF = 9, $p = 0.515$

Words

In QI words, significant differences were found for stops and fricatives and affricates when compared to QA.[1] Stops were most frequent in QI words, more frequent than in QA (QA-30%, QI Words-42%). Fricatives and affricates occurred frequently in QI (20%), but significantly more so in QA (35%). Nasals occurred with frequencies that were not significantly different in QA (25%) and QI words (34%). Glides and liquids were similarly infrequent in both QI and QA (Glides: QA - 3%, QI Words - 2%; Liquids: QA - 7%, QI Words - 2%). A comparison of QI babbling and words and QA for manner is shown in Figure 4-6.

Figure 4-6. Consonant Manner in Quichua Adults & Infants



[1] QI Words to QA: Stops: t = 3.098, DF = 11, p = 0.011; Nasals: t = 0.319, DF = 11, p = 0.755; Glides: t = 1.785, DF = 11, p = 0.101; Fricatives & Affricates: t = 3.942, DF = 11, p = 0.003; Liquids: t = 0.000, DF = 11, p = 1.000

Consonant Manner in Quichua and English-Learning Infants

Babbling

In babbling, manner patterns did not differ significantly between QI and EI for stops, nasals, glides, or liquids; differences were found for fricatives and affricates.[1] Results are shown in Figure 4-7. In both QI and EI, stops were most frequent (QI-47%, EI-54%). Nasals (QI-15%, EI-18%) and glides (QI-10%, EI-13%) occurred with similar frequency in both QI and EI as well. QI produced fricatives and affricates more frequently than EI (27% and 12% respectively). Liquids were produced infrequently by both (QI-2%, EI-4%).

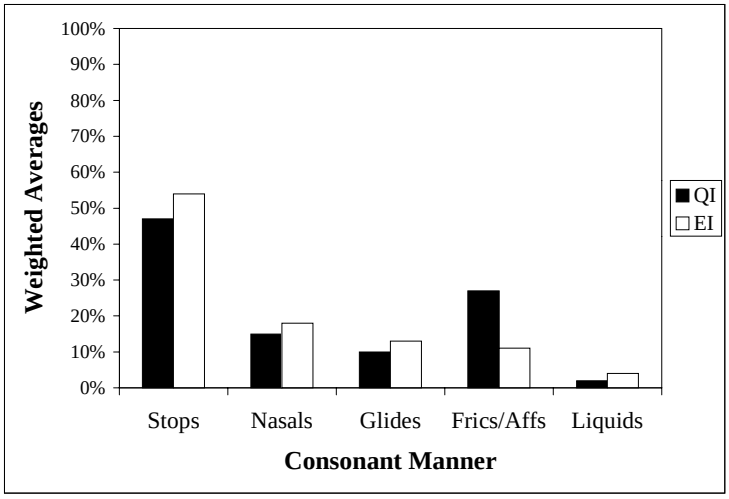
Differences from the overall babbling period were found when analyzing the 9-13 month olds but not the older infants.[2] In the 9-13 month olds, no significant differences were found when comparing manner.

---

[1] QI to EI Babbling: Stops: $t = 1.526$, DF = 11, $p = 0.155$; Nasals: $t = 0.505$, DF = 11, $p = 0.623$; Glides: $t = 1.235$, DF = 11, $p = 0.243$; Fricatives & Affricates: $t = 3.475$, DF = 11, $p = 0.006$; Liquids: $t = 2.476$, DF = 11, $p = 0.031$

[2] QI to EI 9-13 Months: Stops: $t = 0.419$, DF = 7, $p = 0.687$; Nasals: $t = 0.041$, DF = 7, $p = 0.969$; Glides: $t = 0.018$, DF = 7, $p = 0.986$; Fricatives & Affricates: $t = 1.357$, DF = 7, $p = 0.217$; Liquids: $t = 1.491$, DF = 7, $p = 0.179$; QI to EI 13-17 Months: Stops: $t = 0.834$, DF = 10, $p = 0.424$; Nasals: $t = 0.598$, DF = 10, $p = 0.563$; Glides: $t = 1.819$, DF = 10, $p = 0.098$; Fricatives & Affricates: $t = 3.140$, DF = 10, $p = 0.011$; Liquids: $t = 1.538$, DF = 10, $p = 0.155$; QI to EI 17-22 Months: Stops: $t = 1.760$, DF = 7, $p = 0.121$; Nasals: $t = 1.240$, DF = 7, $p = 0.255$; Glides: $t = 0.632$, DF = 7, $p = 0.547$; Fricatives & Affricates: $t = 5.299$, DF = 7, $p < 0.001$; Liquids: $t = 0.736$, DF = 7, $p = 0.486$

Figure 4-7. Consonant Manner in Quichua & English-Learning Infants' Babbling

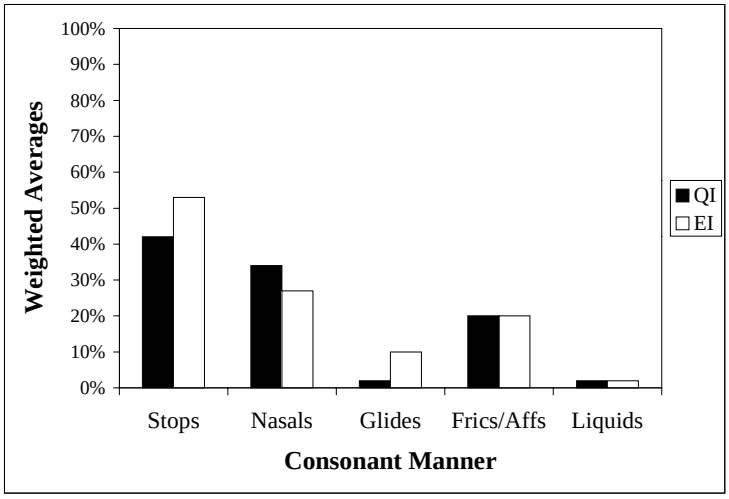


Words

In words, significant differences were not found for any manner category.[1] The trends for manner for words are compared in Figure 4-8. Both groups showed similar preferences for stops (QI-42%, EI-53%), followed by nasals (QI-34%, EI-27%), and fricatives and affricates (QI-20%, EI-20%). Glides were more likely in EI (QI-2%, EI-10%), while liquids were infrequent for both QI and EI (QI-2%, EI-2%).

[1] QI to EI Words: Stops: $t = 0.595$, DF = 10, $p = 0.565$; Nasals: $t = 0.212$, DF = 10, $p = 0.837$; Glides: $t = 1.854$, DF = 10, $p = 0.093$, Fricatives & Affricates: $t = 2.184$, DF = 10, $p = 0.054$, Liquids: $t = 0.000$, DF = 10, $p = 1.000$

Figure 4-8. Consonant Manner in Quichua- & English-Learning Infants' Words



Consonant Manner Summary

Language differences were observed for manner. Fricatives and affricates and nasals occurred significantly more frequently in QA, while liquids occurred significantly more frequently in EA.

For babbling, QI preferred stops, followed by fricatives and affricates, nasals, glides, and liquids. For QI words, 3 infants preferred stops; nasals were preferred by the other three. Fricatives and affricates were also frequent.

In babbling, stops and glides were significantly more frequent in QI than in QA. In contrast, fricatives and affricates were significantly more frequent in QA than QI. Nasal and liquid frequency in QI babbling and QA did not significantly differ. From 9 to 17 months of age, QI also differed from QA by producing significantly fewer nasals.

In words, stops occurred significantly more frequently in QI than in QA. Fricatives and affricates occurred significantly more frequently in QA.

In babbling, QI and EI showed similar preferences for stops, nasals, glides, and liquids. Differences were a significantly greater frequency of fricatives and affricates in QI than in EI babbling. The 9 to 13 month olds differed from the group by not significantly differing from EI in fricative and affricate production. In words, QI and EI did not significantly differ for any manner category, both groups preferring stops, then nasals, then fricatives and affricates.

VOWELS

Total vowels analyzed for each group were as follows: QA–10,967, EA–9,657, QI: Babbling–16,450, QI: Words–318, EI: Babbling–24,851, EI: Words–4,708.

Vowel Front/Back Patterns

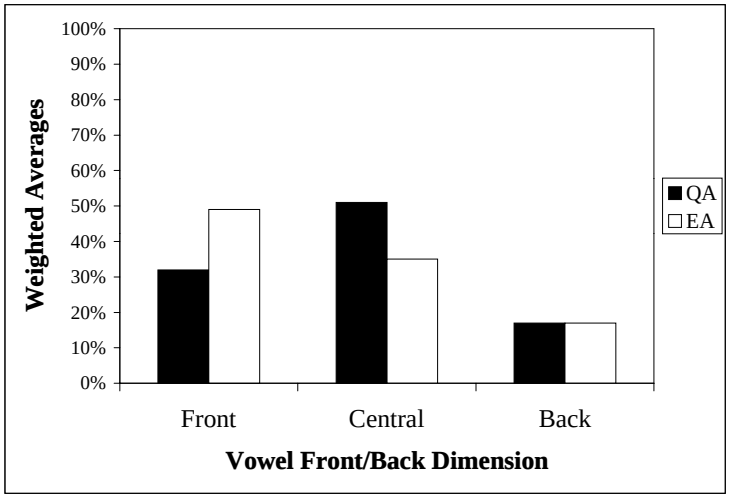
Vowel Front/Back Patterns in Quichua and English

Figure 4-9 compares QA and EA front/back patterns. QA averaged 32% front, 51% central, and 17% back vowels. EA averaged 49% front, 35% central, and 17% back vowels. The frequency of front and central vowels differed significantly across languages, while the frequency of back vowels did not.[1] The

[1] QA to EA: Front: $t = 16.593$, DF = 12, $p < 0.001$; Central: $t = 15.199$, DF = 12, $p < 0.001$; Back: $t = 0.023$, DF = 12, $p = 0.982$

greater frequency of central vowels in QA and the greater frequency of front vowels in EA account for the differences.

Figure 4-9. Vowel Front/Back Patterns in Quichua & English



Vowel Front/Back Patterns in Quichua Infant Babbling and Words

For QI babbling, front/back patterns were significant.[1] Front vowels were most frequent (52%), followed by central (42%), and back (7%). In words, a significant difference for front/back patterns was found.[2] Central vowels were most frequent (45%), followed by back vowels (38%), and front vowels (17%).

[1] QI Babbling: X^2 = 102.5, DF = 2, p = 0.0001
[2] QI Words: X^2 = 7.94, DF = 2, 0.0189

Vowel Front/Back Patterns in Quichua Adults and Quichua Infants

Babbling

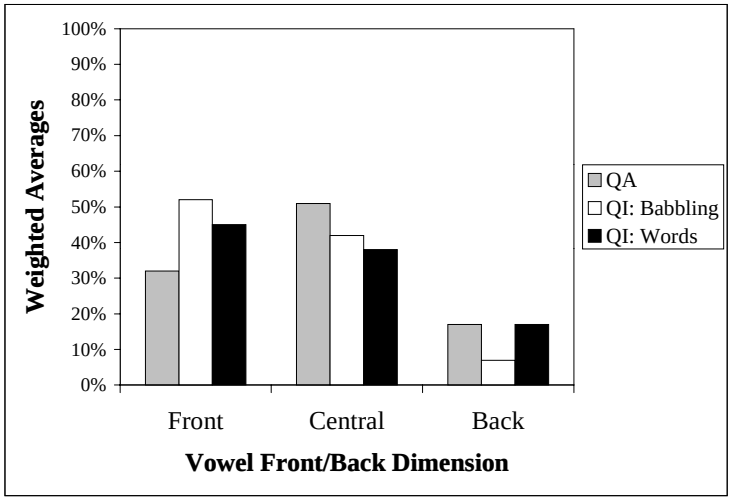
Differences in front/back frequency for front, central, and back vowels were observed in QI and QA.[1] In babbling, QI produced front vowels most frequently (52%), followed by central (42%), and back (7%). QA produced central vowels most frequently (51%), followed by front (32%), and then back (17%). When comparing QI babbling by age category to QA, some age-specific differences were found in the 9-13 and 13-17 month olds from the entire babbling period.[2] 9 to 13 month old QI did not differ significantly from QA in the frequency of central vowels. This was the result of large differences in central vowel frequency in the infants–ranging from 40% to 64% central–while QA produced central vowels 51%. QI 13 to 17 month olds also did not differ significantly from QA in the frequency of central vowel production, although the average for 13 to 17 month olds was lower than QA (36% vs. 51% respectively). Again, QI varied drastically in their production of central vowels, ranging from 13% to 60%. Front/back patterns in QI and QA are compared in Figure 4-10.

---

[1] QI Babbling to QA: Front: $t = 6.334$, DF = 12, $p < 0.001$; Central: $t = 3.881$, DF = 12, $p = 0.002$; Back: $t = 5.295$, DF = 12, $p < 0.001$

[2] QI 9-13 Months to QA: Front: $t = 6.215$, DF = 8, $p < 0.001$; Central: $t = 1.236$, DF = 8, $p = 0.252$; Back: $t = 14.950$, DF = 8, $p < 0.001$; QI 13-17 Months to QA: Front: $t = 3.162$, DF = 11, $p = 0.010$; Central: $t = 2.093$, DF = 11, $p = 0.060$; Back: $t = 6.094$, DF = 11, $p < 0.001$; QI 17-22 Months to QA: Front: $t = 6.189$, DF = 10, $p = 0.001$; Central: $t = 4.296$, DF = 10, $p = 0.002$; Back: $t = 4.375$, DF = 10, $p = 0.001$

Figure 4-10. Vowel Front/Back Patterns in Quichua Adults & Infants



Words

In words, QI tended to produce front vowels most frequently (45%), followed by central (38%) and then back (17%). In contrast, QA produced central vowels most frequently (51%), followed by front (32%), and then back (17%). However, front/back patterns in QI words varied widely and QA and QI did not differ significantly.[1] A comparison of front/back patterns in QA and QI words is shown in Figure 4-10.

[1] QA to QI Words: Front: t = 1.668, DF = 11, p = 0.123; Central: t = 2.179, DF = 11, p = 0.052; Back: t = 0.215, DF = 11, p = 0.834

Vowel Front/Back Patterns in Quichua and English-Learning Infants

Babbling

During the entire babbling period, QI and EI front/back patterns differed significantly for back vowels but not front or central vowels.[1] Front/back patterns are shown in Figure 4-11. There was a lower frequency of back vowels produced by QI (7%) than EI (15%).

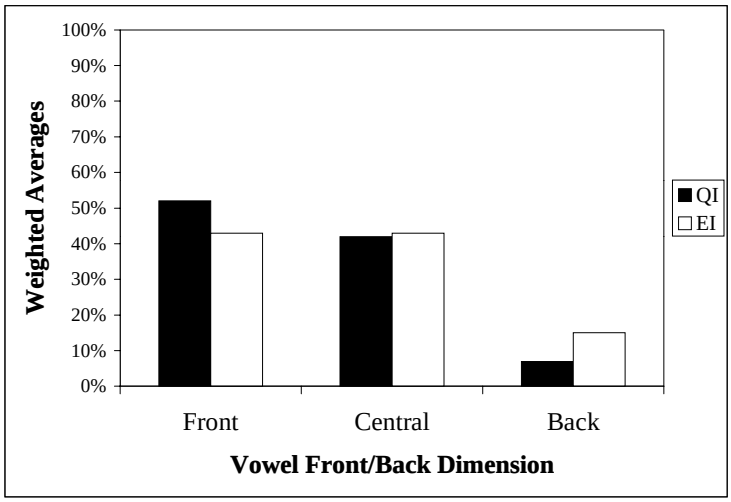
Results for front/back patterns in 13 to 17 month olds and 17 to 22 month olds were the same as for group analysis. However, in the 9 to 13 month old group in babbling, no significant differences in front/back patterns were observed between QI and EI.[2] From 9 to 13 months of age, both QI and EI produced more front and central vowels (QI: 43% and 52%, EI: 45% and 42% respectively) and few back vowels (QI: 5%, EI: 13%).

---

[1] QI to EI Babbling: Front: $t = 2.276$, DF = 11, $p = 0.044$; Central: $t = 0.150$, DF = 11, $p = 0.884$; Back: $t = 2.909$, DF = 11, $p = 0.015$

[2] QI to EI 9-13 Months: Front: $t = 0.457$, DF = 7, $p = 0.661$; Central: $t = 0.878$, DF = 7, $p = 0.409$; Back: $t = 1.845$, DF = 7, $p = 0.107$; QI to EI 13-17 Months: Front: $t = 1.498$, DF = 10, $p = 0.165$; Central: $t = 0.448$, DF = 10, $p = 0.663$; Back: $t = 2.890$, DF = 10, $p = 0.017$;
QI to EI 17-22 Months: Front: $t = 1.434$, DF = 7, $p = 0.195$; Central: $t = 0.057$, DF = 7, $p = 0.956$; Back: $t = 2.544$, DF = 7, $p = 0.038$

Figure 4-11. Vowel Front/Back Patterns in Quichua & English-Learning Infants' Babbling

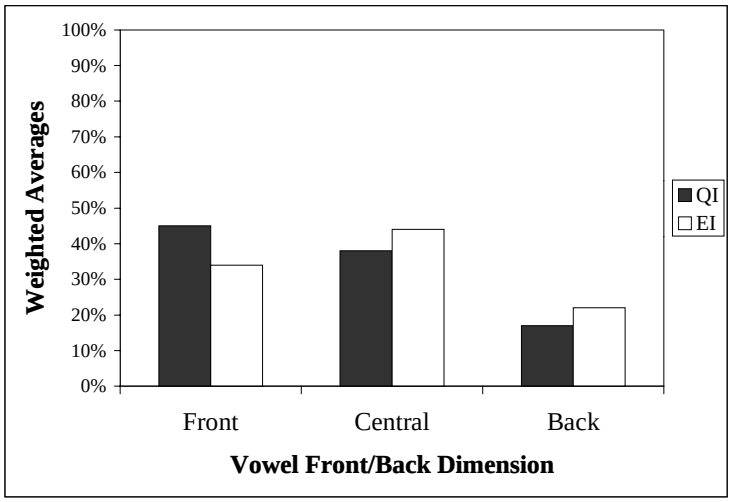


Words

In QI and EI words, no significant differences in front/back patterns were found.[1] Group trends were for more frequent production of front vowels (45%) over central vowels (38%) in QI; the reverse was true for EI, where central vowels (44%) were more frequent than front vowels (34%). Back vowels were least frequent in both (QI-17%, EI-22%). Results for QI and EI words are compared in Figure 4-12.

[1] QI to EI Words: Front: $t = 0.845$, DF = 10, $p = 0.418$; Central: $t = 0.357$, DF = 10, $p = 0.728$; Back: $t = 0.919$, DF = 10, $p = 0.380$

Figure 4-12. Vowel Front/Back Patterns in Quichua & English-Learning Infant's Words



Vowel Front/Back Patterns Summary

Significant differences in QA and EA were found in front/back patterns. QA were most likely to produce central vowels. In contrast, EA produced significantly more front vowels. Back vowels were similarly infrequent in both QA and EA.

In babbling, front vowels were produced most frequently, followed by central and back vowels. In words, QI produced central vowels most frequently, followed by back and front. QA produced central vowels most frequently, followed by front and back vowels. The differences between QI and QA were significant for babbling, but not for words.

For the entire babbling period, QI and EI varied slightly in front/back patterns. QI produced significantly fewer back vowels. However, from 9 to 13 months of age, QI and EI did not significantly differ in front/back patterns.

In words, vowels did not vary significantly between QI and EI; however, there were differing trends that were nonsignificant. While QI produced slightly more front than central vowels, the reverse was true for EI. Individual variation and a small data set were complicating factors in this comparison.

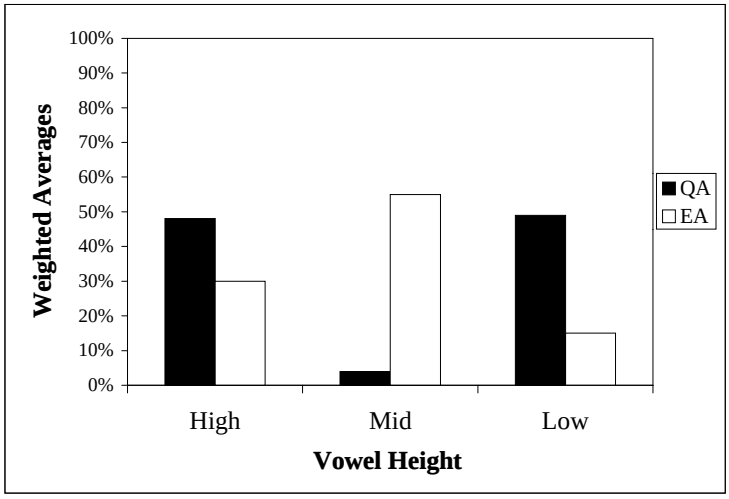
Vowel Height

Vowel Height in Quichua and English Adults

Figure 4-13 compares height for QA and EA. QA averaged 48% high, 4% mid, and 49% low vowels. There are no phonemic mid vowels in Quichua. EA averaged 30% high, 55% mid, and 15% low vowels. These height differences were significant[1] and are accounted for by the greater frequency of high and low vowels in QA and the greater frequency of mid vowels in EA.

[1] QA to EA: High: $t = 13.197$, DF = 12, $p < 0.001$; Mid: $t = 16.080$, DF = 12, $p < 0.001$; Low: $t = 34.639$, DF = 12, $p < 0.001$

Figure 4-13. Vowel Height in Quichua & English



Vowel Height in Quichua Infant Babbling and Words

Babbling

In babbling, height showed significant patterns for QI.[1] Mid vowels were most frequent (53%), followed by high (31%), and low vowels (16%).

Words

In QI words, a significant height pattern was found for the group.[2] This was for a greater frequency of mid vowels (46%) and approximately equal productions of high and low vowels (26% and 27% respectively).

---

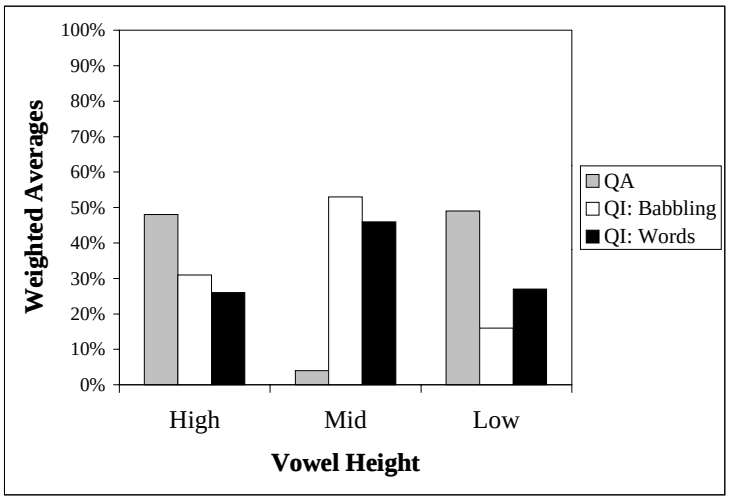
[1] QI Babbling: X^2 = 372.71, DF = 2, p = 0.0001
[2] QI Words: X^2 = 77.94, DF = 2, p = 0.0001

Vowel Height in Quichua Adults and Quichua Infants

Babbling

In babbling, a comparison of QI to QA for height found significant differences for the entire babbling period as well as by age group.[1] In QI, mid vowels were most frequent (53%), followed by high (31%) and low vowels (16%). In contrast, in QA low (49%) and high vowels (48%) were most frequent and mid vowels were least frequent (4%). These results are shown in Figure 4-14.

