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Developmental Variation in Children's Acquisition of Metrical Structure: How early treatment of stressless syllables can inform phonological theory

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DEVELOPMENTAL VARIATION IN CHILDREN'S ACQUISITION OF METRICAL STRUCTURE

HOW EARLY TREATMENT OF STRESSLESS SYLLABLES CAN INFORM PHONOLOGICAL THEORY

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Abstract

The present study uses 26 color photos to elicit a total of 14 words conforming to a very specific pattern: a stressless syllable word-initially, followed by a stressed syllable, and at most one more stressless syllable. This was found to be a particularly difficult metrical structure for the two- and three-year old participants to produce in an adult-like manner. Based on the findings that a fairly reliable (if language-particular) order of acquisition is observable for contrasts of both place and manner of articulation, the case is made for a system of six emergent features, which may be characterized as combinable phonological elements. The predictive power of such elements is best exploited when they are arranged into a specific, psychologically plausible order of acquisition. When properly ordered, these emergent elements are capable of explaining a great deal of the observed phonological variation.

Table of Contents

Acknowledgements iv

Abstract v

Table of Contents vi

List of Tables ix

1. Introduction 1

    1.1. Motivation 1

    1.2. Background Research 3

    1.3. Purpose of Study 4

    1.4. Overview of Chapters 5

2. Research Methods 7

    2.1. Participants 7

    2.2. Materials 8

    2.3. Procedure 10

3. Results of Study 12

    3.1. Overview of Responses 12

    3.2. Overall Tendencies 18

    3.3. Individual Strategies 21

    3.4. Usage of Dummy Syllables 30

    3.5. Summary 35

4. Discussion 36

    4.1. The Need for Emergent Features 36

    4.2. Building an Inventory with Emergent Elements 41

    4.3. Application of the Framework to English 47

4.4. Analyses of Observed Alternations 55

5. Conclusion 60

5.1. Overall Findings 60

5.2. Limitations of Study 61

5.3. Recommendations 62

References 63

Appendices 67

A. IRB Letter of Approval 67

B. Overall Production Data 68

C. Individual Production Data 71

C.1. M3C (3;5;19) 73

C.2. M2B (2;7;7) 74

C.3. M2D (2;10;0) 75

C.4. M2A (2;6;5) 76

C.5. F2B (2;10;0) 77

C.6. F2D (2;11;16) 78

C.7. F4A (3;7;27) 79

C.8. F4C (3;11;27) 80

C.9. F1 (2;2;12) 81

C.10. M2C (2;8;8) 82

C.11. F2E (2;11;22) 83

C.12. M3A (3;1;13) 84

C.13. M1 (2;3;25) 85

C.14. F2A (2;9;16) 86

C.15. M3B (3;5;15) 87

C.16. F2C (2;11;15) 88

C.17. F3 (3;3;28) 89

C.18. M3D (3;5;27) 90

C.19. M4 (3;6;16) 91

C.20. F4B (3;11;26) 92

D. Common Words Fitting the WS(W) Pattern 93

Vita 97

List of Tables

3.1. Tally of target word production by individual participants 13

3.2. Participants' accuracy in first syllable production 14

3.3. Proportions of response types by individual participant 15

3.4 Proportions of response types by target vocabulary item 16

3.5. Relative difficulty ratings of the target vocabulary items' word-initial onsets 17

3.6. Relative difficulty ratings for word-initial onsets 18

3.7. Relative difficulty ratings for voiced vs. voiceless onsets 19

3.8. Relative difficulty ratings for simple vs. complex onsets 19

3.9. Relative difficulty ratings for stop onsets at three places of articulation 19

3.10. Average syllable reduction and initial syllable stress for individual participants 22

3.11. Tally of phonological simplifying processes used by individual participants 25

3.12. Total instances of WISS onset selection and adaptation for individual participants 28

3.13. Adjusted WISS onset selection and adaptation figures 29

3.14. Usage of dummy syllables by participant, item, and method of application 31

3.15. A process approach to dummy syllable usage 33

4.1. Distribution of word-initial stops in the vocabulary of Spanish-speaking children 36

4.2. Distribution of common WISS onsets by major place of articulation 37

4.3. Distribution of common WISS stop onsets by place of articulation 37

4.4. Traditional taxonomy of the phonemic inventory of Gikuyu 41

4.5. Emergent elements proposed for Gikuyu 42

4.6. The phonemic inventory of Gikuyu recast in terms of emergent elements 46

4.7. Traditional taxonomy of the phonemic inventory of English 47

4.8. Emergent elements proposed for English 48

4.9. The phonemic inventory of English recast in terms of emergent elements 53
B.1. Phonetic forms of participant utterances of the most frequently identified targets 68
B.2. Phonetic forms of participant utterances of the least frequently identified targets 70
C.1. Production data for participant M3C 73
C.2. Production data for participant M2B 74
C.3. Production data for participant M2D 75
C.4. Production data for participant M2A 76
C.5. Production data for participant F2B 77
C.6. Production data for participant F2D 78