Figure 4-14. Vowel Height in Quichua Adults & Infants



[1] QI Babbling to QA: High: t = 7.515, DF = 12, p < 0.001; Mid: t = 15.422, DF = 12, p < 0.001; Low: t = 17.436, DF = 12, p < 0.001; QI 9-13 Months to QA: High: t = 7.131, DF = 8, p < 0.001; Mid: t = 9.305, DF = 8, p < 0.001; Low: t = 14.320, DF = 8, p < 0.001; QI 13-17 Months to QA: High: t = 3.691, DF = 11, p = 0.004; Mid: t = 9.604, DF = 11, p < 0.001; Low: t = 7.070, DF = 11, p < 0.001; QI 17-22 Months to QA: High: t = 6.898, DF = 10, p < 0.001; Mid: t = 30.556, DF = 10, p < 0.001; Low: t = 23.890, DF = 10, p < 0.001

Words

In words, QI produced an almost equal proportion of high (38%) and mid (37%), and slightly fewer low vowels (25%). QA, in contrast, produced more high (48%) and low (49%) vowels, and very few mid vowels (4%). These height differences between QA and QI words were significant.[1] Both QI and QA produced many high vowels, but QI produced more mid and fewer low vowels. Results are shown in Figure 4-14.

Vowel Height in Quichua and English-Learning Infants

Babbling

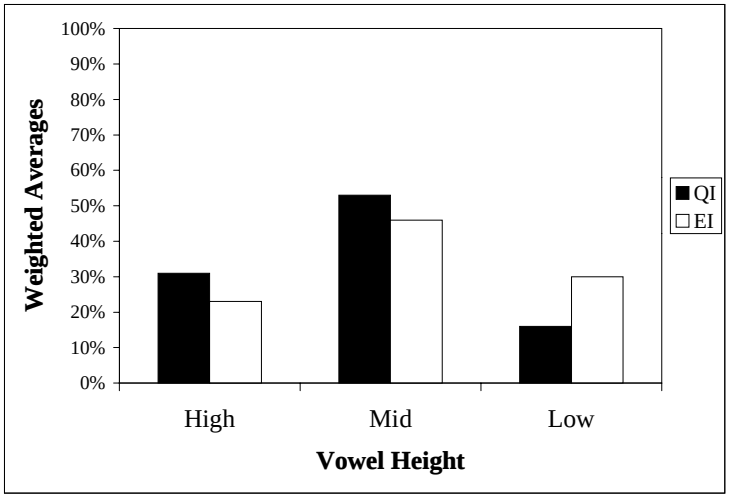
When comparing height for the entire babbling period for QI versus EI, significant differences were found in the frequency of mid vowels.[2] QI produced more mid vowels than EI (53% vs. 46%). QI also tended to produce fewer low vowels than EI (16% vs. 30%) and more high vowels (31% vs. 23%), although individual preferences varied and differences were not significant. These findings are shown in Figure 4-15.

---

[1] QA to QI Words: High: $t = 2.359$, DF = 11, $p < 0.038$; Mid: $t = 7.967$, DF = 11, $p < 0.001$; Low: $t = 7.451$, DF = 11, $p < 0.001$

[2] QI to EI Babbling: High: $t = 2.160$, DF = 11, $p = 0.053$; Mid: $t = 2.542$, DF = 11, $p = 0.028$; Low: $t = 4.936$, DF = 11, $p < 0.001$

Figure 4-15. Vowel Height in Quichua & English-Learning Infants' Babbling



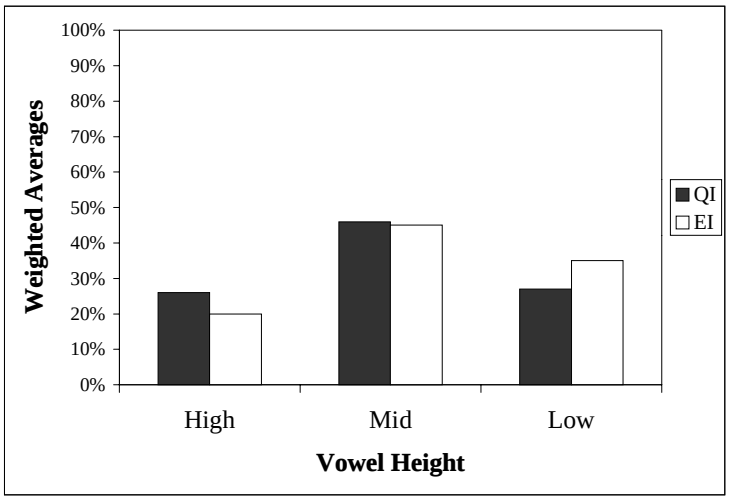
In babbling, age group differences were found for height.[1] From 9 to 13 months of age, QI and EI differed significantly in the frequency of mid vowels, with QI producing more mid vowels than EI (64% vs. 45%). There were no significant differences in height in the 13 to 17 month old QI and EI. And from 17 to 22 months of age, QI and EI differed in the frequency of both high and low vowels, but not in the frequency of mid vowels. While both QI and EI produced mid vowels most frequently (52% vs. 46%), high vowels were second in frequency for QI but third in frequency for EI (34% vs. 21%). Low vowels were least frequent in 17 to 22 month old QI but second in frequency in EI (15% vs. 33%).

[1] QI to EI 9-13 Months: High: $t = 0.575$, DF = 7, $p = 0.583$; Mid: $t = 3.048$, DF = 7, $p = 0.020$; Low: $t = 1.398$, DF = 7, $p = 0.205$; QI to EI 13-17 Months: High: $t = 1.567$, DF = 10, $p = 0.148$; Mid: $t = 0.196$, DF = 10, $p = 0.849$; Low: $t = 1.578$, DF = 10, $p = 0.145$; QI to EI 17-22 Months: High: $t = 3.578$, DF = 7, $p = 0.011$; Mid: $t = 1.442$, DF = 7, $p = 0.192$; Low: $t = 6.146$, DF = 7, $p < 0.001$

Words

For QI and EI words, height comparisons are shown in Figure 4-16. No significant differences in height were found in QI and EI.[1] In QI, mid vowels were most frequent (46%), low and high vowels were approximately equal in frequency (27% and 26% respectively). In EI, mid vowels were most frequent (45%), followed by low (35%) and high (20%). The lack of significance is likely due to individual variation in QI. Four infants produced mid vowels, one infant produced low vowels, and one produced high vowels most frequently.

Figure 4-16. Vowel Height in Quichua and English-Learning Infants' Words



[1] QI to EI Words: High: t = 1.014, DF = 10, p = 0.335, Mid: t = 0.330, DF = 10, p = 0.748; Low: t = 1.149, DF = 10, p = 0.278

Vowel Height Summary

Significant differences in QA and EA were found for height. In QA, almost all vowels were high and low vowels, with an infrequent occurrence of mid vowels. In contrast, in EA mid vowels occurred most frequently.

QI group patterns were significant for babbling and words. In babbling and in words, mid vowels were most frequent, followed by high and low vowels.

In both babbling and words, QI produced significantly more mid vowels and significantly fewer high and low vowels than QA.

In babbling, QI varied slightly from EI in height patterns. QI produced significantly more mid vowels from 9 to 13 months of age. QI and EI did not significantly differ in height patterns from 13 to 17 months of age. From 17 to 22 months of age, QI produced significantly more high vowels and significantly fewer low vowels.

In words, height did not vary significantly between QI and EI. Mid vowels were produced most frequently by both groups.

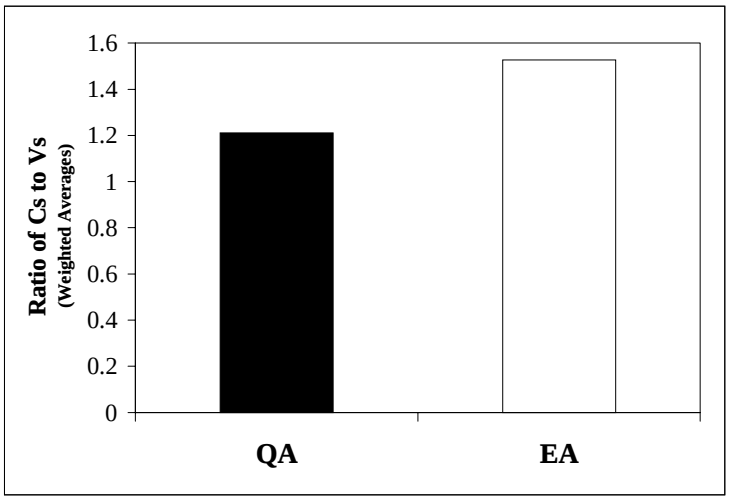
Consonant-Vowel (CV) Ratio

CV Ratio in Quichua and English

As shown in Figure 4-17, the ratio of consonants to vowels was greater in EA than in QA. EA produced 1.5 consonants for every vowel, and QA produced 1.2 consonants for every vowel. These findings suggest more complex syllable

shapes in English. The difference in consonant-to-vowel ratios in QA and EA was significant.[1]

Figure 4-17. CV Ratios in Quichua & English



CV Ratios in Quichua Infant Babbling and Words

In babbling[2] and in words,[3] no significant differences between individual infants in either babbling or words in CV ratios was found. Both groups produced a one-to-one ratio of consonants to vowels.

CV Ratios in Quichua Adults and Infants

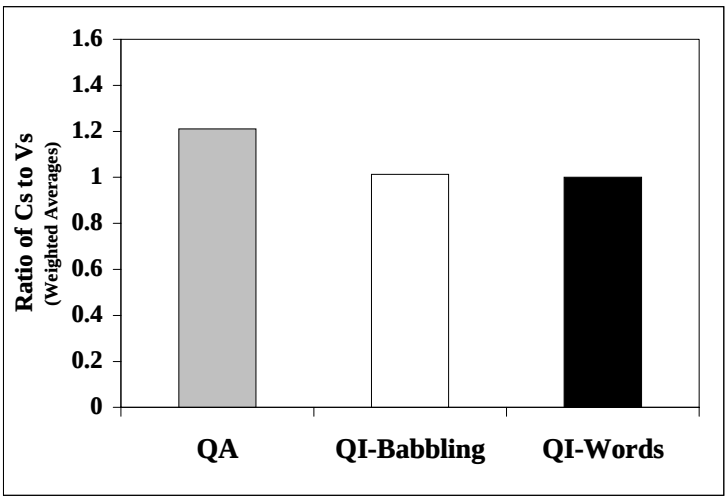
For babbling[1] and words[2], QA and QI were significantly different in the ratio of consonants and vowels. These findings are shown in Figure 4-18. In

---

[1] QA to EA: $t = 12.958$, DF = 12, $p < 0.001$
[2] QI Babbling: $X^2 = 0.19$, DF = 1, $p = .6610$
[3] QI Words: $X^2 = 0.55$, DF = 1, $p = .4579$

babbling, QI produced a 1 to1 ratio of consonants and vowels, and QA produced 1.2 consonants for every vowel. This significant difference between QI and QA existed for all age groups.[3] QI words contained a 1 to 1 ratio of consonants and vowels, proportionately fewer consonants than in QA.

Figure 4-18. CV Ratios in Quichua Adults & Infants



CV Ratios in Quichua and English-Learning Infants

Babbling:

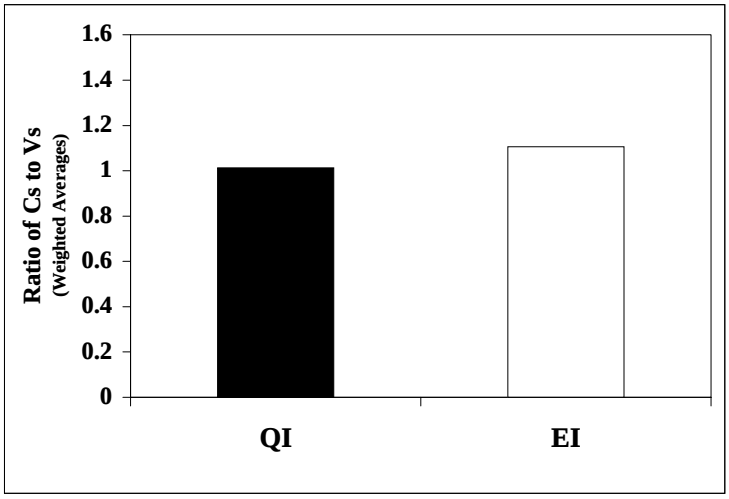
Consonants and vowels were approximately equal for QI and EI. As shown in Figure 4-19, QI averaged a ratio of one-to-one production of consonants and vowels, and EI averaged 1.1 consonants for every one vowel. These

---

[1] QI Babbling to QA: $t = 5.930$, DF = 12, $p < 0.001$
[2] QI Words to QA: $t = 3.155$, DF = 11, $p = 0.010$
[3] QI 9-13 Months to QA: $t = 8.112$, DF = 8, $p < 0.001$; QI 13-17 Months to QA: $t = 7.541$, DF = 11, $p < 0.001$; QI 17-22 Months to QA: $t = 5.397$, DF = 10, $p < 0.001$

differences in CV ratios were not significant.[1] Nor were there significant differences between QI and EI babbling by age group.[2]

Figure 4-19. CV Ratios in Quichua & English-Learning Infants' Babbling



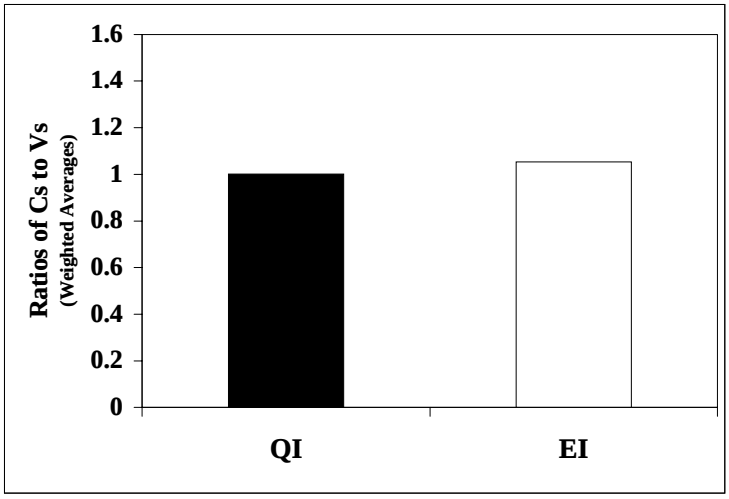
Words:

QI produced a 1:1 ratio of consonants to vowels, and EI produced a 1:1.05 ratio of consonants to vowels. The variation in CV ratio was greater between individuals than across languages and no significant differences were found.[3] CV ratios in QI and EI words are compared in Figure 4-20.

---

[1] QI to EI Babbling: t = 1.696, DF = 11, p = 0.117
[2] QI to EI 9-13 Months: t = 1.493, DF = 7, p = 0.179; QI to EI 13-17 Months: t = 0.928, DF = 10, p = 0.376; QI to EI 17-22 Months: t = 0.386, DF = 7, p = 0.711
[3] QI to EI Words: t = 1.584, DF = 10, p = 0.144

Figure 4-20. CV Ratios in Quichua and English-Learning Infants' Words



CV Ratios Summary

EA produced a significantly greater ratio of consonants to vowels than QA. In QI babbling and words, infants produced a 1:1 ratio of consonants to vowels. When compared to QI babbling and words, QA produced a significantly greater frequency of consonants to vowels. QI and EI did not produce significant differences in the ratio of consonants to vowels in babbling or words.

Word Length Patterns

Total number of syllables analyzed for each group was as follows: QA–4,794, EA–8,195, QI: Babbling–9,885, QI: Words–208, EI: Babbling–13,053, EI: Words–3786.

Word Length Patterns

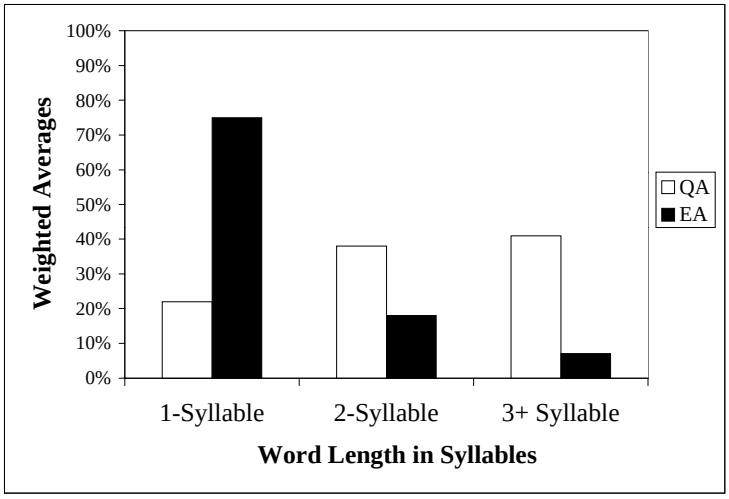
Total number of syllables analyzed for each group was as follows: QA–4,794, EA–8,195, QI: Babbling–9,885, QI: Words–208, EI: Babbling–13,053, EI: Words–3786.

Word Length Patterns in Quichua and English

In QA, 22% of the words were one-syllable, 38% were two, and 40% of words had three or more syllables. In EA, the majority of words were one-syllable (75%), followed by two syllables (18%). Very few were three or more syllables long (7%). These differences in word length were significant.[1] Figure 4-21 shows these results.

[1] QA to EA: 1-Syllable: $t = 22.055$, DF = 12, $p < 0.001$; 2-Syllable: $t = 16.599$, DF = 12, $p < 0.001$; 3+-Syllable: $t = 14.284$, DF = 12, $p < 0.001$

Figure 4-21. Word Length Patterns in Quichua & English



Word Length Patterns in Quichua Infant Babbling and Words

Babbling

In babbling, QI primarily produced one-syllable utterances (59%), followed by two-syllable (30%). Three-or-more syllable words occurred only 11% of the time. These utterance length patterns were significant.[1]

Words

In QI words, the group averaged most frequent production of two-syllable words (52%), followed by one-syllable words (38%). However, two infants produced more one-syllable than two syllable words (40% versus 35% and 80%

[1] QI Babbling: X^2 = 210.95, DF = 2, p = 0.0001

versus 20%, respectively). No significant patterns for word length in QI words were found.[1]

Word Length Patterns in Quichua Adults and Quichua Infants

Babbling

In babbling, QI produced more one-syllable utterances (59%) than QA (22%), with three-or-more syllables most frequent in QA (41%), but infrequent in QI (11%). These utterance length differences were significant[2] and are shown in Figure 4-22. In QI babbling by age was compared to QA, all utterance length differences were significant as they had been for the entire babbling period, except that QI 17 to 22 months of age did not differ significantly from QA in the frequency of two-syllable utterances (QI: 33%, QA: 38%).[3]

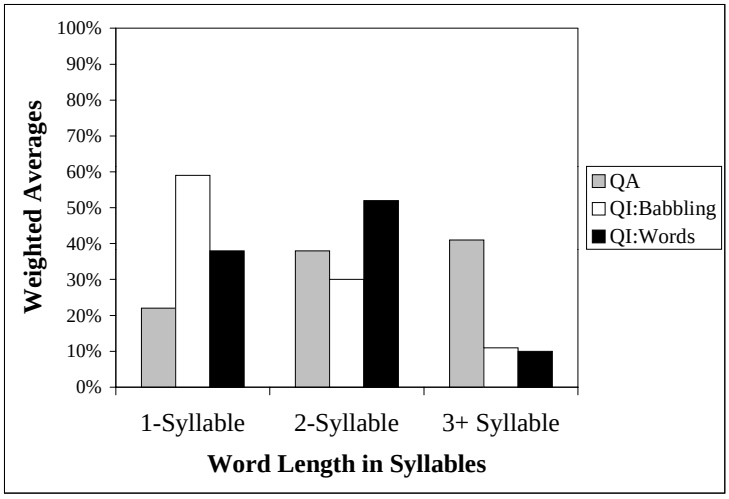
---

[1] QI Words: $X^2 = 1.30$, DF = 2, $p = 0.5228$

[2] QI Babbling to QA: 1-Syllable: $t = 11.776$, DF = 12, $p < 0.001$; 2-Syllable: $t = 3.262$, DF = 12, $p = 0.007$; 3+-Syllable: $t = 12.315$, DF = 12, $p < 0.001$

[3] QI 9-13 Months to QA: 1-Syllable: $t = 9.397$, DF = 8, $p < 0.001$; 2-Syllable: $t = 5.601$, DF = 8, $p < 0.001$; 3+-Syllable: $t = 8.219$, DF = 8, $p < 0.001$; QI 13-17 to QA: 1-Syllable: $t = 9.977$, DF = 11, $p < 0.001$; 2-Syllable: $t = 5.320$, DF = 11, $p < 0.001$; 3+-Syllable: $t = 8.837$, DF = 11, $p < 0.001$; QI 17-22 to QA: 1-Syllable: $t = 9.502$, DF = 10, $p < 0.001$; 2-Syllable: $t = 1.704$, DF = 10, $p < 0.119$; 3+-Syllable: $t = 11.129$, DF = 10, $p < 0.001$

Figure 4-22. Word Length Patterns in Quichua Adults & Infants



Words

QI produced two-syllable words most frequently, followed by one-syllable and few three-or-more syllable words. QI produced significantly more one-syllable words (QI: 22%, QA: 38%) and significantly fewer three-or-more syllable words (QI: 10%, QA: 41%) than QA.[1]

Word Length Patterns in Quichua and English-Learning Infants

Babbling

For babbling, utterance length patterns differed significantly between QI and EI for one-syllable and three-or-more syllable utterances.[2] These differences

[1] QI Words to QA: 1-Syllable: $t = 2.619$, DF = 11, $p = 0.024$; 2-Syllable: $t = 2.019$, DF = 11, $p = 0.068$; 3+-Syllable: $t = 4.273$, DF = 11, $p = 0.001$

[2] QI to EI Babbling: 1-Syllable: $t = 3.892$, DF = 11, $p = 0.003$; 2-Syllable: $t = 1.300$, DF = 11, $p = 0.220$; 3+-Syllable: $t = 3.972$, DF = 11, $p = 0.002$

are shown in Figure 4-23. Although the order of syllable length preference was the same, the preference for one-syllable utterances was greater in QI (59%) than in EI (43%). In addition, QI produced three-or-more syllable utterances significantly less frequently than EI (QI: 11%, EI: 24%).

Utterance length in syllables differed in infants by age. 9 to 13 month old QI produced one-syllable utterances most often, followed by two-syllable and three-syllable utterances. In contrast, 9 to 13 month old EI produced one- and two-syllable utterances with near equal frequency, followed by three-or-more syllable utterances. The greater frequency of one-syllable utterances and lower frequency of three-or-more syllable utterances in 9 to 13 month old QI when compared to EI were significant.[1]

From 13 to 17 months of age, both QI and EI produced one-syllable utterances most frequently, followed by two-syllable and three-or-more syllable utterances. However, there were significant differences in the frequency of these categories. QI produced significantly more one-syllable (QI: 64%, EI: 45%) and significantly fewer three-or-more syllable (QI: 11%, EI: 23%) babbling utterances than EI.[2]

From 17 to 22 months of age, QI and EI did not differ in babbling utterance length.[3] Both QI and EI produced one-syllable utterances most

---

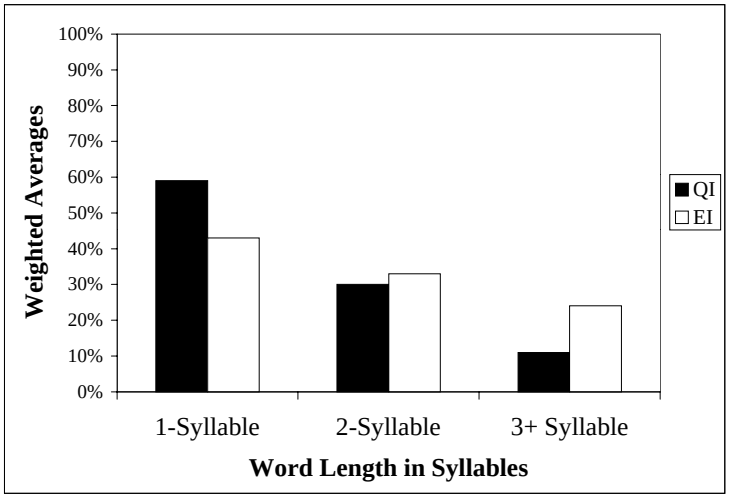
[1] QI to EI 9 to 13 Months: 1-Syllable: $t = 3.392$, DF = 7, $p = 0.013$; 2-Syllable: $t = 4.013$, DF = 7, $p = 0.006$; 3+-Syllable: $t = 2.793$, DF = 7, $p = 0.027$

[2] QI to EI 13 to 17 Months: 1-Syllable: $t = 3.021$, DF = 10, $p = 0.014$; 2-Syllable: $t = 2.161$, DF = 10, $p = 0.056$; 3+-Syllable: $t = 3.251$, DF = 10, $p = 0.009$

[3] QI to EI 17 to 22: 1-Syllable: $t = 1.292$, DF = 7, $p = 0.238$; 2-Syllable: $t = 0.499$, DF = 7, $p = 0.633$; 3+-Syllable: $t = 2.156$, DF = 7, $p = 0.067$

frequently (QI: 55%, EI: 48%), followed by two-syllable (QI: 33%, EI: 31%), and three-or-more-syllable (QI: 12%, EI: 22%).

Figure 4-23. Utterance Length in Quichua & English-Learning Infants' Babbling



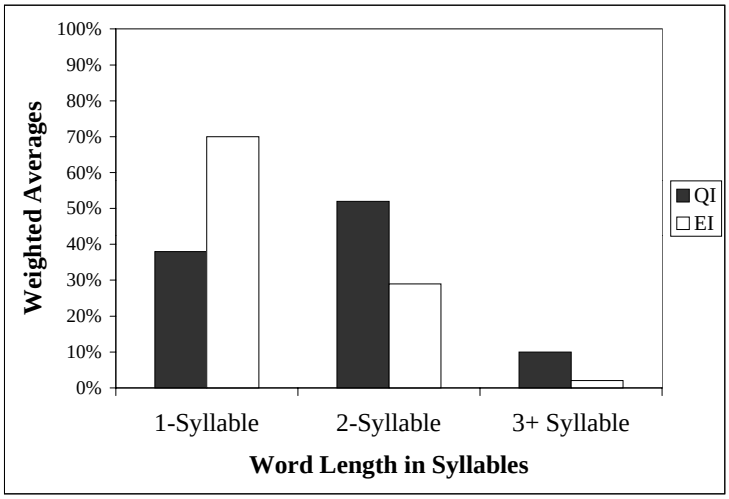
Words

For words, QI produced two-syllable utterances more frequently than EI (QI: 52%, EI: 29%). These differences were significant.[1] While QI tended to produce fewer one-syllable words (QI: 38%, EI: 70%) and more three-or-more syllable words (QI: 10%, EI: 1%), infants varied widely within language groups and these two types did not differ significantly. Nevertheless, four of the six QI produced two-syllable words most frequently whereas all EI produced one-

[1] QI to EI Words: 1-Syllable: t = 3.284, DF = 10, p = 0.009; 2-Syllable: t = 2.220, DF = 10, p = 0.050; 3+-Syllable: t = 1.975, DF = 10, p = 0.076

syllable words with the most frequency. Results for QI and EI words are shown in Figure 4-24.

Figure 4-24. Word Length Patterns in Quichua & English-Learning Infants' Words



Word Length Patterns Summary

QA and EA differ significantly in number of syllables in words, with three-or-more syllables most frequent in QA and one-syllable most frequent in EA.

In babbling, QI produced one-syllable utterances, followed by two-syllables and three-or-more syllables. In words, no significant group pattern was found, with two-syllable words most frequent in four infants and one-syllable words most frequent in two.

In babbling, QI produced significantly more one-syllable, fewer two-syllable, and fewer three-or-more-syllable utterances than QA. However, by 17 to 22 months of age, QI did not differ significantly from QA in the frequency of two-syllable utterances.

QI words did not significantly differ from QA in the frequency of two-syllable words; however, QI words were significantly more often one-syllable in length and significantly less often three-or-more syllable in length.

Between 9 and 17 months, QI produced significantly more one-syllable babbling utterances and significantly fewer three-or-more syllable utterances than EI. The 17 to 22 month old groups did not significantly differ in syllable length of utterances. Both groups favored one-syllable utterances, with three-or-more syllable utterances produced least often.

In words QI showed a significantly greater frequency of two-syllable words than EI. QI tended to produce fewer one-syllable words and more three-or-more syllable words than EI, although the differences were not significant.

INTRASYLLABIC INFORMATION

Consonant-Vowel (CV) Co-occurrence

Total consonant-vowel pairs analyzed for each group were as follows: QA–14,653, EA–7,821, QI: Babbling–9,594, QI: Words–289, EI: Babbling–26,174, EI: Words–3,633.

CV co-occurrence results are shown in the form of CV co-occurrences observed, divided by CV co-occurrences expected (based on frequency of occurrence of consonants and vowels in the data).

CV Co-occurrence Patterns in Quichua and English

QA and EA differed significantly in preferred CV co-occurrences.[1] As shown in Table 4-1, most consonant-vowel co-occurrences in EA were at rates equal to or less than that expected by chance. The only exception was the preference for dorsal-central vowel co-occurrences. On the other hand, QA showed many higher-than-expected consonant-vowel co-occurrences. These were labial-central, coronal-front, dorsal-central, and dorsal-back.

Table 4-1. Observed to Expected CV-Co-Occurrence in Quichua & English (Weighted Averages)

LANGUAGE		**CONSONANTS**		
	VOWELS	**Labial**	**Coronal**	**Dorsal**
Quichua	**Front**	0.86	**1.27**	0.47
	Central	**1.14**	0.88	**1.17**
	Back	0.88	0.81	**1.55**
English	**Front**	1.00	1.00	**1.01**
	Central	0.97	0.99	**1.16**
	Back	**1.01**	1.00	0.96

[1] QA to EA: $X^2 = 68.46$, DF = 4, $p = 0.0001$

CV Co-occurrence Patterns in Quichua Infant Babbling and Words

In babbling, significant group patterns for CV co-occurrence were found.[1] As shown in Table 4-2, higher-than-expected co-occurrences were labial-central, coronal-front, dorsal-back, and dorsal-central. In words, significant CV co-occurrence patterns were also found for labial-central, coronal-front, and dorsal-back co-occurrences.[2]

CV Co-occurrence Patterns in Quichua Adults and Quichua Infants

Babbling

Both QI babbling and QA showed higher-than-expected co-occurrences of coronal-front, labial-central, dorsal-back, and dorsal-central. These results are shown in Table 4-2. Significant differences between QI and QA were found.[3] There were higher higher-than expected ratios in QI babbling than in QA for labial-central, dorsal-back, and dorsal-central co-occurrences.

Words

Both QI words and QA showed higher-than-expected coronal-front, labial-central, and dorsal-back co-occurrences; QA also produced higher-than-expected dorsal-central co-occurrences. In addition, QI words had larger observed-to-

---

[1] QI Babbling: X^2 = 299.48, DF = 4, p = 0.0001
[2] QI Words: X^2 = 233.03, DF = 3, p = 0.0001
[3] QA to QI Babbling: X^2 = 30.5, DF = 4, p = 0.0001

expected ratios of these consonant-vowel co-occurrences than were present in QA. The difference between the two groups was significant.[1]

Table 4-2. Observed to Expected CV Co-occurrence in Quichua Adults & Infants (Weighted Averages)

UTTERANCE TYPE		**CONSONANTS**		
	VOWELS	**Labial**	**Coronal**	**Dorsal**
Adults	**Front**	0.86	**1.27**	0.47
	Central	**1.14**	0.88	**1.17**
	Back	0.88	0.81	**1.55**
Babbling	**Front**	0.76	**1.21**	0.36
	Central	**1.36**	0.81	**1.34**
	Back	0.64	0.73	**2.82**
Words	**Front**	0.41	**2.61**	0.00
	Central	**1.62**	0.76	0.75
	Back	0.38	0.24	**2.13**

CV Co-Occurrence Patterns in Quichua and English-Learning Infants

Babbling

In babbling, CV co-occurrence patterns differed significantly between QI and EI.[2] As noted previously, QI produced higher-than-expected labial-central, coronal-front, and dorsal-back co-occurrences. These three also occurred at higher-than-expected rates in the EI, although dorsal-back co-occurrences were even more likely in QI babbling. Differences were found in the EI higher-than-

[1] QI Words to QA: X^2 = 118.54, DF = 3, p = 0.0001
[2] QI to EI Babbling: X^2 = 31.34, DF = 4, p = 0.0001

expected labial-back co-occurrences and in the QI higher-than-expected dorsal-central co-occurrences. A comparison of these QI and EI CV co-occurrence patterns is shown in Table 4-3.

Table 4-3. Observed to Expected CV Co-Occurrence in Quichua & English-Learning Infants' Babbling (Weighted Averages)

LANGUAGE		**CONSONANTS**		
Quichua	**VOWELS**	**Labial**	**Coronal**	**Dorsal**
	Front	0.76	**1.21**	0.36
	Central	**1.36**	0.81	**1.34**
	Back	0.64	0.73	**2.82**
English	**Front**	0.68	**1.27**	0.91
	Central	**1.28**	0.80	0.91
	Back	**1.11**	0.79	**1.54**

Words

In words, CV co-occurrence patterns differed significantly between QI and EI.[1] The results are shown in Table 4-4. Preferred consonant-vowel co-occurrences of coronal-front, labial-central, and dorsal-back existed in both groups, although the proportion of expected to occurred was much greater in QI than EI. In addition, EI produced higher-than-expected dorsal-front and coronal-back co-occurrences.

[1] QI to EI Words: $X^2 = 26.96$, DF = 3, $p = 0.0001$

Table 4-4. Observed to Expected CV Co-Occurrence in Quichua & English-Learning Infants' Words (Weighted Averages)

LANGUAGE		**CONSONANTS**		
Quichua	**VOWELS**	**Labial**	**Coronal**	**Dorsal**
	Front	0.41	**2.61**	0.00
	Central	**1.62**	0.76	0.75
	Back	0.38	0.24	**2.13**
English	**Front**	0.92	**1.06**	**1.27**
	Central	**1.14**	0.84	0.71
	Back	0.84	**1.24**	**1.14**

CV Co-Occurrence Summary

QA differed significantly from EA in higher-than expected labial-central, coronal-front, and dorsal-back co-occurrences. Both QA and EA produced higher-than-expected dorsal-central co-occurrences.

In both QI babbling and words, preferred group CV co-occurrence patterns were labial-central, coronal-front, and dorsal-back co-occurrences. In addition, QI babbling included higher-than-expected dorsal-central co-occurrences.

Both QI babbling and words differed significantly from QA in preferred consonant-vowel co-occurrences. The same co-occurrences of higher-than-expected labial-central, coronal-front, and dorsal-back occurred in all three groups; however, they occurred at much higher rates in QI babbling and words than in QA.

In both babbling and words, QI and EI produced higher-than-expected co-occurrences of coronal-front, dorsal-back, and labial-central. The co-occurrences

were significantly more frequent in QI than EI utterances. In babbling, both groups also produced higher-than-expected dorsal-central co-occurrences. In addition, EI showed labial-back preferences in babbling and dorsal-front and coronal-back preferences in words.

Intersyllabic Information

Consonant Reduplication and Variegation

Analyses of consonant variegation versus reduplication and place versus manner variegation patterns involved syllable-initial consonants in all CVCV shapes. This included CVCV words as well as CVCV bisyllabic occurrences within longer utterances.

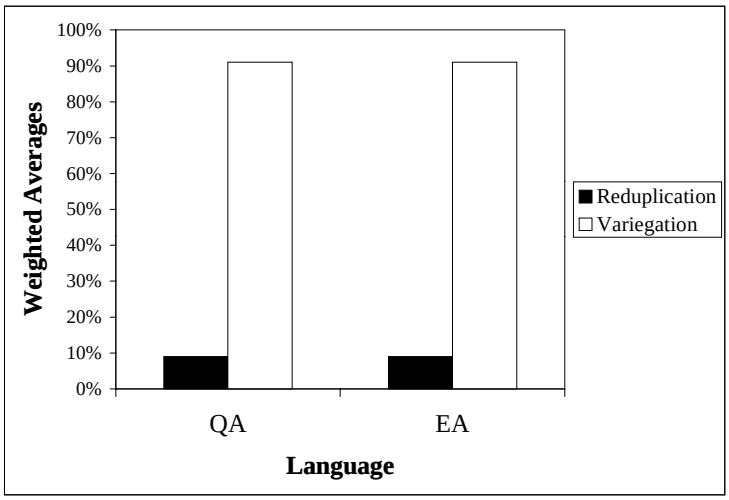
Total consonant-consonant pairs analyzed for each group were as follows: QA–4,837, EA–1,383, QI: Babbling–2,730, QI: Words–100, EI: Babbling–8,819, EI: Words–1,024.

Consonant Reduplication vs. Variegation and Types of Variegation in Quichua and English

In both QA and EA, the majority of consonant pairs were variegated (91% for each), with only 9% of consonant pairs reduplicated in both language environments. Language differences in reduplication versus variegation patterns

were not significant.[1] A comparison of reduplication versus variegation for QA and EA is shown in Figure 4-25.

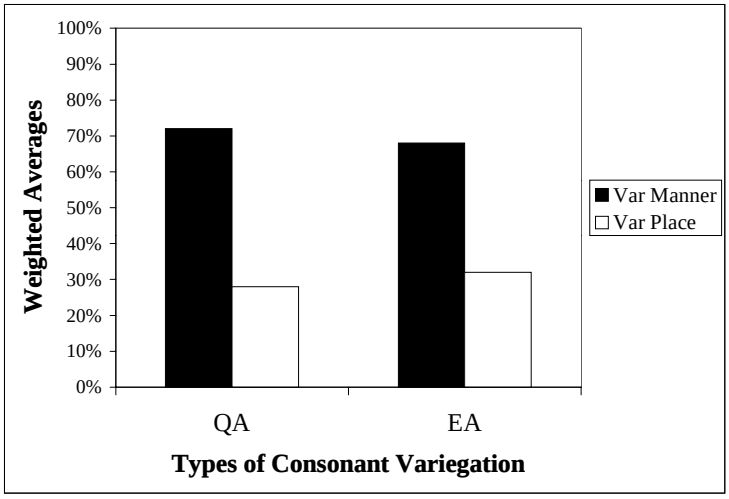
Figure 4-25. Consonant Reduplication and Variegation in Quichua & English



QA and EA CVCV types of variegation patterns did not differ significantly.[2] Both QA and EA preferred manner variegation (QA: 72%, EA: 68%) to place variegation. Figure 4-26 compares these patterns.

[1] Reduplication vs. Variegation: QA to EA: t = 0.081, DF = 12, p = 0.937
[2] Variegated Manner vs. Variegated Place: QA to EA: t = 1.036, DF = 12, p = 0.321

Figure 4-26. Consonant Variegation Patterns in Quichua & English



Consonant Reduplication vs. Variegation and Types of Variegation in Quichua Infant Babbling and Words

Babbling

No significant reduplication and variegation patterns were found for the QI group for the entire babbling period.[1] As a group, QI produced variegated consonant pairs more frequently (54% of the time); however, infants ranged from 40% to 70% variegation. 9 to 13 and 17 to 22 month olds showed significant group patterns, preferring variegation to reduplication. Thirteen to 17 month olds tended towards a preference for reduplication, but varied widely by individual child and group patterns were not significant.[2]

---

[1] Reduplication vs. Variegation: QI Babbling: $X^2 = 2.39$, DF = 1, $p = 0.1220$

[2] Reduplication vs. Variegation: QI 9-13 Months: $X^2 = 122.06$, DF = 1, $p < 0.0001$; QI 13-17 Months: $X^2 = 1.38$, DF = 1, $p = 0.2394$; QI 17-22 Months: $X^2 = 11.48$, DF = 1, $p = 0.0007$

Types of variegation patterns in QI babbling were compared to determine whether group preferences for manner or place variegation were consistent across individuals. A significant preference for manner variegation was found for the entire babbling period as well as QI by age group.[1]

Words

In words, no significant preference for variegation or reduplication was found.[2] QI tended to prefer reduplication in words, but individual frequencies of reduplication varied from 50% to 100%.

Statistical comparison of variegation patterns in QI words could not be conducted due to the infrequency of manner and place reduplication patterns. There were only 9 consonant changes in QI words reflecting consonant variegation changes: of these, eight were manner variegation changes and one was a place variegation change.

Consonant Reduplication vs. Variegation and Types of Variegation in Quichua Adults and Quichua Infants

Babbling

Comparisons of QI babbling to QA for reduplication and variegation patterns showed significant differences for the entire babbling period and by age

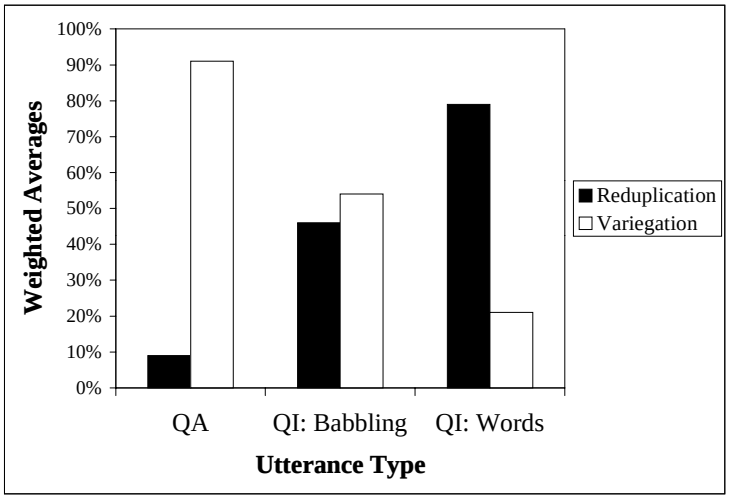
---

[1] Variegated Manner vs. Variegated Place: QI Babbling: $X^2 = 106.2$, DF = 1, $p < 0.0001$; QI 9-13 Months: $X^2 = 451847$, DF = 1, $p < 0.0001$; QI 13-17 Months: $X^2 = 85.11$, DF = 1, $p < 0.0001$; QI 17-22 Months: $X^2 = 58.56$, DF = 1, $p < 0.0001$

[2] Reduplication vs. Variegation: QI Words: $X^2 = 3.16$, DF = 1, $p = 0.0756$

group.[1] Results are shown in Figure 4-27. Variegated forms were more frequent than reduplicated forms in both QI babbling and QA, although significantly less so in QI (QI: 54%, QA: 91%).

Figure 4-27. Consonant Reduplication and Variegation in Quichua Adults & Infants



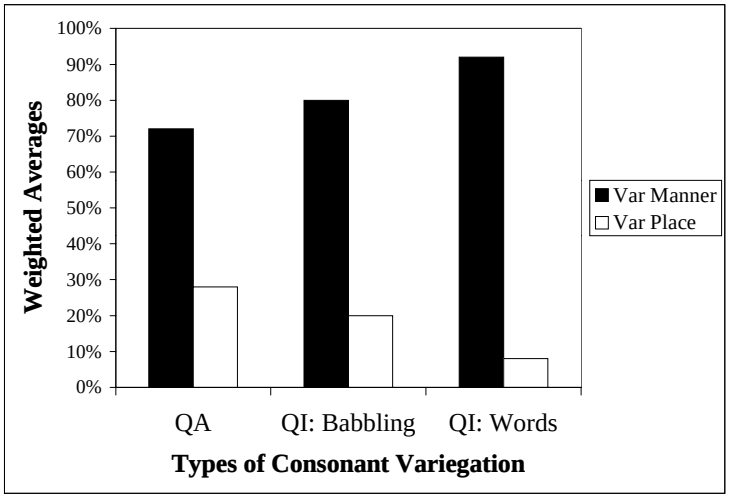
A comparison of QA and QI babbling manner and place variegation patterns did not differ significantly for the entire babbling period.[2] Both QA and QI preferred manner to place variegation in CVCVs (QI: 80%, QA: 72%). These patterns are shown in Figure 4-28.Age-specific comparisons of QI to QA for variegation patterns showed significant differences from 9 to 17 months of age,

[1] Reduplication vs. Variegation: QI Babbling to QA: $t = 12.236$, DF = 12, $p < 0.001$; QI 9-13Months to QA: $t = 11.827$, DF = 7, $p < 0.001$; QI 13-17 Months to QA: $t = 9.401$, DF = 11, $p < 0.001$; QI 17-22 Months to QA: $t = 9.650$, DF = 10, $p < 0.001$

[2] Variegated Manner vs. Variegated Place: QI Babbling to QA: $t = 1.916$, DF = 12, $p = 0.079$

but no significant difference from 17 to 22 months of age.[1] The 9 to 13 and 13 to 17 month olds preferred manner variegation significantly more than QA (QI 9-13 months: 87%, QI 13-17 months: 85%, QA: 72%), whereas 17 to 22 month olds more closely reflected QA in their preference for manner variegation (QI 17-22 months: 75%, QA: 72%).

Figure 4-28. Consonant Variegation Patterns in Quichua Adults & Infants



Words

Reduplication and variegation patterns were compared in QI words and QA. QI preferred reduplication (79%), a significant difference from QA overwhelming preference for variegation (91%).[2] These differences are shown in

[1] Variegated Manner vs. Variegated Place: QI 9-13 Months to QA: t =2.628, DF = 7, p = 0.034; QI 13-17 Months to QA: t = 2.611, DF = 11, p = 0.025; QI 17-22 Months to QA: t = 0.558, DF = 10, p =0.589

[2] Reduplication vs. Variegation: QI Words to QA: t = 11.684, DF = 11, p < 0.001

Figure 4-28. Too few QI words were produced to statistically compare variegation patterns to QA utterances; however, both QI words and QA showed preferences for manner variegation (QI words: 92%, QA: 72%).