C.7. Production data for participant F4A 79
C.8. Production data for participant F4C 80
C.9. Production data for participant F1 81
C.10. Production data for participant M2C 82
C.11. Production data for participant F2E 83
C.12. Production data for participant M3A 84
C.13. Production data for participant M1 85
C.14. Production data for participant F2A 86
C.15. Production data for participant M3B 87
C.16. Production data for participant F2C 88
C.17. Production data for participant F3 89
C.18. Production data for participant M3D 90
C.19. Production data for participant M4 91
C.20. Production data for participant F4B 92

Chapter 1: Introduction

1.1. Motivation

Across languages, metrical structure has been shown to be an important factor in the mental representation of phonological systems (e.g. Gerken, 1991; Fisher & Tokura, 1996; Harris & Edmund, 2003). Nowhere is this more evident than in the early pronunciation of young children. Their apparent errors are often guided by systematic phonological principles, which have the overall effect of simplifying their nascent sound system as a whole. A strict separation of prosody and speech segments is impossible as a modification to one aspect of pronunciation typically affects the other. Accordingly, over-generalized phonological patterns do not always result in the simplification of individual words. A child's simplistic representation of a given word may occasionally result in what could be interpreted as a *more* complex phonological structure than the adult counterpart.

An example of such a paradoxical mispronunciation is my own daughter's substitution of something like [tu'bjanə] for the word *banana*. Her mental representation of the word would seem to be at least as complex as that of an adult, until you consider that early in her pronunciation of English, the only syllable that could possibly occur without stress at the start of a word was [tu]. Other forms included [tu'ʤaməz] for *pajamas*, [tu'gɛn] for *again*, and [tu'lɪʃəs] for *delicious*. It would seem that such common words as *today*, *tomorrow*, and *together* (all active in her vocabulary at the time) were the basis for her odd pronunciation of these words. It seems that the metrical structure of the affected words (i.e. a syllable sequence of unstressed before stressed with another stressless syllable optionally following) was given precedence over their segmental content.

My daughter eventually lifted her restriction that all word-initial stressless syllables (henceforth WISSs) be pronounced [tu], but only gradually. The second WISS type to be allowed was [pə], reflected by a change in her pronunciation of *potato*. This form was then over-generalized to more recently acquired words like *tortilla* (pronounced [pə'tiə]) and *apartment* (pronounced [pə'pɑɹtmənt]). Of course, the segment [p] was present early in her phonological development, but it was not allowed to function as a WISS onset until sometime around her third birthday.

1.2. Background Research

A nearly identical situation was observed by Amalia Gnanadesikan (2004), only in this case the "dummy" syllable was [fi] instead of [tu]. Gnanadesikan used an Optimality Theoretic approach to argue that the phonological representations of her subject were adult-like but subject to several restructuring constraints. Her justification was the observed regularity with which the onset of the second syllable could be predicted based on the adult forms, a regularity to which my daughter's production did not conform.

In any case, words beginning with a stressless syllable seem to present a special problem for the phonological acquisition of English. If contrasts made in this position mirror much earlier phonemic contrasts, then the proposition of a universal hierarchy of phonological contrast (e.g. Jakobson & Waugh, 2002; Dresher, 2009) can be evaluated. If the first contrast of place to be exhibited is invariably labial vs. coronal and the second involves a contrast between these two places and guttural sounds (including both velar and glottal sounds), then the hierarchy will be supported. This was the case for my daughter, though strictly speaking, a labial WISS onset like [p] would be expected to precede the coronal [t] (Jakobson & Halle, 1956).

1.3. Purpose of Study

The present study aims to determine if there is empirical support for a contrastive hierarchy of features (e.g. Dresher, 2009) and if so which features are implicated in this hierarchy and in what order. Acquisitional data will be used to evaluate existing theories of phonological representation, and some adjustments and modifications will be suggested. Generalizations will be made across participants acquiring English, and the extent of individual variation observed will be noted as well. In response to Gnanadesikan (2004), phonological regularities peculiar to WISS modification will be sought, but it may be that these innovations are part of a broader scheme.