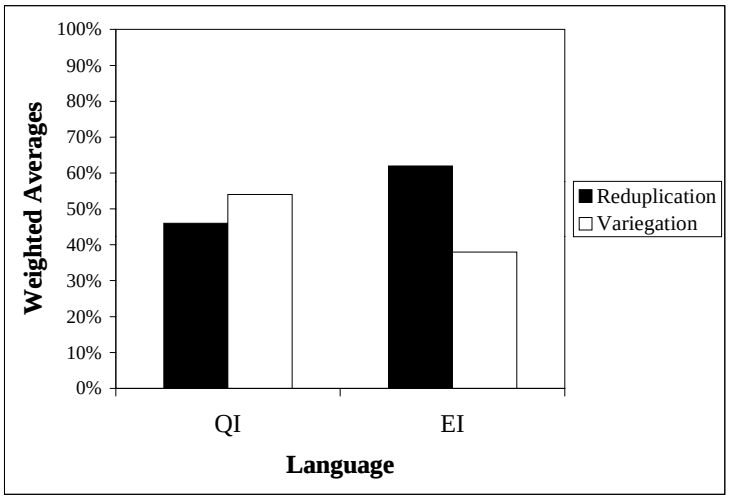
Consonant Reduplication vs. Variegation and Types of Variegation in Quichua and English-Learning Infants

Babbling

For the entire babbling period and by age group, QI and EI did not differ significantly in the frequency of reduplicated and variegated CVCV patterns.[1] In general, QI reduplicated consonants in CVCVs 46% of the time and EI reduplicated consonants 62% of the time; however, the large range in frequency of reduplicated consonants in the EI (30% to 81%) resulted in the lack of differences. These differences are shown in Figure 4-29.

[1] Reduplication vs. Variegation: QI to EI Babbling: $t = 2.024$, DF = 11, $p = 0.068$; QI to EI 9-13Months: $t = 0.615$, DF = 6, $p = 0.561$; QI to EI 13-17 Months: $t = 0.551$, DF = 10, $p = 0.594$; QI to EI 17-22 Months: $t = 1.480$, DF = 7, $p = 0.182$

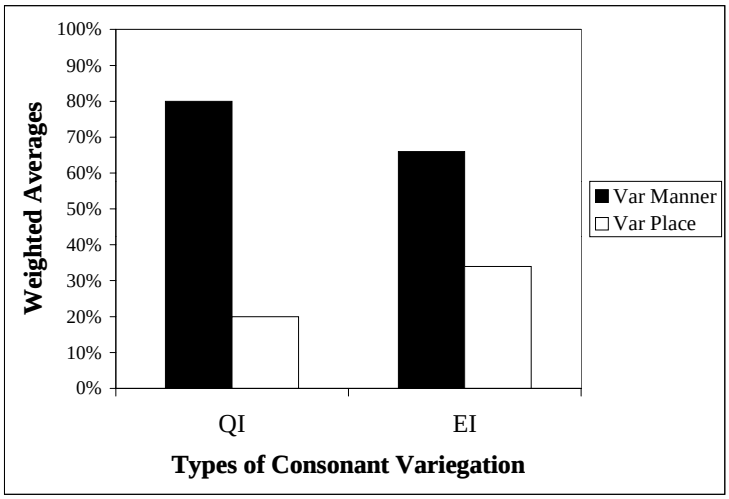
Figure 4-29. Consonant Reduplication and Variegation in Quichua & English-Learning Infants' Babbling



Manner and place variegation patterns were compared in QI and EI babbling. QI and EI differed significantly in variegation patterns for the entire babbling period. During babbling, CVCV utterances demonstrating manner variegation were produced 80% by QI and 66% by EI. From 9 to 13 months of age, both QI and EI preferred manner variegation (QI: 87%, EI: 73%). This preference for manner variegation was also present in the older infants; however, QI significantly preferred manner variegation to EI (13-17 Months QI: 85%, EI: 64%; 13-17: 64%; 17-22 Months QI: 76%, EI: 55%).[1] The group results are shown in Figure 4-30.

[1] Variegated Manner versus Variegated Place: QI to EI Babbling: $t = 2.248$, DF = 1, $p = 0.046$; QI to EI 9-13 Months: $t = 0.774$, DF = 6, $p = 0.468$; QI to EI 13-17 Months: $t = 2.855$, DF = 10, $p = 0.018$; QI to EI 17-22 Months: $t = 2.778$, DF = 7, $p = 0.028$

Figure 4-30. Consonant Variegation Patterns in Quichua & English-Learning Infants' Babbling

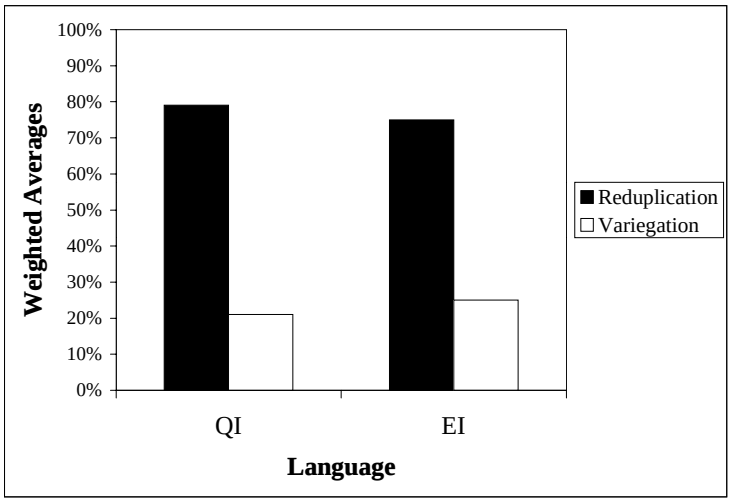


Words

In words, QI and EI did not differ significantly in reduplication and variegation patterns.[1] For both QI and EI words, consonants were most frequently reduplicated (QI: 79%, EI: 75%). A comparison of consonant reduplication and variegation in QI and EI words is shown in Figure 4-31.

[1] Reduplication vs. Variegation: QI to EI Words: $t = 0.359$, DF = 10, $p = 0.727$

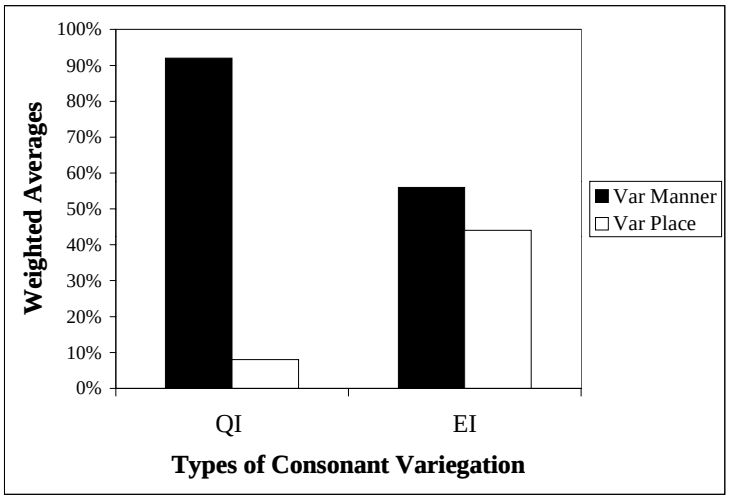
Figure 4-31. Consonant Reduplication and Variegation in Quichua & English-Learning Infants' Words



Variegation patterns in QI and EI words were not significantly different.[1] Both groups showed a preference for manner variegation (QI: 92%, EI: 56%) over place reduplication. Results are shown in Figure 4-32.

[1] Variegated Manner vs. Variegated Place: QI to EI Words: t = 2.183, DF = 5, p = 0.079

Figure 4-32. Consonant Variegation Patterns in Quichua & English-Learning Infants' Words



Consonant Reduplication vs. Variegation and Types of Variegation Summary

QA and EA produced CVCVs with consonant variegation much more frequently than reduplication. In addition, QA and EA demonstrated the same preference for manner over place variegation.

In QI babbling and words, no significant patterns were found for consonant reduplication and variegation. In QI babbling, consonant variegation was preferred over reduplication, while words showed a tendency toward reduplication.

QI babbling showed a significant preference for manner over place variegation in consonants. This same preference was seen in QI words, although the infrequency of CVCV words resulted in a nonsignificant pattern.

Both QI babbling and QA contained more variegated than reduplicated utterances, although QA produced significantly more variegation than QI. Manner variegation was preferred over place variegation in both QI babbling and QA. Nine to 17 month olds showed a significantly greater preference for manner over place variegation compared to QA. At 17 to 22 months, QI did not significantly differ in their preference for manner variegation from QA.

QI words differed from QA in the preference for reduplication compared with the QA preference for variegation. Variegation patterns in QI words could not be statistically compared to QA because of the low frequency of variegation changes in QI; however, both QI and QA showed a preference for manner variegation.

In QI and EI babbling, QI produced slightly more variegated consonant patterns in CVCVs while EI preferred reduplicated consonants; however, the differences were not significant. QI and EI babbling did not differ in variegation patterns from 9 to 13 months, with both groups showing an overwhelming preference for consonant manner variegation. From 13 to 22 months of age, QI and EI differed significantly, accounted for by the greater frequency of variegation in QI, although variegated manner was still preferred by both groups.

In words, both QI and EI used reduplication much more frequently than variegation. Variegation patterns could not be compared statistically because of the limited frequency of variegation in QI words; however, both QI and EI showed preferences for variegated manner.

Vowel Reduplication and Variegation

Vowel variegation and reduplication patterns and types of variegation patterns in all CVCV shapes were analyzed, including CVCV words as well as CVCV disyllabic occurrences within longer utterances.

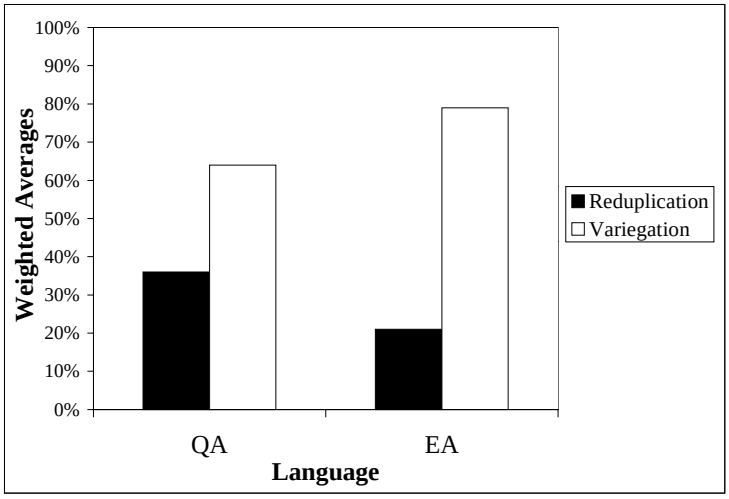
Total vowel-vowel pairs analyzed for each group were as follows: QA–4,846, EA–1,470, QI: Babbling–5,240, QI: Words–111, EI: Babbling–8,907, EI: Words–824.

Vowel Reduplication vs. Variegation and Types of Variegation in Quichua and English

In both QA and EA, the majority of intersyllabic vowel patterns demonstrated variegation (QA: 64%, EA: 79%). Language differences in the frequency of variegation and reduplication patterns were significant.[1] They are accounted for by the greater use of vowel variegation in CVCVs in EA. Reduplication and variegation patterns are compared for QA and EA in Figure 4-33.

[1] Reduplication vs. Variegation: QA to EA: $t = 9.349$, DF = 12, $p < 0.001$

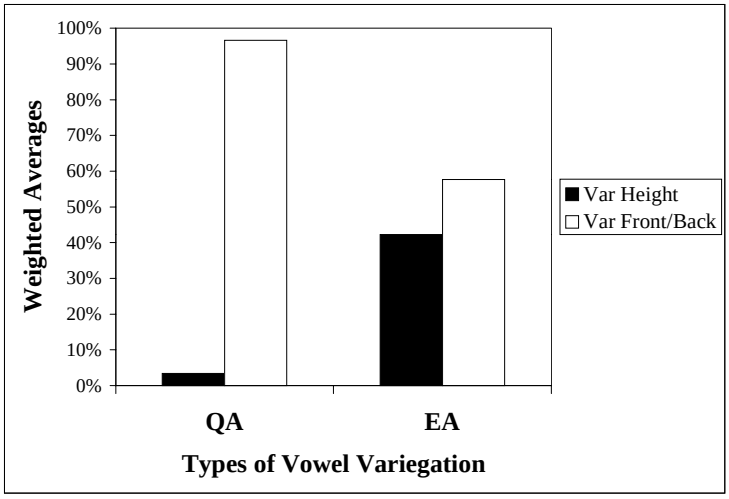
Figure 4-33. Vowel Reduplication and Variegation in Quichua & English



EA and QA were found to differ significantly in CVCV productions for vowel front/back variegation and vowel height variegation.[1] Both preferred vowel front/back variegation to height variegation. This preference was significantly greater in QA than EA (97% and 58% respectively). This finding is not surprising as the three phonemic vowels in Quichua – /i, a, u/ – vary in front/back placement (analysis didn't include covariation of both height and front/back variegation). Figure 4-34 compares types of variegation in QA and EA.

[1] Front/Back versus Height Variegation: QA to EA: $t = 10.127$, DF = 12, $p < 0.001$

Figure 4-34. Vowel Variegation Patterns in Quichua & English



Vowel Reduplication vs. Variegation and Types of Variegation in Quichua Infant Babbling and Words

Babbling

In QI, no significant pattern for intersyllabic vowel reduplication and variegation was found for the entire babbling period or for the 17 to 22 month olds. Significant patterns were found in the 9 to 13 and 13 to 17 month olds.[1] For the entire babbling period, vowel reduplication occurred 53%, although this varied from 43% to 62%. In the 9 to 13 and 13 to 17 month olds, all infants preferred reduplication, whereas in the 17 to 22 month olds, reduplication and variegation occurred at approximately the same rate.

[1] Reduplication vs. Variegation: QI Babbling: X^2 = 2.36, DF = 1, p = 0.1242; QI 9-13 Months: X^2 = 4.42, DF = 1, p = 0.0356; QI 13-17 Months: X^2 = 12.92, DF = 1, p = 0.0003; QI 17-22 Months: X^2 = 0.15, DF = 1, p = 0.7004

For the entire babbling period, QI preferred variegated height to variegated front/back (60% vs. 40%).[1] The same significant preference for variegated height was seen in the 9 to 13 month olds. No significant preference for variegation type was observed in the 13 to 22 month olds, although as a group, variegated height was preferred.[2]

Words

In QI, no significant preference for reduplication or variegation was found. Two infants produced CVCVs with more variegated vowels, two infants with more reduplicated vowels, and one infant produced an equal frequency of each.[3] The group trend was toward variegated vowels in CVCVs (61%). There was also no significant pattern for types of variegated vowels in CVCVs in QI words.[4] This is likely due to the limited number of CVCVs containing variegated vowels, as all infants preferred height reduplication to front/back reduplication in words.

---

[1] Variegated Height vs. Variegated Front/Back: QI Babbling: $X^2 = 5.36$, DF = 1, $p = 0.0207$

[2] Variegated Height vs. Variegated Front/Back: QI 9-13 Months: $X^2 = 2185.69$, DF = 1, $p < 0.0001$; QI 13-17 Months: $X^2 = 2.19$, DF = 1, $p = 0.1392$; QI 17-22 Months: $X^2 = 3.48$, DF = 1, $p = 0.0623$

[3] Reduplication vs. Variegation: QI Words: $X^2 = 1.15$, DF = 1, $p = 0.2839$

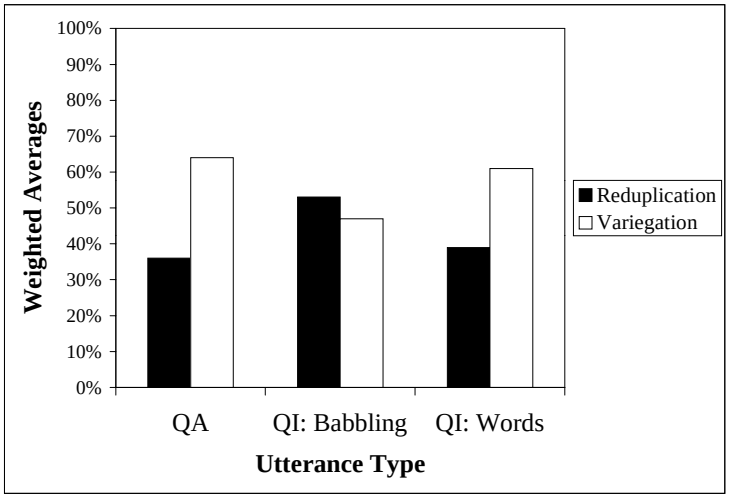
[4] Variegated Height vs.Variegated Front/Back: QI Words: $X^2 = 0.26$, DF = 1, $p = 0.6121$

Vowel Reduplication vs. Variegation and Types of Variegation in Quichua Adults and Quichua Infants

Babbling

QI babbling and QA differed in the frequency of vowel reduplication and variegation patterns for the entire babbling period and by age.[1] In QI babbling, vowel reduplication occurred 53% of the time in CVCVs. In contrast, vowel reduplication occurred 36% of the time in QA. Results are shown in Figure 4-35.

Figure 4-35. Vowel Reduplication and Variegation in Quichua Adults & Infants



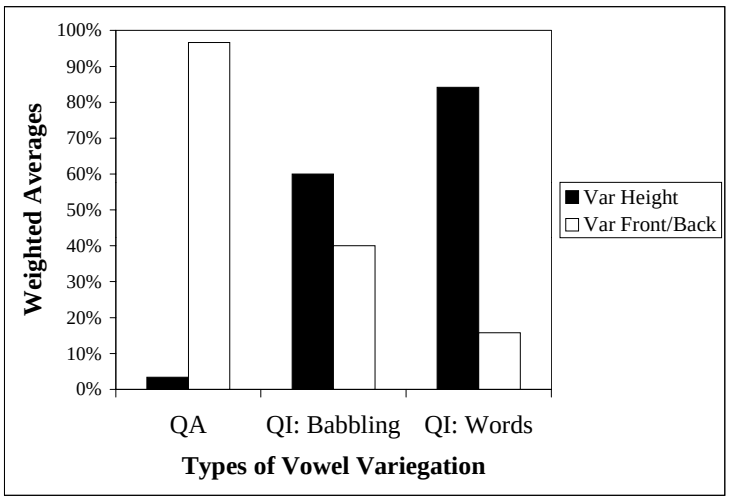
QA and QI differed significantly in variegated vowel patterns in CVCVs, both for the entire babbling period and by age group.[2] These differences were

[1] Reduplication vs. Variegation: QI Babbling to QA: t = 7.975, DF = 12, p < 0.001; QI 9-13 Months to QA: t = 6.198, DF = 7, p < 0.001; QI 13-17 Months to QA: t = 9.704, DF = 11, p < 0.001; QI 17-22 Months to QA: t = 5.000, DF = 10, p < 0.001

[2] Variegated Height vs. Variegated Front/Back: QI Babbling to QA: t = 10.700, DF = 12, p < 0.001; QI 9-13 Months to QA: t =19.101, DF = 7, p < 0.001; QI 13-17 Months to QA: t = 8.783, DF = 11, p < 0.001; QI 17-22 Months to QA: t = 10.451, DF = 10, p < 0.001

accounted for by the preference of QI for height variegation (60%). QA only produced CVCVs with vowel height variegation 3% of the time. Results are shown in Figure 4-36.

Figure 4-36. Vowel Variegation Patterns in Quichua Adults & Infants



Words

In QI and QA differences were found when comparing vowel reduplication and variegation patterns.[1] Results are shown in Figure 4-35. Variegation occurred most frequently (61% vs. 64% respectively). However, within the QI group there was dramatic variation in the frequency of variegated utterances – from 20% to 100%.

[1] Reduplication vs. Variegation: QI Words to QA: t = 4.303, DF = 11, p = 0.001

QI and QA differed significantly in vowel height versus front/back variegation patterns.[1] This difference was accounted for by the preference for height variegation in QI words (84%). Height variegation occurred only 3% in QA. Results are shown in Figure 4-36.

Vowel Reduplication vs. Variegation and Types of Variegation in Quichua and English-Learning Infants

Babbling

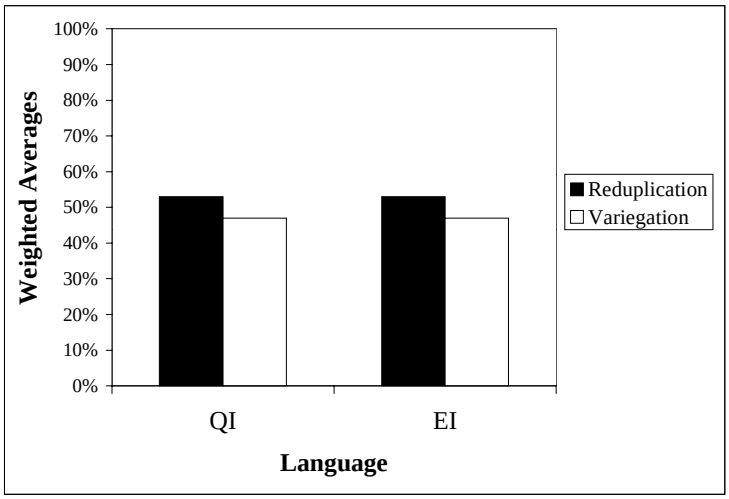
In QI and EI, reduplication and variegation patterns for vowels in CVCVs did not significantly differ for the entire babbling period or by age.[2] Both QI and EI preferred vowel reduplication (53% each). Results are shown in Figure 4-37.

---

[1] Variegated Height vs. Variegated Front/Back: QI Words to QA: $t = 8.732$, DF = 9, $p < 0.001$

[2] Reduplication vs. Variegation: QI to EI Babbling: $t = 0.028$, DF = 11, p = 0.978; QI to EI 9-13Months: $t = 0.205$, DF = 6, $p = 0.844$; QI to EI 13-17 Months: $t = 1.386$, DF = 10, $p = 0.196$; QI to EI 17-22 Months: $t = 0.482$, DF = 7, $p = 0.644$

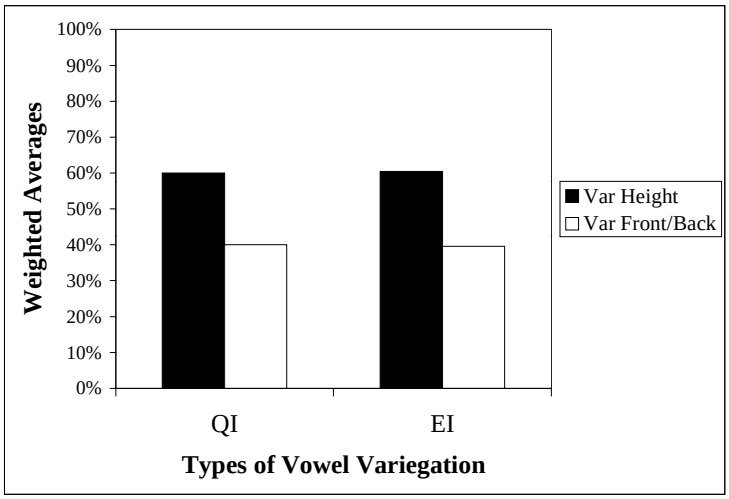
Figure 4-37. Vowel Reduplication and Variegation in Quichua & English-Learning Infants' Babbling



QI and EI babbling preferences for height variegation versus front/back variegation did not differ for the entire babbling period or by age.[1] Results are shown in Figure 4-38. Both QI and EI preferred vowel height variegation in babbling (60% each).

[1] Variegated Height vs. Variegated Front/Back: QI to EI Babbling: t = 0.001, DF = 11, p = 1.000; QI to EI 9-13 Months: t = 0.516, DF = 6, p = 0.624; QI to EI 13-17 Months: t = 0.433, DF = 10, p = 0.674; QI to EI 17-22 Months: t = 0.000, DF = 7, p = 1.000

Figure 4-38. Vowel Variegation Patterns in Quichua & English-Learning Infants' Babbling

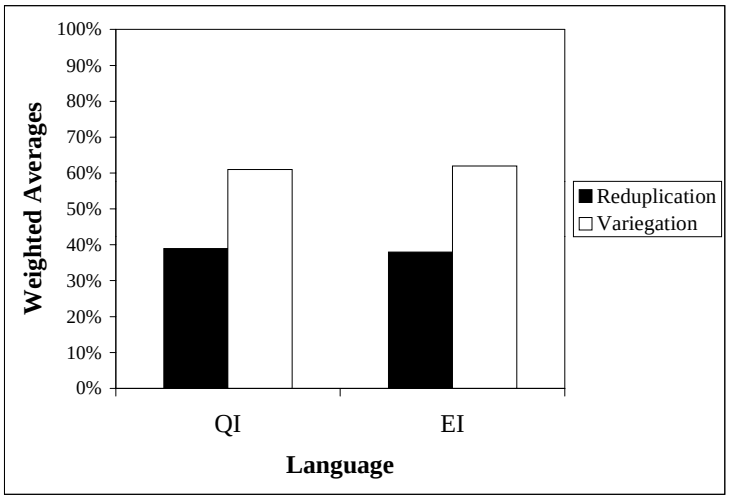


Words

In both QI and EI, vowels were most frequently variegated (QI: 61%, EI: 62%). No significant differences in vowel variegation and reduplication patterns were found between the two language groups.[1] Results are shown in Figure 4-39.

[1] Reduplication vs. Variegation: QI to EI Words: t =0.365, DF = 10, p = 0.722

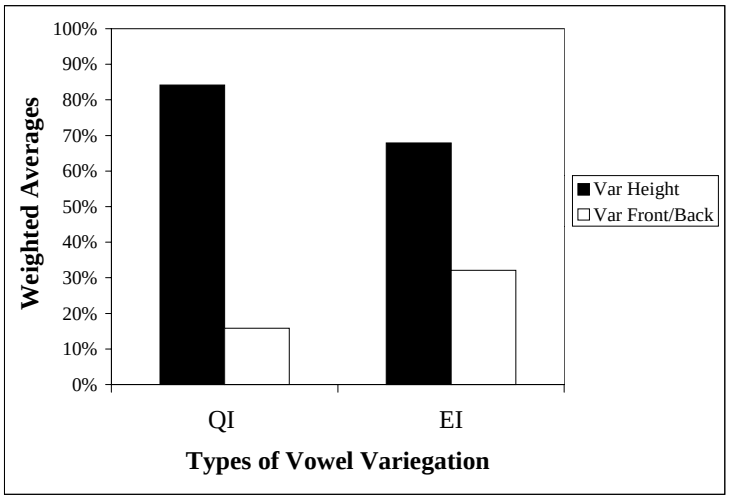
Figure 4-39. Vowel Reduplication and Variegation in Quichua & English-Learning Infants' Words



In QI and EI words, the differences between vowel height and front/back variegation patterns were not significant.[1] Height variegation occurred more frequently in both QI and EI (84% and 68% respectively). Results are shown in Figure 4-40.

[1] Height vs. Front/Back Variegation: QI to EI Words: t = 0.128, DF = 8, p = 0.902

Figure 4-40. Vowel Variegation Patterns in Quichua & English-Learning Infants' Words



Vowel Reduplication vs. Variegation and Types of Variegation Summary

QA and EA preferred vowel variegation to reduplication in CVCVs, although this preference was greater in EA. Front/back variegation occurred more frequently in QA and EA, although to a significantly greater degree in QA than in EA.

Nine to 17 month old QI significantly preferred vowel reduplication to variegation. Seventeen to 22 month old QI did not show a significant preference for reduplication or variegation, with both occurring at about the same rate. Vowel height variegation was preferred during the entire babbling period for QI, significantly so from 9 to 13 months of age.

In QI words, no significant preference for vowel variegation or reduplication was found, although the group tended towards more variegated

vowels. Vowel height reduplication occurred more frequently than front/back reduplication, although the difference was not significant.

In QI babbling, reduplication and variegation patterns differed significantly from QA: QI preferred reduplication and QA preferred variegation. QI babbling and QA also showed significant differences for height and front/back variegation in vowels. Vowel height variegation occurred more frequently in QI but was almost nonexistent in QA.

QI words showed significant differences from QA in the occurrence of vowel reduplication and variegation, although both groups preferred variegation to reduplication. Vowel height variegation predominated in QI words. In QA height variegation was extremely infrequent.

In QI and EI, no significant differences were found in vowel reduplication or in vowel height variegation over front/back variegation in babbling.

QI and EI words did not differ in the preference for vowel variegation or for height over front/back variegation.

Anterior-Posterior Patterns

Intersyllabic patterns for consonant place change were analyzed to determine whether anterior-posterior consonant changes (e.g., labial to coronal, coronal to dorsal) were more frequent than posterior-anterior changes in CVC words and CVCV bisyllabic occurrences within longer utterances.

Anterior-Posterior Patterns in Consonant-Vowel-Consonant Productions (CVCs)

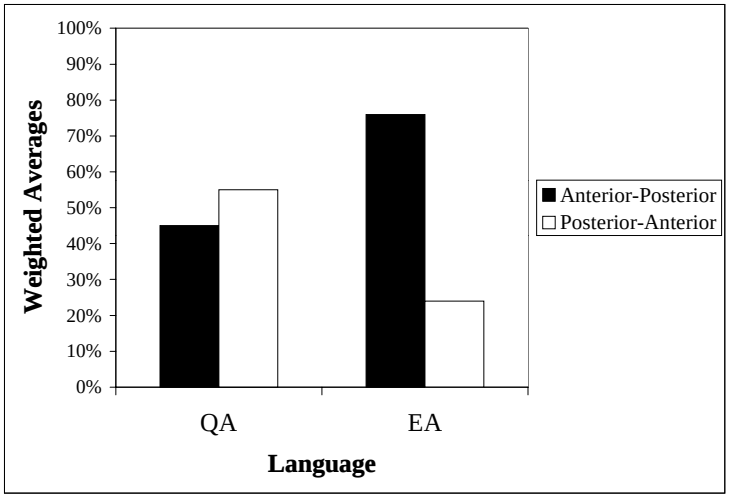
Total CVC words analyzed for each group were as follows: QA–173, EA–1,650, QI: Babbling–301, QI: Words–5, EI: Babbling–529, EI: Words–319. Since only five QI words contained the CVC pattern, and only one of these demonstrated a change in consonant place, no statistical analysis of QI words was conducted.

Anterior-Posterior Patterns for CVCs in Quichua and English

QA and EA anterior-posterior patterns in CVCs are compared in Figure 4-41. Posterior-anterior changes were more frequent in QA (55%) whereas anterior-posterior changes were more frequent in EA (76%). These differences were significant.[1]

[1] QA to EA: $t = 5.061$, DF = 12, $p < 0.001$

Figure 4-41. Anterior-Posterior Patterns for CVCs in Quichua and English



Anterior-Posterior Patterns for CVCs in Quichua Infant Babbling and Words

In babbling, significant patterns for CVC consonant place change were found for the entire babbling period and for each age group.[1] Anterior-posterior changes were produced 63% compared to 37% for posterior-anterior changes. Too few CVC words were produced to analyze statistically.

Anterior-Posterior Patterns for CVCs in Quichua Adults and Quichua Infants

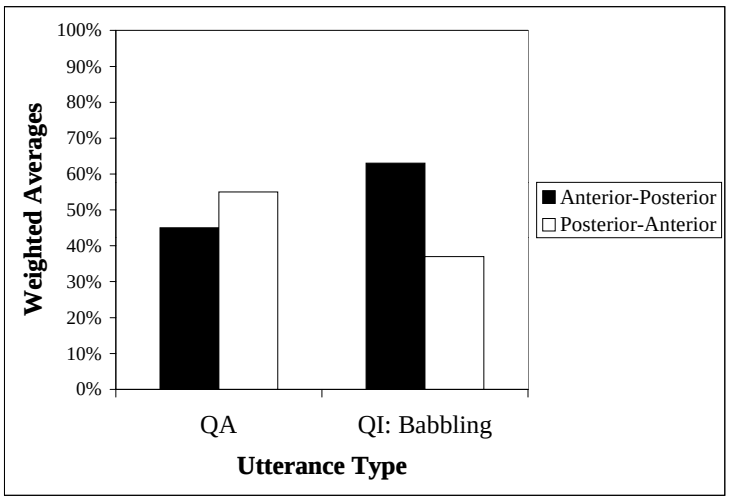
In QI babbling, anterior-posterior changes occurred more frequently than posterior-anterior (64% vs. 36%), whereas in QA, posterior-anterior changes were more frequent (55% vs. 45%). The differences were not significant.[2] When

[1] QI Babbling: $X^2 = 18.58$, DF = 1, $p < 0.0001$; QI 9-13 Months: $X^2 = 19.65$, DF = 1, $p < 0.0001$; QI 13-17 Months: $X^2 = 23.01$, DF = 1, $p < 0.0001$; QI 17-22 Months: $X^2 = 8.37$, DF = 1, $p = 0.0038$

[2] QA to QI Babbling: $t = 2.398$, DF = 12, $p = 0.034$

comparing QI babbling by age, all three age groups showed a trend towards greater frequency of anterior-posterior changes than QA. This difference was only significant in the 13 to 17 month olds.[1] Differences between QI babbling and QA are shown in Figure 4-42.

Figure 4-42. Anterior-Posterior Patterns for CVCs in Quichua Adults & Infants



Anterior-Posterior Patterns for CVCs in Quichua and English-Learning Infants

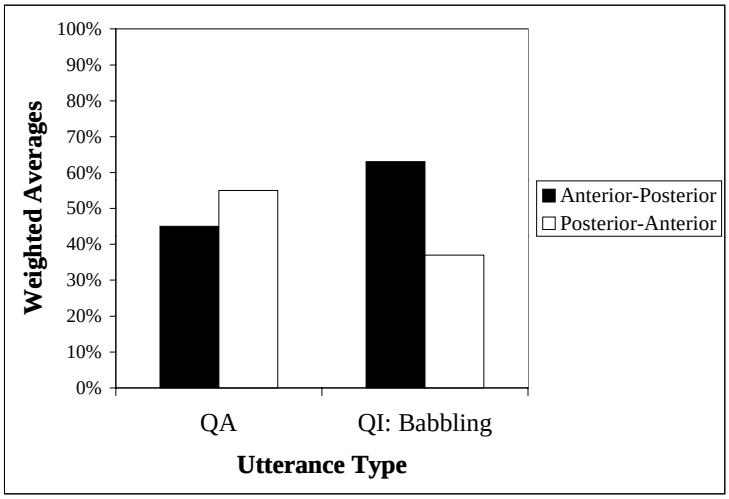
In QI and EI babbling, consonant place change patterns did not differ significantly for the entire babbling period or for any age group.[2] As seen in Figure 4-43, CVC utterances were more likely to demonstrate anterior-posterior

[1] QI 9-13 Months to QA: $t = 0.404$, DF = 7, $p = 0.698$; QI 13-17 Months to QA: $t = 3.085$, DF = 10, $p = 0.012$; QI 17-22 Months to QA: $t = 1.490$, DF = 10, $p = 0.167$

[2] QI to EI Babbling: $t = 1.064$, DF = 11, $p = 0.311$; QI to EI 9-13 Months: $t = 0.297$, DF = 6, $p = 0.776$; QI to EI 13-17 Months: $t = 1.093$, DF = 9, $p = 0.303$; QI to EI 17-22 Months: $t = 0.050$, DF = 7, $p = 0.962$

(QI: 63%, EI: 64%) than posterior-anterior (QI: 37%, EI: 36%) changes in both language groups.

Figure 4-43. Anterior-Posterior Patterns for CVCs in Quichua & English-Learning Infants' Babbling



Anterior-Posterior Patterns for CVCs Summary

QA and EA differed in CVC consonant patterns. In QA, posterior-anterior patterns were more frequent. Anterior-posterior place changes occurred most frequently in EA.

In QI babbling, significant group patterns were for more frequent anterior-posterior changes. The only exception was the 9 to 13 month olds who did not show any preference. QA and QI babbling did not show significant differences except in the 13 to 17 month olds. The trend for all was a greater frequency of anterior-posterior changes in QI than QA.

In QI and EI babbling, no significant differences were found. Both groups preferred anterior-posterior changes.

Anterior-posterior patterns were not analyzed in QI words due to their infrequency of occurrence.

Anterior-Posterior Patterns in Consonant-Vowel-Consonant-Vowel Productions (CVCVs)

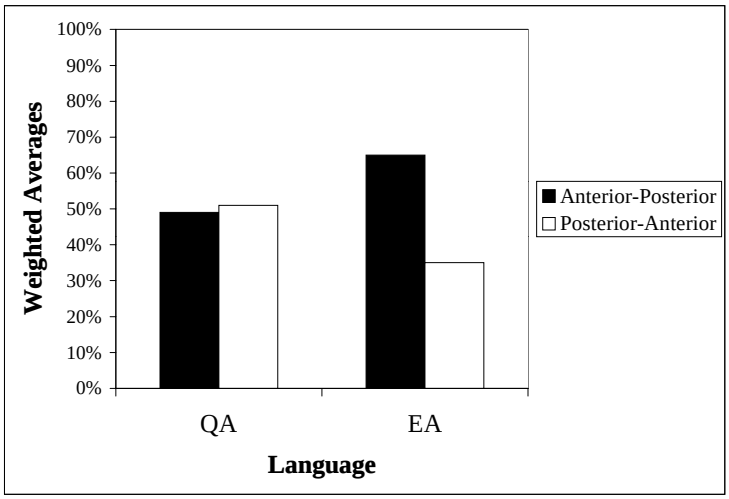
Total words beginning with CVCV patterns analyzed for each group were as follows: QA–2,085, EA–690, QI: Babbling–1,149, QI: Words–76, EI: Babbling–3,158, EI: Words–806.

Anterior-Posterior Patterns for CVCVs in Quichua and English

In QA CVCVs, anterior-posterior and posterior-anterior changes occurred with almost equal frequency (49% and 51% respectively). In EA, anterior-posterior changes occurred with greater frequency than posterior-anterior changes (65% and 35%). The differences between QA and EA for CVCV anterior-posterior patterns were significant and are shown in Figure 4-44.[1]

[1] QA to EA: $t = 3.499$, DF = 12, $p = 0.005$

Figure 4-44. Anterior-Posterior Patterns for CVCVs in Quichua & English



Anterior-Posterior Patterns for CVCVs in Quichua Infant Babbling and Words

In babbling, QI produced CVCV utterances with anterior-posterior changes more frequently than with posterior-anterior changes (53% vs. 47%). These differences were significant for the entire babbling period and by age group.[1]

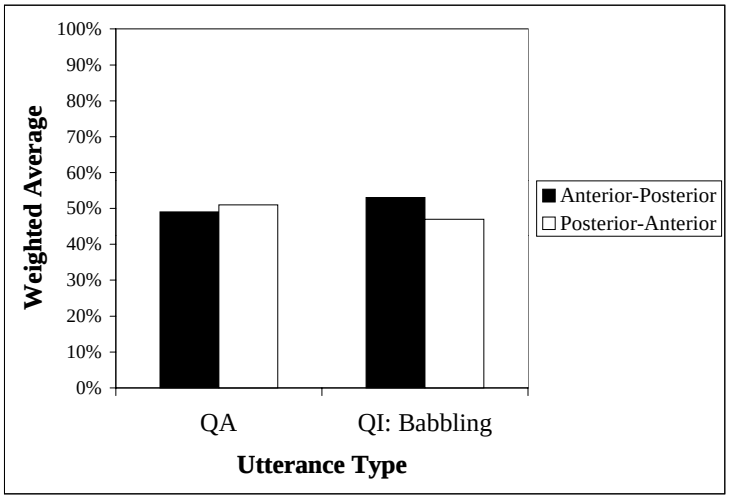
Analysis of QI words could not be conducted because of the infrequent occurrence of CVCVs containing any change. Only three utterances containing these patterns were produced between all six infants. One demonstrated an anterior-posterior pattern and two demonstrated a posterior-anterior pattern.

[1] QI Babbling: $X^2 = 125.64$, DF = 1, $p < 0.0001$; QI 9-13 Months: $X^2 = 52.40$, DF = 1, $p < 0.0001$; QI 13-17 Months: $X^2 = 34.97$, DF = 1, $p < 0.0001$; QI 17-22 Months: $X^2 = 45.74$, DF = 1, $p = 0.0038$

Anterior-Posterior Patterns for CVCVs in Quichua Adults and Quichua Infants

In QI babbling and QA, CVCV utterances did not differ significantly in anterior-posterior preferences for the entire babbling period or by age group.[1] However, QI showed a tendency towards anterior-posterior changes over posterior-anterior changes (47% vs. 53%), whereas QA showed almost equal frequencies of these two patterns (49% vs. 51%). These patterns are shown in Figure 4-45.

Figure 4-45. Anterior-Posterior Patterns for CVCVs in Quichua Adults & Infants

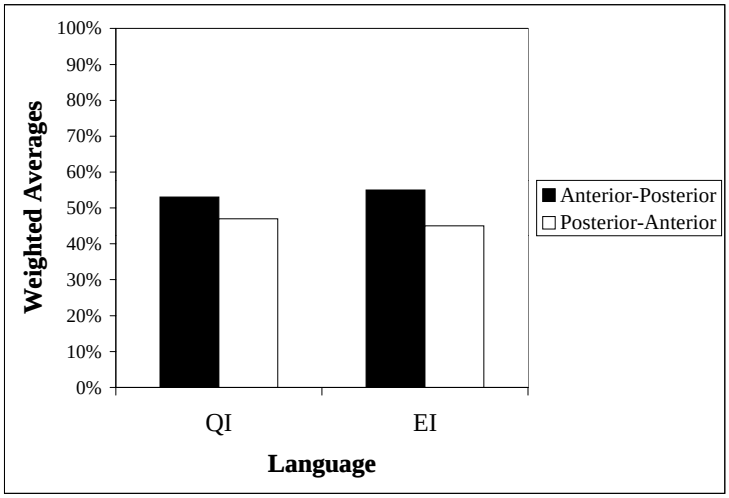


[1] QI Babbling to QA: t = 0.374, DF = 12, p = 0.714; QI 9-13 Months to QA: t = 0.284, DF = 7, p = 0.785, QI 13-17 Months to QA: t = 1.382, DF = 11, p = 0.195, QI 17-22 Months to QA: t = 0.059, DF = 10, p = 0.954

Anterior-Posterior Patterns for CVCVs in Quichua and English-Learning Infants

In QI and EI babbling, consonant place change patterns did not differ significantly for the entire babbling period or by age group.[1] As seen in Figure 4-46, CVCV utterances in babbling were most likely to show anterior-posterior changes in both language environments (QI: 53%, EI: 55%).

Figure 4-46. Anterior-Posterior Patterns for CVCVs in Quichua & English-Learning Infants' Babbling



[1] QI to EI Babbling: t = 0.352, DF = 11, p = 0.731; QI to EI 9-13 Months: t = 0.466, DF = 6, p = 0.657; QI to EI 13-17 Months: t = 0.217, DF = 10, p = 0.833; QI to EI 17-22 Months: t = 0.521, DF = 7, p = 0.618

Anterior-Posterior Patterns for CVCVs Summary

CVCV patterns differed significantly in QA and EA. Anterior-posterior and posterior-anterior changes were equal in frequency in QA whereas EA preferred anterior-posterior changes.

QI produced anterior-posterior changes significantly more frequently than posterior-anterior changes in babbling. QI babbling and QA did not differ significantly in anterior-posterior preferences, although QI showed a slight preference for anterior-posterior changes whereas QA produced both anterior-posterior and posterior-anterior changes with equal frequency. In QI and EI babbling, no significant differences were found. Both groups preferred anterior-posterior changes.

CHAPTER 5: DISCUSSION

The present study was a longitudinal investigation of speech acquisition from a crosslinguistic perspective. It was undertaken to explore the relative contributions of perceptual influences from the ambient environment and production factors in early speech acquisition. These factors were explored by comparing infant babbling and early word productions in Quichua to infant babbling and early word productions in American English, as well as to ambient language influences represented by Quichua and American English phonology. Differences between Quichua and English were investigated by comparing adult utterances.

Previous research has shown that the interaction between perceptual distinctiveness and articulatory complexity may impact phonetic inventories in languages (Lindblom, 1992). The ways in which these factors may be interrelated in early speech acquisition is not well explored. To fully understand speech acquisition, we need to understand the interaction and relative contributions of ambient language perceptual information and production factors during this period.

Few studies for understanding overall patterns in early speech acquisition with large databases have been conducted on languages other than English. Most available studies are diary studies (e.g., Ingram, 1981; Tuaycharoen, 1978; Vogel, 1975), some of which were conducted by linguist parents, (e.g., Teixeira and Davis, submitted; Vihman, 1985). Some studies are anecdotal reports of small

databases (e.g., Ingram, 1981), report general findings for children that vary widely in age range (e.g., Boysson-Bardies et al., 1981; Levitt & Wang, 1991; Pye, 1986), or provide pooled results without taking into account individual infant variation (e.g., (Boysson-Bardies, 1993; Levitt, 1993). Many do not report statistical significance but base their findings on descriptive trends (e.g., Ingram, 1981; Ingram, 1988; Levitt & Aydelott-Utman, 1992; Oller & Eilers, 1982; Vogel, 1975).

To determine the relative effects of production factors and ambient language perceptual influences on speech acquisition, it is first necessary to fully understand phonetic and phonological properties of the ambient language. Detailed analysis of both infant and adult transcripts within a language environment, as well as statistical comparisons of infant productions to those of adult speakers and infants from other language environments are needed. Previous studies have made claims regarding ambient language influences with casual reference to, but no analysis of, ambient language properties, weakening their validity (e.g., Ingram, 1981; Levitt & Aydelott-Utman, 1992; Tuaycharoen, 1978; Vogel, 1975).

The present study represents the first longitudinal analysis of speech acquisition in a non-Indo-European language to address the potential role of perceptual influences from ambient language input versus child internal production factors. Seven Quichua-learning infants who were between the ages of 9 and 16 months at the onset of the study were followed longitudinally for approximately six months. Babbling and lexically based utterances were

compared to six English-learning infants in the same chronological age range and to speech samples from seven Quichua and seven English adult speakers. The goal was to determine the similarities and differences of Quichua infant utterances to utterances of English-learning infants of the same age, and to adult speakers in their respective ambient language environments. Data were divided into three age ranges for babbling (9 to 13, 13 to 17, and 17 to 22 months) for analysis. Words were analyzed separately from babbling. Statistical analysis was conducted to determine whether differences between groups were significant or whether individual variation within groups was greater.

Three research hypotheses were tested. Production constraints were predicted to predominate over perceptual influences from the ambient language environment for 1) segmental inventories of consonants and vowels and utterance shapes, 2) intrasyllabic, and 3) intersyllabic patterns. The latter two hypotheses were based on predictions of the frame dominance hypothesis (Davis & MacNeilage, 1995a; Davis et al., in press; MacNeilage et al., 1997).

THEORETICAL FRAMEWORK

Frame Dominance

The "Frames then Content" hypothesis (MacNeilage & Davis 1990, 1993) has been evaluated in English (Davis & MacNeilage, 1990, 1994, 1995; Davis et al. in press), and to a limited degree in other Indo-European languages (Boysson-Bardies, 1993; Teixeira & Davis, submitted; Zlatic et al., 1997; Zmarich & Lanni, 1999). This hypothesis was evaluated in Quichua, a language that presents

significant differences from English in phonetic properties and phonological structure. The analysis of adult language environments makes it possible to determine whether infant utterances more greatly reflect their ambient language properties or babbling of infants from another language environment. The phonetic and phonological differences between Quichua and English allow consideration of the potential role of ambient language perceptual effects in understanding acquisition of speech production skill.

The Frames, then Content perspective suggests that speech is produced in babbling and early periods of word use by production of “frames,” conceived as being based on rhythmic oscillation of the mandible accompanied by phonation. Segmental “content” elements develop later as articulators gain independence of movements within serial sequences. In earliest stages, little or no segmental “content” is expected; instead, "frame dominance" is predicted before the infant develops control over articulators in sequences. Consonants, produced when the mandible is closed, and vowels, produced when the mandible is open, are predicted to be interdependent based on inertial tendencies within movement sequences. In addition, consonants and vowels across syllables are constrained by these inertial properties inherent in the rhythmic oscillation of the mandible without independence of other articulators. Variegation patterns observed are based on mandibular amplitude differences resulting in manner changes rather than independent tongue, lip, or velum movement resulting in place of articulation changes. These frames are predicted to be the result of general production constraints resulting from the lack of individual control of speech articulators by

the infant. Thus babbling and early speech in any language are predicted to be subject to frame dominance production constraints, regardless of the frequency of consonant and vowel patterns in the ambient language.

Predictions regarding production patterns have included a proposal of an increase in the production of labials in first words. This prediction is based on expected difficulty of initiating speech movements while simultaneously interfacing the lexicon (MacNeilage & Davis, 1990; MacNeilage & Davis, 1993). Labials are predicted to occur more frequently since their production is simpler than that for coronals and dorsals: jaw closure during an oscillation cycle with no accompanying tongue movement. Supporting the production ease of labials are findings that the utterances of a 20 to 25 month old child immediately following 15 months of aphonia due to a tracheotomy were primarily comprised of labials (Locke & Pearson, 1990). An increase in labials in first words has been found in English-learning infants (Davis et al., in press; Stoel-Gammon, 1985; Stoel-Gammon & Dunn, 1985). This labial increase has also been found to varying degrees in infants from French, English, Swedish, and Japanese environments (Boysson-Bardies et al., 1992). Labials were relatively more frequent in the early words of two Brazilian Portuguese infants when compared to labial frequency in the ambient language (Teixeira & Davis, submitted).

As the infant develops independent control of the articulators, frame dominance is predicted to become less pervasive. However, based on data from English-learning infants, this independence does not occur during babbling and first words. A first step towards segmental independence that has been observed

in first words is a labial-coronal pattern in disyllabic words. This labial-coronal pattern has been observed in English-learning infants' first words as well as in dictionary counts in 10 languages (Davis et al., in press; MacNeilage et al., 2000a; MacNeilage et al., 2000b). It has also been observed in the first words of two Brazilian-Portuguese infants (Teixeira, 1980). MacNeilage and colleagues have suggested that this pattern is an example of infants producing anterior-posterior patterns. This pattern has been explained by a principle of "start easy-end hard." They propose that this pattern is an example of producing the easier movement necessary for the more anterior consonant first, resulting from the difficulty of initiating a speech action while simultaneously interfacing the lexicon. This is proposed as a self-organizational response to biomechanical, cognitive, and motor constraints when producing early words (Davis et al., in press; MacNeilage et al., 2000a).

Dynamic Systems

Production factors based on Frames then Content predictions describe the majority of the speech patterns observed in these Quichua infants, particularly intrasyllabic co-occurrence and intersyllabic variegation patterns. However, perceptual influences were apparent in consonant and vowel properties and utterance shapes. Both production constraints and interaction with the language environment appeared to influence the sequential and segmental qualities of utterances in early speech acquisition in these Quichua infants. Supporting these findings is the assertion by Studdert-Kennedy (1986) that the path to development

may be partially fixed, such as in production constraints, but also variable, in this case, based on ambient language influences. He notes that the infant must be "sensitive to environmental contingencies and equipped with a variable repertoire of responses." Perhaps perception and production are not autonomous factors during speech acquisition. They may be more appropriately viewed as inextricably linked, consistent with Lindblom's suggestion that a balance between perception and production must exist in acquisition also, although with perceptual information important to a lesser degree than it is in adult languages (Lindblom, 1992).

One theoretical framework that provides a powerful metaphor for the connection between environmental and internal production factors is dynamic systems (Thelen, Kelso, & Fogel, 1987; Thelen & Smith, 1995). Dynamic systems is intended to describe both cognition and behavior in complex biological systems. According to dynamic systems, developing humans are complex biological organisms comprised of many heterogeneous components, including the mind and body. These components may develop separately but must be functionally coordinated. Development is not seen as pre-deterministic. Instead, the contribution of many elements is viewed as resulting in a novel end state. Relative to speech acquisition, it differs from other cognitive models by attempting to explain the process of development, not the final state (Thelen & Smith, 1995; van Gelder & Port, 1995).

A key factor in the dynamic systems perspective is the notion of "self-organization." Dynamic systems are self-organizing in the sense that at specific

points in development certain behaviors prevail over others. The preferred behaviors are thought to be "stable attractors," resulting from system-oriented preferences for one behavior above others. Self-organization typically occurs in the form of rapid reorganization of the system from one stable attractor to another at specific points in development as the result of slight internal changes in the system or in inputs to the system. Stable attractors have varying levels of stability. Thus, while many facets of development are highly variable, in very stable attractor states, small disturbances to the system will have little effect and may not be observable (Thelen & Smith, 1995; van Gelder & Port, 1995).

Also characteristic of development from a dynamic system perspective is dramatic and often nonlinear behavioral changes, resulting in "phase shifts." These phase shifts are from one stable attractor to a newer, often more complex one. Examples of phase shifts are the emergence of babbling from previously nonrhythmic vocalizations, or first words, from nonmeaningful babbling, in the infant. Phase shifts coincide with change occurring on a gradual, more linear manner, without marked disruption in the system (Thelen & Smith, 1995: 63). An example of a more gradual and linear change would be changes over time in the consonant inventory of an infant that slowly reflects ambient language properties.

Infants are seen as coming into the world with a set of adaptive biases in the form of intrinsic urges and needs. These biases direct the infant toward certain stimuli, resulting in the developmental changes observed in phase shifts (Thelen & Smith, 1995: 315). A possible adaptive bias in the case of speech

development might be the sounds and sound patterns of a language, while a stable attractor might be production factors related to articulatory simplicity.

Culture

Based on findings in this study, production constraints and perceptual influences appear interrelated in speech acquisition. Using dynamic systems as a metaphor allows us to explore the way in which these heterogeneous components may be intertwined. However, in addition to production and perception factors, culture also may play a critical role in the pacing of development. In this study, limited word use and shorter babbling utterances appear to reflect cultural influences. Although proponents of dynamic systems as an explanation for speech acquisition have noted the importance of social aspects during early development (Thelen & Smith, 1995: 328), their primary focus has been on the biological and physiological aspects of development. Little attempt to explain how culture affects development has been made within dynamic systems theory.

Vygotsky has emphasized the importance of culture as guiding all aspects of development in children. According to Vygotsky, the child is first and foremost a participant in the culture, and language needs are built within the societal needs for communication (Vygotsky, 1978). Within a Vygotskyan framework, children are viewed as active participants in their own development. From this perspective, biology and culture are not alternative influences but inseparable aspects of a developing system (Rogoff, 1990). From birth, infants are expected to build on skills and abilities from a societal perspective. Being an

active participant in society is the infant's main motivation during development, thus the articulatory complexity of producing sounds would interface with the importance of these sounds for communication. For that reason the influences of the culture on Quichua infant utterance length and word frequency observed in this study could be considered to result from the infant's desire to be a communicative participant in society.

FINDINGS

Phonological differences between Quichua and English motivated this study as a means to understand interaction of production constraints and ambient language influences during speech acquisition. Quichua and English were found to differ markedly in both segmental and syllabic features. Quichua has more dorsals and fewer labials, as well as more fricatives and affricates and fewer liquids, than English. Quichua has only three vowels, of which the low central /a/ occurs with the most frequency. Quichua words are predominately three-or-more syllables, whereas words in English are overwhelmingly one-syllable. Words in English are composed of more syllables with complex consonant clusters, while Quichua is primarily composed of simple consonant-vowel syllables.

Production Factors

In this study, the major predictions of the Frames then Content theory applying to speech acquisition were confirmed. Quichua infants overwhelmingly produced the sound patterns in babbling and words predicted by frame

dominance. The intrasyllabic and intersyllabic patterns of both Quichua infants and English-learning infants were remarkably similar, despite differences in ambient language influences from Quichua and English.

CV Co-occurrence Patterns

CV co-occurrence preferences predicted for labial-central, coronal-front, dorsal-back, as well as dorsal-central were observed in both languages. In babbling and in words, Quichua infants and English-learning infants were similar in CV co-occurrence patterns. Quichua infants produced labial-central, coronal-front, and dorsal-back combinations in babbling and words, and dorsal-central preferences in babbling. All of these co-occurrences occurred significantly more often in the infants' productions than in the ambient language. The Quichua infants demonstrated the same predicted consonant-vowel co-occurrences, although at a significantly greater rate, than did English learners. Quichua and English-learning infants differed in the Quichua infants' dorsal-central preferences and the English infants' labial-back preferences in babbling and dorsal-front and coronal-back preferences in words. These findings for predicted CV co-occurrence patterns, consistent with previous studies of English (Davis et al., in press; Davis & MacNeilage, 1990, 1994, 1995) and Indo-European languages (Boysson-Bardies, 1993; Davis et al., 1999a; Teixeira & Davis, submitted; Zlatic et al., 1997) strongly indicate the important status of frame dominance in early infant productions.

It is possible that cross-language differences in frequency of CV co-occurrences are due to different transcription conventions. The English-learning infants' labial-back, dorsal-front, and coronal-back vowel combinations may suggest a transcription bias that erroneously suggests lower production effects. If one primarily transcribes using the English phonemic vowel system, rounded vowels made at any place in the oral cavity are likely to be transcribed as back vowels–the only phonemic round vowels in English. In contrast, no high or mid unrounded vowels are likely to be transcribed as back vowels, since these are not phonemic in English. If frame dominance predictions were correct, but rounded front or central vowels were transcribed as back vowels, coronal-back and labial-back combinations would have been transcribed, as is the case in the English infants' early words and babbling respectively. If high-unrounded back vowels were transcribed as front vowels, an erroneously high rate of dorsal-front combinations would have resulted, similar to that observed in English infants' early words. Acoustic analyses will be necessary to understand transcription effects and determine if frame dominance predictions are even stronger than has been reported previously.

An unpredicted CV co-occurrence pattern was found in English, Quichua, and in Quichua infants. This was a tendency for dorsal consonants to co-occur with central vowels. Its existence in both Quichua infants and adults could be interpreted as an ambient language influence. However, if this were a learned pattern based on ambient language influences, one would expect its frequency to increase in infants over time in the gradual, linear manner predicted by dynamic

systems. The frequency of dorsal-central co-occurrences is actually higher in Quichua infants than Quichua adults. For this reason it can be interpreted as a production system effect based on articulatory proximity: perhaps consonants produced in the palatal region but transcribed as dorsals co-occurred with central vowels. This seems likely, since many adult languages report the allophonic production of palatal for velar stops when abutted by front vowels (Ladefoged, 1975). A second possibility is that unrounded mid back vowels were erroneously transcribed as central vowels. Acoustic analysis will also be necessary to address these questions.

Quichua adults produced the same CV co-occurrence patterns observed in infants. English adults did not, instead producing all but dorsal-central co-occurrences at chance levels. These findings on English spontaneous speech samples differ from dictionary analysis of English words, in which coronal-front and dorsal-back preferences persist (MacNeilage et al., 2000a). These differences between spontaneous speech and dictionary analysis for CV co-occurrence patterns in English suggest that words used more frequently in conversation are composed of more random frequencies of consonant and vowel combinations, whereas the actual English word corpus tends towards predicted consonant-vowel co-occurrence preferences. MacNeilage, Davis, Kinney, and Matyear (2000a) found that in languages where preferred consonant-vowel co-occurrences exist, they tend to be those predicted by frame dominance. Co-occurrence patterns in the Quichua adults mirror findings in other languages.

The fact that CV co-occurrences exist in babbling and first words, and in languages, suggests the frame as a stable attractor for the organization of human language. It appears that from the onset of speech-like syllables, frame dominance serves a self-organizational function in speech acquisition. Frame dominance may become weaker in adult languages as the need for perceptual distinctiveness grows and may result in a diversification of syllable shapes. Quichua, with only three vowels, a reliance on word length for diversifying vocabulary, and a smaller vocabulary than English, may not depend on syllabic complexity to attain perceptual distinctiveness to the same extent. It would be interesting to determine if other languages with small vowel inventories or smaller vocabulary sizes also show the CV co-occurrence patterns in adults predicted by frame dominance.

Reduplication/Variegation Patterns

Consonants:

In disyllabic productions, consonant variegation was preferred for both Quichua and English. The languages also did not differ in the preference for manner changes over place changes in variegated utterances: manner changes occurred twice as often as place changes in both English and Quichua. Quichua infants differed from their ambient language in preferring consonant reduplication. Quichua adults and infants did not differ significantly in their preference for manner over place variegation. However, from 9 to 17 months, Quichua infants preferred manner variegation significantly more than Quichua

adults. By 17 to 22 months, infants and adults did not significantly differ, suggesting that infant productions were more like adults in their level of manner over place preference. This preference for manner over place changes, or jaw constriction over front/back tongue placement, suggests that the frame predominates throughout babbling. In Quichua infants the frame lessened as infants gained more tongue control later in babbling; however, the continued preference for mandibular amplitude change in Quichua adults points to the importance of the frame as a basic aspect of speech organization retained in languages as well.

In contrast, words and babbling of Quichua and English-learning infants did not differ in intersyllabic consonant variegation patterns. In babbling, Quichua infants and English-learning infants produced an almost equal proportion of consonant reduplication and variegation; in words, both showed a 3:1 preference for reduplication. And in both babbling and words, Quichua and English-learning infants preferred manner to place changes in disyllabic utterances.

Based on these two languages, adult speakers appear alike in their preference for consonant manner over place variegation in disyllabic utterances. In contrast, infants show a greater frequency of consonant reduplication, producing almost equal frequencies of variegation and reduplication in disyllabic utterances. This use of reduplication concurrent with variegation is consistent with other research (Kent, Mitchell, & Sancier, 1991; Smith, Brown-Sweeney, & Stoel-Gammon, 1989). The preference for manner over place variegation in

Quichua infants confirms predictions of the frame dominance hypothesis for infants in a non-Indo-European language environment and is consistent with previous studies (Davis & MacNeilage, 1995a; Davis et al., in press; MacNeilage et al., 1997). The fact that manner variegation was the predominant pattern in babbling utterances suggests that infants are primarily varying jaw amplitude in variegated utterances. The persistence of this type of patterning for variegated sequences in English- and Quichua-speaking adults is another indication of persistence of basic production system patterns in the face of a need to diversify within serial sequences for increase in message transmission. In contrast to a potential expansion into equivalent use of place and manner variegation that might be expected on perceptual grounds, as well as with increased articulator independence, these adult speakers have retained a basic feature of the production system found in infants. This persistence is consistent with a general tendency in 10 languages studied of CV co-occurrence constraints (MacNeilage et al., 1999), which has been interpreted as an inertial effect maintained despite pressure to increase the message set. In the case of persistence of manner over place variegation, this pattern indicates that adjustments in amplitude during mandibular oscillation may be a more productive means of achieving variegation than front-back movement of the tongue. The fact that this manner over place preference is retained in languages, even as the individual sound capacity increases, suggests the importance of the frame as a stable attractor, one which appears to be a self-organizing production property during babbling that continues to dominate in adult language forms.

Vowels:

Vowel variegation in disyllabic productions was significantly more frequent in English than Quichua, although both languages preferred this pattern to vowel reduplication. In utterances with vowel variegation, both languages preferred vowel front/back to height variegation, although Quichua showed significantly more front/back variegation than English. Quichua has three vowels that differ in the front/back dimension. Vowel height dimension differences in Quichua are two dimensional, with two high vowels (high front /i/, high back /u/) and one low central vowel (/a/). Thus it is not surprising that front/back changes occurred more frequently. This preference for front/back variegation also exists in English, which has a much richer vowel inventory and a greater opportunity for height variegation. The prevalence of front/back variegation in disyllabic vowel patterns contradicts frame dominance predictions for a preference for jaw amplitude adjustments to tongue front/back movements.

In babbling, Quichua and English-learning infants preferred vowel reduplication to variegation. In contrast, in words both Quichua and English-learning infants preferred vowel variegation to reduplication. In both babbling and words, both groups of infants preferred height variegation to front/back variegation for vowels in disyllabic productions. This greater frequency of height variegation is consistent with frame dominance predictions of amplitude to front/back change preferences, and is similar to the patterns observed in previous

studies of infant babbling (Davis & MacNeilage, 1994; Davis & MacNeilage, 1995) and words (Davis & MacNeilage, in press) in English.

Thus we see infants from languages with radically different vowel systems demonstrating remarkably similar vowel-vowel patterns in disyllabic babbling and words. Infants tended to prefer vowel reduplication in babbling and vowel variegation in words. This difference between babbling and words suggests that that the effects of vowel variegation present in both languages impacts word shapes, but does not influence babbling utterances. It appears that it is only once words are produced, when speech production is interfaced with the lexicon, that the preference for vowel reduplication diminishes. In both babbling and words, variations in mandibular amplitude rather than movement of the tongue for vowels were preferred intersyllabically. In Quichua and English adults, variegation was preferred as were front/back changes. These findings differ from consonant variegation patterns in disyllables as well as from frame dominance predictions for greater height variegation due to the latter's relatively easier production.

From a production-oriented perspective, it appears counterintuitive that preferred vowel variegation patterns require tongue movement rather than the less motorically demanding jaw oscillation. It may be the case that articulatory complexity is required to achieve necessary perceptual distinctiveness, as proposed by Lindblom (1992). Vowel variegation may not be as articulatorily complex as consonant variegation, and perhaps perceptual distinctiveness factors motivate more complex vowel variegation patterns. Vowels, which are more

perceptually salient than consonants, typically longer in duration and greater in energy, may have more pressure than consonants to shift out of the stable state proposed by dynamic systems theory, in order to permit increasing message complexity. This is supported by the finding that infants in both language environments preferred vowel variegation to reduplication in words, while reduplication was preferred in babbling, suggesting that vowel variegation is important in achieving message complexity needs.

Word Shapes:

In CVCs and CVCVs in babbling, Quichua and English-learning infants did not differ in their preference for anterior-posterior over posterior-anterior consonant changes. Anterior-posterior consonant sequences have been found for first words in English (Davis et al., in press). Unfortunately, Quichua infants' words could not be analyzed for anterior-posterior patterns because of their low frequency. Nevertheless, this tendency was shown to be true for Quichua infant babbling in one-syllable and multi-syllable utterances.

Languages have shown a preponderance of words demonstrating anterior-posterior changes initially, suggesting that this may be a universal pattern in languages (MacNeilage & Davis, 1999b; MacNeilage & Davis, 2000; MacNeilage et al., 1999; MacNeilage et al., 2000b). Quichua did not show this pattern, instead demonstrating approximately equal occurrences of anterior-posterior and posterior-anterior consonant sequence changes. This difference may be explained by methodological differences of this study from previous studies.

Available language analyses have only looked at labial-coronal relationships (MacNeilage & Davis, 2000; MacNeilage et al., 2000a). This study examined anterior-posterior patterns for labial-coronal-dorsal relationships because of the higher frequency of dorsals in Quichua. The present findings suggest that it is not just an anterior to posterior change that is occurring, but more specifically a tendency to produce labial consonants followed by either coronal or dorsal changes. This pattern is supported by the Davis, MacNeilage, and Matyear (1997) study of first words of English learners, in which labial-coronal and labial-dorsal patterns were most frequent, but equal frequencies of coronal-dorsal and dorsal-coronal patterns occurred (Davis et al., in press). To answer this question, a more detailed study of the Quichua data that separates labial-coronal and labial-dorsal relationships from coronal-dorsal relationships, rather than grouping them all as anterior-posterior changes, is needed.

Summary:

Predicted intrasyllabic labial-central, coronal-front, and dorsal-back co-occurrences were produced at rates significantly greater than chance for babbling and words in infants and in Quichua adults. Intersyllabic consonant and vowel variegations demonstrated changes in amplitude rather than within-sequence independence of articulator movements. Consonants differed in manner at a much greater rate than place of articulation for both infants and adults. Vowels differed in height at a much greater rate than front/back placement for all groups analyzed except Quichua adults. The predicted anterior-posterior patterns for

consonants in CVCs and CVCVs were found in infants in babbling, Quichua demonstrated equal frequencies of anterior-posterior and posterior-anterior patterns. Quichua infant words were too few to be analyzed for anterior-posterior patterns.

The same findings in Quichua as have been found in other languages indicate the importance of production factors in understanding the nature of speech acquisition. Many of the intrasyllabic and intersyllabic patterns predicted by the frame dominance hypothesis and observed in the infants' utterances also occurred in the ambient language, although not to the same extent as in the infants. Based on the parallel findings in infants and adults, it appears that the frame, in the form of consonant-vowel co-occurrence patterns and intersyllabic sequences, is a basic organizational factor in humans producing complex serial output in languages. It appears that production-based factors are a principle underlying factor in babbling and first words, and are so basic to the production mechanism that they are retained in modern languages.

Consonant Vowel Ratios

Production factors also appeared to predominate in infant consonant-vowel ratios. Syllable shapes differed between ambient language environments. Quichua has fewer consonant clusters and final consonants, and a higher frequency of simple consonant-vowel syllables produced overall than English. However, Quichua and English-learning infants did not differ in syllable structures produced. Both groups of infants produced primarily simple

consonant-vowel shapes in both babbling and words as has been broadly noted in other studies of this period (Kent & Bauer, 1985; Stoel-Gammon, 1985; Vihman, 1992). These Quichua infants produced simpler syllables, consisting primarily of consonant-vowel syllable structures, than existed in the ambient language.

These results suggest a generality of production of a basic consonant-vowel alternation during the early speech acquisition period, regardless of the frequency of more complex syllable shapes in the ambient language environment. This syllable structure is produced with a basic close-open movement of the jaw, with the consonant production occurring during the closed phase of the cycle and the vowel during the open phase. Ambient language environment shows little effect on the predominance of this cyclical behavior in the early stages of speech acquisition, since both Quichua and English-learning infants produced significantly simpler syllables than in their ambient languages through 22 months of age in both babbling and words.

Given the strength and generality of intrasyllabic and intersyllabic patterns in infants' babbling and early words, as well as simple consonant-vowel syllables, the syllable shape predicted by frame dominance might represent a stable attractor (Thelen & Smith, 1995) resulting from production system propensities. Predicted patterns based on articulatory proximity due to inertial tendencies in the oral cavity appear to be stable attractors during babbling and early words, as their frequency is at rates well above chance in infants from both Quichua and English language environments. In addition, these co-occurrences continue to be present at rates higher than predicted by chance in adult speakers of these and other

languages (MacNeilage et al., 2000a). The fact that these patterns are retained in languages and are present in infants from different language environments, the seven in the present study of Quichua, as well as 5 French, 5 Swedish, and 5 Japanese infants, (Boysson-Bardies, 1993), 1 of 2 Brazilian Portuguese children (Teixeira & Davis, submitted), and 1 of 2 Serbian-American bilinguals (Zlatic et al., 1997), suggests that they can be considered a stable attractor in a complex system for infants. To further understand the generality of these patterns during speech acquisition, they need to be explored in additional languages, particularly those that may show differing preferred CV co-occurrence patterns.

Since adult and infant patterns are similar with regard to intrasyllabic and intersyllabic patterns, it could be suggested that the infants are learning these motor patterns through exposure to the ambient language. If motor skill learning were occurring, one would expect to see a gradual increase in the frequency of a particular element, becoming more and more similar to the adult language as time progressed. What appears instead is a stronger occurrence of these CV co-occurrence patterns in the infants than in adults, with a weaker influence in languages. For this reason it appears more appropriate to describe these patterns as stable attractors, prevailing in infant babbling and words and at a lesser level in adult languages as the need for perceptual distinctiveness increases.

Ambient Language Influences

Consonant Inventory

While similarities in consonant inventory between Quichua and English-learning infants predominates, indicating the importance of production factors, consonant inventory showed the strongest ambient language effects. In babbling, Quichua and English-learning infants primarily produced coronal stops, nasals, and glides as has been noted in other studies of this period (Davis & MacNeilage, 1995a; Oller et al., 1976; Vihman et al., 1986; Vihman et al., 1985). In addition, both groups produced few liquids (Gildersleeve-Neumann et al., 2000). What stands out in these findings is the predominance of basic sounds (Lindblom, 1992) in the babbling and words of all the infants in both Quichua and English. Stop, nasal, and glide manner and labial and coronal place of articulation account for the majority of speech productions in babbling in both language environments. The findings that coronals > labials > dorsals mirror findings from previous studies of babbling (Boysson-Bardies & Vihman, 1991; Davis & MacNeilage, 1995a; Roug, Landberg, & Lundberg, 1989; Stoel-Gammon, 1985).

Nine to 13 month old Quichua and English-learning infants did not differ in consonant place or manner categories, despite differences in the ambient language environment frequency for these sound characteristics. By 17 to 22 months of age Quichua infants produced significantly more dorsals, significantly fewer labials, and significantly more fricatives and affricates than English-learning infants, indicating ambient language effects in the context of frequencies

of these sound types in their ambient environment. These findings suggest that production constraints have a primary influence during early babbling, but that during the late babbling age, ambient language influences may begin to appear in infants' speech productions. The differences in the frequency of fricatives and affricates, sounds requiring greater tongue precision in their production (Gildersleeve-Neumann et al., 2000), appear to be effects of the ambient language environment. Unlike previous studies in which ambient language properties are alluded to but not analyzed, this study has carefully compared both adult and infant speech properties to understand whether differences in infants may be influenced by differences in the adult languages.

In early words, Quichua and English-learning infants did not differ in their relative use of consonant manner. This was despite ambient language influences for greater frequency of fricatives and affricates and fewer liquids in Quichua. However, consonant place of articulation differed significantly by language group. In words, Quichua infants produced significantly fewer words with labials than English-learning infants. The frequency of labials decreased from babbling to words in Quichua infants, potentially reflecting the lower frequency of labials in Quichua speakers. This decrease in labials in first words is not consistent with reports for English-learning infants (MacNeilage et al., 1997; Stoel-Gammon, 1985) or for infants learning Swedish, French and Japanese in the first word period (Boysson-Bardies & Vihman, 1991).

The decrease in labials in first words of these Quichua infants challenges the generality of the prediction that a labial increase is due to a regression to a

more basic mandibular oscillation cycle with a tongue neutral placement. This regression is thought to occur as the result of the increase in lexical demands of attaching meaning to sound patterns in first words (Davis et al., in press; MacNeilage et al., 1997). This prediction suggested that ease of production effects would be strong enough that a significant increase in labials would be observed in infants even in language environments with lower frequencies of labials. The findings from the present study suggest that ambient language effects may be in part determining the frequency of labials, at least in languages where labials are less frequent. It suggests that the increase in labials in English infants and infants in languages with generally higher frequencies of labials than Quichua may not be solely based on production factors, but may potentially reflect a greater frequency of labials in words in the infants' ambient language. However, the Quichua infants produced few words. If Quichua infants' vocalizations are not attached to meaning until later in development (perhaps from 24 to 36 months), what might be observed is a more general freedom from functional load factors like that observed in English-learning infants later in development. It may be at a later point in development that an increase in labials is observed in Quichua infants' words. It would be necessary to collect data from Quichua infants during a more prolific word production period to determine if this is the case.

Vowel Inventory

Vowel inventories were also similar between Quichua and English-learning infants. Both groups primarily produced vowels in the lower left

quadrant: low and mid front and central vowels. The preponderance of these vowels is consistent with previous research on infant vowel productions (Davis & MacNeilage, 1990; Kent & Bauer, 1985; Locke, 1983) and suggests production constraints guide vowel productions. However, there were vowel production differences late in babbling that appear to reflect limited ambient language influences.

Vowel inventories differ markedly between Quichua and English. English has thirteen monophthongs, produced at all possible vowel height and front/back dimensions with the exception of high central. Quichua has only three: a high-front /i/, a low-central /a/, and a high-back /u/. Unlike Quichua adults, Quichua infants primarily produced front and central mid vowels, with low vowels and back vowels infrequently in both babbling and words. In babbling and words, both Quichua and English-learning infants showed preferences for lower-left quadrant vowels. These findings are consistent with previous findings on vowel acquisition (Bickley, 1983; Buhr, 1980; Davis & MacNeilage, 1995a; Kent & Bauer, 1985; Lieberman, 1980) and suggest the generality of vowels produced with forward or neutral tongue placement and little jaw constriction during early speech acquisition.

Vowel productions during babbling differed slightly between language groups. Quichua infants produced fewer back vowels and more mid vowels than English-learning infants. Nine to 13 month olds did not significantly differ in vowel front/back patterns, although Quichua infants produced more mid vowels. These differences do not appear to be the result of ambient language influences.

From 17 to 22 months, Quichua infants produced more high vowels and English-learning infants produced more low vowels, reflecting ambient language frequencies. In words, there were no differences between Quichua and English-learning infants in vowel front/back or height frequencies.

Thus, progression towards vowel differentiation based on ambient language influences was observed in late babbling. In words, Quichua and English-learning infants did not vary significantly in vowel inventories. This appears to be due to individual variation, resulting in greater within-group than across-group differences. The preference for central vowels in Quichua infants suggests ambient language influences, with the continued preference for mid vowels demonstrating production effects, since no mid vowels exist in Quichua.

Utterance Length Patterns

Word length differs dramatically between Quichua and English. Words are typically much longer in Quichua, with the one-syllable words typical of English unusual in Quichua. Quichua is an agglutinative language and the majority of the words in Quichua are three-or-more syllables in length. Quichua infants did not show these ambient language tendencies for word shape in babbling, as babbling utterances in Quichua were predominantly one-syllable. From 9 until 17 months, Quichua infants produced shorter babbling utterances than English-learning infants. From 17 to 22 months, both infant groups primarily produced one-syllable babbling.

In early words, ambient language effects on word length were observed. Quichua infants primarily produced two-syllable words. English-learning infants overwhelmingly produced one-syllable words, while one-syllable words were infrequent in Quichua infants. What is apparent in words in both languages is the lack of morphological endings. Specifically, the majority of early words in Quichua infants were produced in their root forms. This result supports research suggesting that first words are produced in their root forms without grammatical markers (Bloom, 1973; Brown, 1973). Based on these results the influence of the language on first words results in differences in word length in infants from the onset of words.

It seems counterintuitive that the children from the language with longer words produced shorter babbling utterances. Many English-based studies have suggested that monosyllables are most prevalent in babbling (Davis & MacNeilage, 1995a; Kent & Bauer, 1985; Vihman et al., 1986; Vihman et al., 1985). However, some studies have suggested that in languages with more multisyllabic words, infant babbling and words are composed of more multisyllabic utterances (Ingram, 1981; Levitt & Aydelott-Utman, 1992; Oller & Eilers, 1982; Vogel, 1975). While the current findings for words are consistent with previous studies, the findings for babbling are not.

There have been claims that longer babbling strings are more difficult than shorter ones (Boysson-Bardies, 1999). From a frame dominance perspective, longer babbling strings would result from repeated frames, simply reduplication of mandibular oscillation cycles. These fit with the present findings of a high

occurrence of reduplicated syllables in multisyllabic utterances and preferences for consonant manner over place changes in variegated utterances. Thus while ambient language influences did not lead to the increased occurrence of one-syllable utterances, it does not appear that production factors were clearly the cause either.

Another hypothesis is that shorter length of babbling utterances in Quichua may be a result of cultural influences. Quichua adult-infant vocal interaction is not encouraged to the same degree as it is in mainstream American culture. Quichua speakers in general are quieter than English speakers, with volubility not highly valued in the culture. One parent expressed concern to me that his child was “disordered” because he talked a lot! Perhaps pre-meaningful babbling strings are longer in English and European language environments because of the greater cultural importance placed on volubility (Boysson-Bardies, 1999), thus resulting in encouragement of vocalizations and greater interaction with the infant. Since volubility is highly valued in English-learning environments, infants may receive more reinforcement of longer babbling strings and receive the feedback to continue producing them.

Cultural influences also appear important in explaining the infrequency of words in the Quichua infants. From 17 to 22 months of age, 3.5% of Quichua infants' utterances were words; during the same period, 50% of English-learning infants' were words. This discrepancy made some analyses difficult, particularly those requiring multisyllabic words. Results were complicated to interpret based on low frequency of word occurrence. Such a low level of word production in

two-year-olds would be cause for concern related to language delay if these infants were in the U.S. Yet parent report, hearing screenings, and observation suggested that these children were not language-delayed, but were typically-developing Quichua infants.

As mentioned, there are a number of obstacles to the data interpretation, which may have resulted in reporting word frequencies at a rate lower than they actually were occurring. Typically words are identified through mutual agreement of the parents and the researcher (e.g., Davis et al., in press). In this study, this identification process was extremely difficult to fulfill for many reasons. The families of these infants were illiterate and may have lacked the metalinguistic skill to identify abbreviated word forms as words in their infants. The emphasis on word emergence does not exist in Quichua culture as it does in American culture, and parents were neither accustomed to nor placed high value on identifying words in their infants' utterances. In addition, the author's limited knowledge of Quichua, and absence of prior research on typical first words in Quichua infants, complicated the process of identifying words. For an utterance to be categorized as a word in Quichua required that it be close to its correct phonetic form and that it be treated as communication by the parents. For the above reasons, it is likely that some proportion of early word attempts were not labeled in Quichua in situations where they would have been in U.S. cultural contexts.

Even if many words were not identified in Quichua, it still seems likely that the Quichua infants produced fewer words than English-learning infants did.

From a cultural perspective this is not surprising. Word use is not as necessary for Quichua infants. Their needs are more quickly addressed than those of infants in Western societies since they are constantly carried and many needs are communicated and responded to nonverbally. Communicative attempts are not encouraged by adults to the degree they are in Western society. Even if Quichua infants were attempting meaningful utterances, Quichua adults may not have responded to them as readily as do mainstream American adults.

It does not appear the case that infants are unable to produce words, rather that words are unnecessary for communication needs at this point in a Quichua infants' development. In this study, Adelaida, who was 16 months at the onset of the study, and 22 months at its completion, produced only one word in her first five taping sessions. In the seventh session, her older sister played a naming game with her, requesting that Adelaida repeat various words. Adelaida complied with gusto, yelling highly intelligible nouns, verbs, and deictic terms. Adelaida produced 32 words during this session, and 46 words in her last session, where the game continued. However, outside of the game, the only word she used to communicate needs was the Quichua word for "another." The vast majority of Adelaida’s words contained labials, as has been noted in first words of infants from other language environments. However, her words were solicited rather than spontaneous, and her preference for labials was not observed in the first words of the other Quichua infants.

Other studies have noted differences from U.S. language development expectations based on differing cultural environments. Research on the Kwara'ae

of the Solomon Islands (Watson-Gegeo & Gegeo, 1986) and the Kaluli of New Guinea (Schieffelin & Ochs, 1983) have shown that the integration of infants into the social community is more highly valued than volubility. In both cultures, infants are not spoken to directly. A study of Japanese and Canadian infants and their caregivers suggested that adults apply different cultural rules in responding to preverbal infants, with the Japanese reacting significantly less favorably to infant mouth movements than Canadians (Bloom & Masataka, 1996). A study of language development in Inuit culture found a greater emphasis on nonverbal than verbal interactions in children, noting that linguistic aspects of the acquisition of communication were not as highly valued as communicative social interactions (Crago, 1990; Crago, 1992). In the U.S., differences in language development based on cultural values in white and black working class households in Appalachia have been reported (Heath, 1993). In addition, American parents have been described as having a greater tendency for "vocabulary illusion" than parents from other cultures (Boysson-Bardies, 1999: 129). In other words, American adults credit infants with words when the speech production differs markedly from the adult phonetic form, productions that would be highly unlikely to be identified as words in many other cultures.

Thus the findings that Quichua infants produce few words during the same period that white middle class American infants are producing many words is not surprising. Communication between adults and children in a Quichua culture differs from that in Western culture. One of the many ways we differ is in the use of verbal language: U.S. culture removes children from adult's daily life, requires

more explicit messages, and relies on more verbal than nonverbal communication (Rogoff, 1990). Also, the high value placed on verbal communication and the fact that infants are not participants in the adult world in the U.S. results in the need to "teach" language to children, in the form of simplification of the message. As Rogoff has stated, "children in cultures that do not strictly segregate them from adult activities may develop largely in the context of observing and participating in adult activities, with children being responsible for learning through active observation, sometimes with little adult-child reciprocal conversation" (Rogoff, 1990, p. 20).

Perhaps Quichua infants produce fewer words because the need to use oral language is much lower than it is for English-learning infants. They are not separated from adults but learn by observing and being passive participants in many adult activities. Repetitive narration skills are not highly valued as they are in Western culture - it is unnecessary to excel in the manner we are accustomed to for reciting what ones' day involved as the infant is with or near a parent who performs very similar activities every day. Because infants are carried or held the majority of the day, their needs are well known to their caregivers and don't require verbalization. U.S. infants, on the other hand, participate in many didactic interchanges, perhaps because they require early use of words to communicate in a culture that removes them from day-to-day participation in adult activities.

CONCLUSION

Production factors were found to be the major element contributing to the pre-linguistic and early word-based speech patterns observed in these Quichua infants. The importance of production factors in the form of predicted CV co-occurrence patterns as well as intersyllabic variegation patterns points to the predominance of child-internal production constraints over perceptual influences from the ambient language in this early speech acquisition period. The infants' productions in the two language environments were more similar than the Quichua infants' speech productions were to the adult language models. Infants from both language environments primarily produced stops and nasals at the coronal place of articulation, vowels in the lower left quadrant of the vowel space, syllables with a simple consonant-vowel structure, one-syllable utterances, as well as similar predicted intrasyllabic CV co-occurrence and intersyllabic consonant-consonant and vowel-vowel variegation patterns.

Evidence for ambient language influences was apparent in certain aspects of the infants' productions, particularly consonant inventories in babbling and early words, vowel inventories in late babbling, and utterance length in early words. Dorsals, fricatives, and affricates occurred with more frequency in Quichua than English-learning infants, mirroring the greater frequency of these sounds in the ambient language environment. Labials and liquids, which are infrequent in Quichua, occurred less frequently in Quichua than English-learning infants. Late in babbling, Quichua infants produced more low vowels, consistent with the ambient language. Quichua infants produced more two- and three-or-

more syllable words than English-learning infants did, mirroring the frequent production of multisyllabic words in Quichua. These language-specific influences add a new dimension to predictions based on production influences in this early period of speech acquisition. They indicate that the effects of the ambient language must be incorporated into our understanding of speech acquisition. It should be noted however, that the longer utterances could be seen as frame re-iterations which indicates interaction between patterns available to the production system that may be utilized when the ambient language environment makes them perceptually salient to the infant.

In addition to the information this study provides on sound and sound combination patterns during speech acquisition, findings on limited word use during the early word period and shorter babbling length are new and point to the importance of taking cultural information into account when interpreting research. The lower level of word use is likely both a confounding of methodological issues and cultural differences. A study of word acquisition that follows Quichua infants for a longer period could help to determine the effects each of these factors may play on word use.

In understanding early acquisition of speech production skill we run the risk of taking specific cultural values and goals for granted unless we apply pressure based on cross-cultural research, especially in non-Indo-European language contexts. Continued large-scale longitudinal studies of speech acquisition are necessary to evaluate what have been considered universal factors and separate out those which may be ambient language or cultural factors.

It appears that in the dynamic systems sense many production factors are stable attractors during development, although some may be more stable than others. Mandibular oscillation frames resulting in consonant-vowel co-occurrence patterns within syllables appears to be an extremely stable attractor during development, one which also persists in adult languages in the form of a preponderance of predicted syllable shapes based on proximity of the articulators for the consonant and vowel. These predicted co-occurrence have also been found to predominate in protowords, or words thought to be from the hypothesized original human language, suggesting that the frame may have played a fundamental role in the origin of speech (MacNeilage & Davis, 2000). This frame appears to be an extremely stable attractor because of its production ease, utilizing basic biomechanical properties necessary for mandibular open and close cycles, with minimal movement of the articulators within the cycle.

Ambient language and cultural influences observed, despite the strength of production factors, support the suggestion that an example of a stable attractor in humans may be the need to communicate (Thelen & Smith, 1995). Language must be viewed as part of the process of motivated perception, categorization, and motor skill. Thus child-internal production constraints, such as the production of frames, form a potent stable state in infants and are retained in languages. However, the infant's need to interact with the environment also forms a crucial component in the acquisition of speech production overall.

Results from the present study have implications for the design of future studies of speech acquisition. Additional studies are needed to confirm and/or

challenge the findings reported in this study. Studies in a variety of cultures are necessary to determine what role culture has in development. Future research should also include acoustic analysis to understand transcription differences, verifying or refuting impressionistic findings which have been problematic in this study, particularly in the occurrence of dorsal-central combinations and the relatively greater frequency of predicted consonant-vowel co-occurrences than had previously been found in English. Continued study of Quichua infants at later stages of development in which words are more prevalent would be useful in determining whether labial increases also occur in this language environment, and whether anterior-posterior patterns predominate in a language where dorsals are higher in frequency in the ambient environment.

It will be through continued study of speech acquisition in diverse language environments, as well as under differing developmental conditions, such as hearing loss, that we can understand which aspects of speech acquisition are the result of production factors, internal to the child, and which are the result of motor skill learning via perceptual factors both internal and external to infants. It is important that future cross-language studies also take careful note of the ambient language properties to validly ascertain the significance of the effects of the language spoken around infants. This type of study also reveals what properties in early acquisition may be basic to the productions system and are retained in adult speakers. These patterns may be ultimately seen as basic aspects of complex serial action in humans retained in languages rather than facets of

early speech acquisition lost with development of more facility in skilled movement sequences.

BIBLIOGRAPHY

Bell, A., & Hooper, J. B. (Eds.). (1978). *Syllables and segments*. Amsterdam.

Best, C. T., McRoberts, G. W., & Sithole, N. M. (1988). Examination of perceptual reorganization for nonnative speech contrasts: Zulu click discrimination by English-speaking adults and infants. *Journal of Experimental Psychology: Human Perception and Performance, 14*(3), 345-360.

Bickley, C. (1983). *Acoustic evidence for phonological development of vowels in young infants.* Paper presented at the Tenth International Congress of Phonetic Sciences, Utrecht, The Netherlands.

Bloom, K., & Masataka, N. (1996). Japanese and Canadian impressions of vocalising infants. *International Journal of Behavioral Development, Vol 19*(1), 89-99.

Bloom, L. (1973). *One word at a time: The use of single-word utterances before syntax*. The Hague: Mouton.

Bosma. (1975). Acoustic and physiologic development of the speech apparatus. In D. B. Tower (Ed.), *The Nervous System* (Vol. 3: Human communication and its disorders, pp. 469-481). New York: Raven Press.

Boysson-Bardies, B. (1993). Ontogeny of language-specific syllabic productions. In B. Boysson-Bardies, S. de Schonen, P. Jusczyk, P. MacNeilage, & J. Morton (Eds.), *Developmental neurocognition: Speech and face processing in the first year of life* (pp. 353-363). The Netherlands: Kluwer Academic Publishers.

Boysson-Bardies, B. (1999). *How language comes to children: From birth to two years.* Cambridge, MA, USA: MIT Press.

Boysson-Bardies, B., Hallé, P., Sagart, L., & Durand, C. (1989). A cross-linguistic investigation of vowel formants in babbling. *Journal of Child Language, 16*, 1-17.

Boysson-Bardies, B., Sagart, L., & Bacri, N. (1981). Phonetic analysis of late babbling: A case study of a French child. *Journal of Child Language, 8*, 511-524.

Boysson-Bardies, B., Sagart, L., & Durand, C. (1984). Discernible differences in the babbling of infants according to target language. *Journal of Child Language, 11*, 1-15.

Boysson-Bardies, B., & Vihman, M. M. (1991). Adaptation to language: Evidence from babbling and first words in four languages. *Language, 67*(2), 297-319.

Boysson-Bardies, B., Vihman, M. M., Roug-Hellichius, L., Durand, C., Landberg, I., & Arao, F. (1992). Material evidence of infant selection from the target language. In C. A. Ferguson, L. Menn, & C. Stoel-Gammon (Eds.), *Phonological Development* (pp. 369-392). Parkton, MD: York Press.

Brown, R. (1958). *Words and things*. Glencoe, Illinois: Free Press.

Brown, R. (1973). *A first language: The early stages*. Cambridge, England: Harvard University Press.

Bryk, A. S., & Raudenbush, S. W. (1992). *Hierarchical linear models: Applications and data analysis methods*. Newbury Park, CA: Sage Publications.

Buhr, R. D. (1980). The emergence of vowels in an infant. *Journal of Speech and Hearing Research, 23*(1), 73-94.

Bush, C. N., Edwards, M. L., Luckau, J. M., Stoel, C. M., Macken, M. A., & Peterson, J. D. (1973). *On specifying a system for transcribing consonants in child language*. Stanford, California: Stanford Child Language Project, Stanford University.

Cerrón-Palomino, R. (1985). Panorama de la lingüística andina. *Revista Andina, 3*(2), 509-569.

Cerrón-Palomino, R. (1987). *Lingüística Quechua*. Cuzco, Perú: Centro de Estudios Rurales Andinos "Bartolomé de las Casas".

Cotocachi, M. M. (1998). Propuesta de la escritura fonológica del Kichwa. *draft*.

Crago, M. B. (1990). Development of communicative competence in Inuit children: Implications for speech-language pathology. *Journal of Childhood Communicative Disorders, 13*(1), 73-83.

Crago, M. B. (1992). Ethnography and language socializaton: A cross-cultural perspective. *Topics in Language Disorders, 12*(3), 28-39.

Davis, B. L. (1991). *Davis Observational Checklist for Texas (DOCT)* [Assessment Tool]. Austin, Texas: Texas Department of Health.

Davis, B. L., & MacNeilage, P. F. (1990). Acquisition of correct vowel production: A quantitative case study. *Journal of Speech and Hearing Research, 33*, 16-27.

Davis, B. L., & MacNeilage, P. F. (1994). Organization of babbling: A case study. *Language and Speech, 37*(4), 341-355.

Davis, B. L., & MacNeilage, P. F. (1995a). The articulatory basis of babbling. *Journal of Speech and Hearing Research, 38*, 1199-1211.

Davis, B. L., & MacNeilage, P. F. (1995b, August 13-19). *Articulatory preferences in first words: The Frame Content hypothesis.* Paper presented at the XIII International Congress of Phonetic Sciences, Stockholm, Sweden.

Davis, B. L., MacNeilage, P. F., Gildersleeve-Neumann, C. E., & Teixeira, E. (1999a). Cross-language studies of consonant-vowel co-occurrence constraints in infants and adults: Ambient language effects in first words. *Paper presented at the 20th Annual Infant Phonology Conference*.

Davis, B. L., MacNeilage, P. F., & Matyear, C. (1999b, August). *Intrasyllabic patterns in babbling and early speech.* Paper presented at the 14th International Congress of Phonetic Sciences, San Francisco, CA.

Davis, B. L., MacNeilage, P. F., & Matyear, C. (in press). Acquisition of serial complexity in speech production: A comparison of phonetic and phonological approaches to first word production. *Phonetica*.

Davis, K. (1995). Phonetic and phonological contrasts in the acquisition of voicing: Voice onset time production in Hindi and English. *Journal of Child Language, 22*(2), 275-305.

Deuchar, M., & Clark, A. (1996). Early bilingual acquisition of the voicing contrast in English and Spanish. *Journal of Phonetics, 24*(3), 351-365.

Dinger, M. C., & Blom, J. G. (1973). An investigation of infant babbling. *Proceedings from the Institute of Phonetic Sciences*.

Eilers, R. E., Oller, D. K., & Benito-García, C. R. (1984). The acquisition of voicing contrasts in Spanish and English learning infants and children: A longitudinal study. *Journal of Child Language, 11*, 313-336.

Fletcher, S. G. (1973). Maturation of the speech mechanism. *Folia Phoniatrica, 25*, 161-172.

Garcés, L. F. (1996). Notas sobre la fonología del quichua ecuatoriano. Universidad Politécnica Salesiana.

Gildersleeve-Neumann, C. E., Davis, B. L., & MacNeilage, P. F. (2000). Contingencies governing the production of fricatives, affricates, and liquids in babbling. *Applied Psycholinguistics, 21*, 341-363.

Grégoire, A. (1937). *L'Apprentissage du langage: Les deux premieres annees*. Paris: Felix Alcan.

Grillner, S. (1981). Possible analogies in the control of innate motor acts and the production of sound in speech. In S. Grillner, B. Lindblom, J. Lubker, & A. Persson (Eds.), *Speech Motor Control*. New York: Pergamon Press.

Grillner, S. (1985). Neurobiological bases of rhythmic motor acts in vertebrates. *Science, 228*, 143-149.

Hallé, P. A., & Boysson-Bardies, B. (1996). The format of representation of recognized words in infants' early receptive lexicon. *Infant Behavior & Development, 19*(4), 463-481.

Hallé, P. A., Boysson-Bardies, B., & Vihman, M. M. (1991). Beginnings of prosodic organization: Intonation and duration patterns of disyllables produced by Japanese and French infants. *Language and Speech, 34*(4), 299-318.

Heath, S. B. (1993). The study of cultural activity: Moving toward multiple approaches in research on child development. *Monographs of the Society for Research in Child Development, 58*(8), 175-79.

Hess, C. G. (1992). *La racionalidad de una economía agropecuaria*. Quito, Ecuador: Abya Yala.

Hodge, M. M. (1989). *A comparison of spectral temporal measures across speaker age: Implications for an acoustical characterization of speech acquisition.* Unpublished doctoral dissertation, University of Wisconsin, Madison.

Ingram, D. (1981). The emerging phonological system of an Italian-English bilingual child. *Journal of Italian Linguistics*, 95-113.

Ingram, D. (1988). The acquisition of word-initial [v]. *Language and Speech, 31*, 77-85.

Jakielski, K. J. (1998). *Motor organization in the acquisition of consonant clusters.* Unpublished doctoral dissertation, University of Texas at Austin, Austin, Texas.

Jakobson, R. (1968/1941). *Child language, aphasia and phonological universals* (Keiler, A., Trans.). The Hague: Mouton & Co.

Jasuta, S. J. (1987). *The phonology of the first 50 words: Phonological process and homonomy.* Unpublished doctoral dissertation, The University of Texas at Austin, Austin, Texas.

Jusczyk, P., Luce, P. A., & Charles-Luce, J. (1994). Infants' sensitivity to phonotactic patterns in the native language. *Journal of Memory and Language, 33*, 630-645.

Jusczyk, P. W. (1992). Developing phonological categories from the speech signal. In C. A. Ferguson, L. Menn, & C. Stoel-Gammon (Eds.), *Phonological development: Models, research, implications* (pp. 17-64). Timonium, Maryland: York Press.

Jusczyk, P. W., Cutler, A., & Redanz, N. J. (1993). Infants preference for the predominant stress patterns of English words. *Child Development, 64*, 675-687.

Jusczyk, P. W., Hirsch-Pasek, K., Kemler-Nelson, D. G., Kennedy, L. J., Woodward, A., & Piwoz, J. (1992). Perception of acoustic correlates of major phrasal units by young infants. *Cognitive Psychology, 24*, 252-293.

Kahane, J. C. (1988). Anatomy and physiology of the organism of the peripheral speech mechanism. In M. H. Lass, L. V. McReynolds, J. L. Northern, & D. E. Yoder (Eds.), *Handbook of Speech-Language Pathology and Audiology* . Philadelphia, PA: B.C. Decker.

Kent, R. D. (1981). Articulatory-acoustic perspectives on speech development. In R. E. Stark (Ed.), *Language behavior in infancy and early childhood*. New York: Elsevier/North Holland.

Kent, R. D. (1992). The biology of phonological development. In C. A. Ferguson, L. Menn, & C. Stoel-Gammon (Eds.), *Phonological development: Models, research, implications* (pp. 65-90). Timonium, Maryland: York Press.

Kent, R. D., & Bauer, H. R. (1985). Vocalizations of one-year-olds. *Journal of Child Language, 12*(3), 491-526.

Kent, R. D., Mitchell, P. R., & Sancier, M. (1991). Evidence and role of rhythmic organization in early vocal development in human infants. In J. Fagard & P. H. Wolff (Eds.), *The Development of Timing Control and Temporal Organization in Coordinated Action* (pp. 135-149). Holland: Elsevier Science Publishers B.V.

Kent, R. D., & Murray, A. D. (1982). Acoustic features of infant vocalic utterances at 3, 6, and 9 months. *Journal of the Acoustical Society of America, 72*(2), 353-365.

Kreft, I., & de Leeuw, J. (1998). *Introducing multilevel modeling*. London: Sage.

Krueger, B. (1995). *On variation in early speech production.* Paper presented at the International Conference on Phonology, Stockholm.

Ladefoged, P. (1975). *A course in phonetics*. New York: Harcourt, Brace and Jovanovich Publishers.

Levelt, C. (1994). *On the acquisition of place.* Unpublished doctoral dissertation, Leiden University, Leiden.

Levitt, A. G. (1993). The acquisition of prosody: Evidence from French- and English-learning infants. In B. Boysson-Bardies, S. de Schonen, P. Jusczyk, P. MacNeilage, & J. Morton (Eds.), *Developmental Neurocognition: Speech and Face Processing in the First Year of Life* (pp. 385-398). The Netherlands: Kluwer Academic Publishers.

Levitt, A. G., & Aydelott-Utman, J. G. (1992). From babbling towards the sound systems of English and French: A longitudinal case study. *Journal of Child Language, 19*, 19-49.

Levitt, A. G., & Wang, Q. (1991). Evidence for language-specific rhythmic influences in the reduplicative babbling of French- and English-learning infants. *Language and Speech, 34*(3), 235-249.

Lieberman, P. (Ed.) (1980). *On the development of vowel productions in young infants*. (Vol. 1: Production). New York: Academic Press.

Lindblom, B. (1986). Phonetic universals in vowel systems. In J. J. Ohala & J. J. Jaeger (Eds.), *Experimental Phonology* (pp. 13-44). Orlando, Florida: Academic Press.

Lindblom, B. (1990). On the notion of "possible speech sound". *Journal of Phonetics, 18*, 135-152.

Lindblom, B. (1992). Phonological units as adaptive emergents of lexical development. In C. Ferguson, L. Menn, & C. Stoel-Gammon (Eds.), *Phonological development: Models, research, implications* (pp. 131-163). Timonium, Maryland: York Press.

Lindblom, B., & Maddieson, I. (1988). Phonetic universals in consonant systems. In L. M. Human & C. N. Li (Eds.), *Language, speech and mind: Studies in honor of V. A. Fromkin* (pp. 62-78). London: Routledge.

Locke, J. (1983). *Phonological acquisition and change*. New York: Academic Press.

Locke, J., & Pearson, D. M. (1992). Vocal learning and the emergence of phonological capacity. In C. Ferguson, L. Menn, & C. Stoel-Gammon (Eds.), *Phonological development: Models, research, implications* (pp. 91-129). Timonium, Maryland: York Press.

Locke, J. L., & Pearson, D. M. (1990). Linguistic significance of babbling: Evidence from a tracheostomized infant. *Journal of Child Language, 17*(1), 1-16.

Lombeida-Naranjo, E. B. (1976). *Ecuadorean highland Quechua phonology*, Unpublished doctoral dissertation, University of Texas at Austin, Austin, Texas.

Macken, M. (1993). Developmental changes in the acquisition of phonology. In B. Boysson-Bardies, L. Sagart, & C. Durand (Eds.), *Developmental Neurocognition: Speech and Face Processing in the First Year of Life*. Dordrecht: Kluwer.

Macken, M. A., & Barton, D. (1980). The acquisition of the voicing contrast in Spanish: A phonetic and phonological study of word-initial stop consonants. *Child Language, 7*, 433-458.

MacNeilage, P. F. (1998). The frame/content theory of evolution of speech production. *Behavioral and Brain Sciences, 21*, 499-546.

MacNeilage, P. F., & Davis, B. (1990). Acquisition of speech production: Frames, then content. In M. Jeannerod (Ed.), *Attention and performance XIII: Motor representation and control* (pp. 453-476). Hillsdale, NJ: Lawrence Erlbaum.

MacNeilage, P. F., & Davis, B. L. (1993). A motor learning perspective on speech and babbling. In B. Boysson-Bardies, S. de Schonen, P. Jusczyk, P. MacNeilage, & J. Morton (Eds.), *Changes in speech and face processing in infancy: A glimpse at developmental mechanisms of cognition* (Vol. 69, pp. 341-352). Dordrecht: Kluwer Academic Publishers.

MacNeilage, P. F., & Davis, B. L. (1999a). Consonant (vowel) consonant sequences in early words. *Proceedings of the Fourteenth International Congress of Phonetic Sciences*, 2489-2492.

MacNeilage, P. F., & Davis, B. L. (1999b). Evolution of the form of spoken words. *Evolution of Communication, 3*(1), 3-20.

MacNeilage, P. F., & Davis, B. L. (2000). On the origin of internal structure of word forms. *Science, 288*(21 April), 527-531.

MacNeilage, P. F., Davis, B. L., Kinney, A., & Matyear, C. L. (1999). Origin of serial-output complexity in speech. *Psychological Science, 10*(5), 459-460.

MacNeilage, P. F., Davis, B. L., Kinney, A., & Matyear, C. L. (2000a). The motor core of speech: A comparison of serial organization patterns in infants and languages. *Child Development, 71*(1), 153-163.

MacNeilage, P. F., Davis, B. L., & Matyear, C. L. (1997). Phonetic regression in first words? *Speech Communication, 22*, 269-277.

MacNeilage, P. F., Davis, B. L., Matyear, C. L., & Kinney, A. (2000b). Origin of speech output complexity in infants and in languages. *Psychological Science*, 459-460.

Maddieson, I. (1984). *Patterns of sounds*. Cambridge: Cambridge University Press.

McCullagh, P., & Nelder, J. A. (1989). *Generalized linear models*. (2nd ed.). London; New York: Chapman and Hall.

Mehler, J., Jusczyk, P. W., Lambertz, G., Halsted, N., Bertoncini, J., & Amiel-Tison, C. (1988). A precursor of language acquisition in young infants. *Cognition, 29*, 143-178.

Mines, M., Hanson, B., & Shoup, J. (1978). Frequency of occurrence of phonemes in conversational English. *Language and Speech, 21*, 221-241.

Ministerio de Educación y Cultura. (1982). Caimi Ñucanchic Shimiyuc-Panca. Quito, Ecuador: Pontificia Universidad Católica del Ecuador.

Moon, C., Cooper, R. P., & Fifer, W. P. (1993). Two-day old infants prefer native language. *Infant Behavioral Development, 16*, 495-500.

Moya, R. (1987). *Principios de lingüística quichua*. (Vol. 5): Centro de documentación e información de los movimientos sociales del Ecuador (CEDIME).

Nittrouer, S., Studdert-Kennedy, M., & McGowan, R. S. (1989). The emergence of phonetic segments: Evidence from the spectral structure of fricative-vowel syllables spoken by children and adults. *Journal of Speech and Hearing Research, 32*, 120-132.

Oller, D. K. (1990). Logical International Phonetics Program (LIPP) (Version 1.4) [Computer software]. Miami, Florida: Intelligent Hearing Systems.

Oller, D. K., & Eilers, R. E. (1982). Similarity of babbling in Spanish- and English-learning babies. *Journal of Child Language, 9*, 565-577.

Oller, D. K., & Lynch, M. P. (1992). Infant vocalizations & innovations in infraphonology: Toward a broader theory of development and disorders. In C. A. Ferguson, L. Menn, & C. Stoel-Gammon (Eds.), *Phonological development: Models, research, implications* (pp. 509-536). Timonium, Maryland: York Press.

Oller, D. K., & Steffens, M. L. (1993). Syllables and segments in infant vocalizations and young child speech. In M. Yavas (Ed.), *First and Second Language Phonology* . San Diego: Singular Press.

Oller, D. K., Wieman, L. A., Doyle, W. J., & Ross, C. (1976). Infant babbling and speech. *Journal of Child Language, 3*, 1-11.

Olney, R. L., & Scholnick, E. K. (1976). Adult judgments of age and linguistic differences in infant vocalization. *Journal of Child Language, 3*, 145-155.

Orr, C. (1978). *Dialectos Quichua del Ecuador* (Vol. 2). Quito, Ecuador: Instituto Lingüístico de Verano.

Piske, T. (1995). *Articulatory patterns in early speech production.* Paper presented at the International Conference on Phonology, Stockholm.

Polka, L., & Werker, J. F. (1994). Developmental changes in perception of nonnative vowel contrasts. *Journal of Experimental Psychology: Human Perception and Performance, 20*(2), 421-435.

Pujol, R., Lavigne-Rebillard, M., & Uziel, A. (1991). Development of the human cochlea. *Acta Oto-Laryngologica - Supplement, 482*, 7-12.

Pye, C. (1986). One lexicon or two?: An alternative interpretation of early bilingual speech. *Journal of Child Language, 13*, 591-593.

Pye, C., Ingram, D., & List, H. (1987). A comparison of initial consonant acquisition of English and Quiché. In K. E. Nelson & A. van Kleeck (Eds.), *Children's Language* (Vol. 6, pp. 175-190). Hillsdale, New Jersey: Lawrence Erlbaum.

Querleu, D., Renard, X., Boutteville, C., & Crepin, G. (1988). Fetal hearing. *European Journal of Obstetrics, Gynecology, & Reproductive Biology, 28*(3), 191-212.

Redford, M. A., MacNeilage, P. F., & Davis, B. L. (1997). Production constraints on utterance-final consonant characteristics in babbling. *Phonetica, 54*, 172-186.

Rogoff, B. (1990). *Apprenticeship in thinking: Cognitive development in social context*. New York: Oxford University Press.

Roug, L., Landberg, I., & Lundberg, L. J. (1989). Phonetic development in early infancy: A study of four Swedish children during the first eighteen months of life. *Journal of Child Language, 16*, 19-40.

Schieffelin, B. B., & Ochs, E. (1983). A cultural perspective on the transition from prelinguistic to linguistic communication. In R. M. Golinkoff (Ed.), *The transition from prelinguistic to linguistic communication*. Hillsdale, New Jersey: Erlbaum.

Smith, B. L., Brown-Sweeney, S., & Stoel-Gammon, C. (1989). A quantitative analysis of reduplicated and variegated babbling. *First Language, 9*, 175-190.

So, L. K. H., & Dodd, B. J. (1995). The acquisition of phonology by Cantonese-speaking children. *Journal of Child Language, 22*, 473-495.

Stager, C. L., & Werker, J. F. (1997). Infants listen for more phonetic detail in speech perception than in word-learning tasks. *Nature, 388*(July 24,), 381-382.

Stark, R. E. (1980). Stages of speech development in the first year of life. In G. H. Yeni-Komshian, J. Kavanagh, & C. A. Ferguson (Eds.), *Child phonology: Production* (Vol. 1, pp. 73-91). New York: Academic Press.

Stoel-Gammon, C. (1985). Phonetic inventories, 15-24 months: A longitudinal study. *Journal of Speech and Hearing Research, 28*, 505-512.

Stoel-Gammon, C., & Cooper, J. (1984). Patterns of early lexical and phonological development. *Journal of Child Language, 11*, 247-71.

Stoel-Gammon, C., & Dunn, J. (1985). Normal phonological development. In C. Stoel-Gammon & J. Dunn (Eds.), *Normal and disordered phonology in children* (pp. 15-46). Baltimore: University Park Press.

Studdert-Kennedy, M. (1986). Sources of variability in early speech development. In J. S. Perkell & D. H. Klatt (Eds.), *Invariance and variability in speech processes.* (pp. 58-84). Hillsdale, NJ, USA: Lawrence Erlbaum Associates, Inc.

Teixeira, E. R. (1980). *A study of articulation testing with special reference to Portuguese.* Unpublished doctoral dissertation, University of London, London.

Teixeira, E. R., & Davis, B. L. (submitted). Early sound patterns in the speech of two Brazilian Portuguese speakers.

Thelen, E., Kelso, J. A. S., & Fogel, A. (1987). Self-organizing systems and infant motor development. *Developmental Review, 7*, 39-65.

Thelen, E., & Smith, L. B. (1995). *A dynamic systems approach to the development of cognition and action*. Cambridge, MA: A Bradford Book, MIT Press.

Thevenin, D. M., Eilers, R. E., Oller, D. K., & Lavoie, L. (1985). Where's the drift in babbling drift? A cross-linguistic study. *Applied Psycholinguistics, 6*, 3-15.

Torero, A. (1972). Lingüística e historia de la sociedad andina. In A. Escobar (Ed.), *El Reto del Multilingüismo en el Perú* (pp. 51-106). Lima: IEP.

Torero, A. (1983). La familia lingüística quechua. In B. Pottier (Ed.), *America Latina en sus lenguas indígenas* (pp. 61-92). Caracas, Venezuela: UNESCO - Monte Avila.

Tuaycharoen, P. (1978). The babbling of a Thai baby: Echoes and responses to the sounds made by adults. In N. Waterson & C. Snow (Eds.), *The development of communication* (pp. 111-125). Chicester, Great Britain: John Wiley & Sons, Ltd.

van Gelder, T., & Port, R. F. (1995). It's about time: An overview of the dynamical approach to cognition. In R. F. P. Port & T. van Gelder (Eds.), *Mind as motion: Explorations in the dynamics of cognition* (pp. 1-43). Cambridge, Massachusetts: The MIT Press.

Vihman, M. M. (Ed.). (1978). *Consonant harmony: Its scope and function in infant language*. Stanford, CA: Stanford University Press.

Vihman, M. M. (1985). Language differentiation by the bilingual infant. *Journal of Child Language, 12*, 207-324.

Vihman, M. M. (1992). Early syllables and the construction of phonology. In C. A. Ferguson, L. Menn, & C. Stoel-Gammon (Eds.), *Phonological development: Models, research, implications* (pp. 393-421). Timonium, Maryland: York Press.

Vihman, M. M., DePaolis, R., & Davis, B. L. (1998). Is there a "trochaic bias" in early word learning: Evidence from infant production in English and French. *Child Development, 69*(4), 935-949.

Vihman, M. M., Ferguson, C. A., & Elbert, M. (1986). Phonological development from babbling to speech: Common tendencies and individual differences. *Applied Psycholinguistics, 7*, 3-40.

Vihman, M. M., Macken, M. S., Miller, R., Simmons, H., & Miller, J. (1985). From babbling to speech: A re-assessment of the continuity issue. *Language, 61*(2), 397-427.

Vihman, M. M., & McCune, L. (1994). When is a word a word? *Journal of Child Language, 21*, 517-542.

Vogel, I. (1975). One system or two: An analysis of a two-year-old Romanian-English bilingual's phonology. *Papers & Reports on Child Language Development, 9*, 43-62.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Watson-Gegeo, K. A., & Gegeo, D. W. (1986). Calling-out and repeating routines in Kwara'ae children's language socialization. In B. B. Schieffelin & E. Ochs (Eds.), *Language socialization across cultures* (pp. 17-50). New York: Cambridge University Press.

Werker, J. F., & Lalonde, C. E. (1988). Cross-language speech perception: Initial capabilities and developmental change. *Developmental Psychology, 24*, 672-683.

Werker, J. F., & Pegg, J. E. (1992). Infant speech perception and phonological acquisition. In C. A. Ferguson, L. Menn, & C. Stoel-Gammon (Eds.), *Phonological development: Models, research, implications* (pp. 285-311). Timonium, Maryland: York Press.

Werker, J. F., & Tees, R. C. (1983). Developmental changes across childhood in the perception of non-native speech sounds. *Canadian Journal of Psychology, 37*, 278-286.

Werker, J. F., & Tees, R. C. (1984). Cross-language speech perception: Evidence for perceptual reorganization during the first year of life. *Infant Behavior and Development, 7*, 49-63.

Werker, J. F., & Tees, R. C. (1999). Influences on infant speech processing: Toward a new synthesis. *Annual Review of Psychology, 50*, 509-535.

Whalen, D. H., Levitt, A. G., & Wang, Q. (1991). Intonational differences between the reduplicative babbling of French- and English-learning infants. *Journal of Child Language, 18*, 501-516.

Zlatic, L., MacNeilage, P. F., Matyear, C. L., & Davis, B. L. (1997). Babbling of twins in a bilingual environment. *Applied Psycholinguistics, 18*, 453-469.

Zmarich, C., & Lanni, R. A. (1999). Phonetic and acoustic study of babbling in an Italian infant. *Proceedings of the 5th International Conference on Spoken Language Processing, 2*, 2703-2706.