1.4. Overview of Chapters

Chapter 2 describes the elicited production task that was used in the present study and analyzes the demographics of the children who participated in this task. In short, 26 pictures were used to elicit a total of 16 words conforming to the sort of metrical pattern described in Appendix D. In Chapter 3, the results of this study are presented in various format and several generalizations are made. First, there seems to be a general preference across participants for coronal (i.e. dental, alveolar, or palatal) consonants, followed closely by labial (i.e. bilabial or labiodental), and last of all guttural (i.e. velar, pharyngeal, or glottal). Second, a contrast between stops and fricatives is found likely to be acquired before voicing contrasts in obstruents. Third, no clear cross-participant pattern can be found regarding the production of dummy WISSs (i.e. the findings of Gnanadesikan, 2004, are not supported).

In Chapter 4, the case is made for emergent, privative distinctive features, which may be characterized as language-particular phonological elements. The predictive power of such elements is best exploited by arranging them into a specific, psychologically plausible order of acquisition. Using this method, the phonemic contrasts of Gikuyu, a Bantu language exhibiting a very compact, symmetrical inventory, can be represented using only four distinctive elements (and one additional element/feature to capture important allophonic alternation). To represent all the sounds of English (both phonemes and phonologically active allophones), only six elements are required. When properly ordered, these emergent elements are capable of predicting a great deal of the phonological variation observed in the production data of the two- and three-year-old participants. The five elements proposed for Gikuyu happen to carry over to English *exactly*, but no claim is made as to their universality.

In Chapter 5, the general findings of the study are summarized and a few of its limitations are pointed out. Two additional studies along the present line of research are suggested: a longitudinal study and a forced-choice perception task to be administered to a much larger sample of participants. Additionally, it is recommended that the mode of analysis outlined here be applied to additional languages in order to determine the extent to which the proposed elements are universal or language-particular.

Chapter 2: Research Methods

2.1. Participants

For the present study, a total of 20 normally developing English-speaking children between the ages of 2;2 and 3;11 (10 male and 10 female) were recruited from two child care centers in El Paso, Texas. These child care centers were selected for their lack of bilingual education and relatively high proportion of clients from other regions of the United States. All the involved children were characterized as monolingual by their caretakers, with only minimal exposure to secondary languages. Each participant was responsive during his or her interview, and so none had to be discarded from the study.

According to caretaker responses to a short questionnaire, 9 of these participants (5 male and 4 female) were not learning or in contact with any language other than English. 4 participants (2 male and 2 female) were said to be in contact with Spanish, but their proficiency level was listed as 0 out of 5 (listed as "None" on the questionnaire). With a proficiency level of 1 out of 5 ("Very Basic"), 6 participants (2 male and 4 female) were said to be in contact with Spanish, and 1 participant (male) was said to be in contact with German. Taken as a group, the participants' mean proficiency level in a second language (Spanish or German) was reported as 0.35 out of 5 (closest to "None"). Therefore, any possible influence of such a language on the participants' developing sound system is expected to be minimal.

There was a fairly even distribution of participants across the age range from 2;2 to 3;11. The mean age was 3;1 for all participants taken together, 3;0 for males and 3;2 for females. For the 11 participants in contact with either Spanish or German, the mean age was 3;1, and for the purely monolingual participants, it was 3;0. Overall, the variables of age, gender, and exposure to a second language do not seem to be related to one another in any interesting way.

2.2. Materials

The experimental battery consisted 26 full-page laminated photo printouts. Each photo was selected to represent a particular object, animal, or food and elicit a target vocabulary item. Originally, the target items were considered to include any words whose first syllable did not take primary lexical stress (i.e. all underlined words in the list below). This was merely a safeguard to ensure that enough production data could in fact be collected from the 20 young participants. The target items were later refined to include only those words conforming to a very specific pattern: a completely unstressed syllable followed by a syllable with primary lexical stress optionally followed by one more stressless syllable. In current standard American English, the lexical items marked with an asterisk below do not conform to this metrical template and could therefore have been left out of the test battery.

1. an apartment complex
2. a balloon
3. a bunch of balloons
4. a banana
5. a bunch of bananas
6. a burrito
7. a chihuahua*
8. a computer
9. several kinds of dessert
10. a flamingo
11. a giraffe
12. a gorilla
13. a guitar
14. a kangaroo*

15. an orangutan*

16. a set of pajamas

17. a piano

18. a baked potato

19. a plate of mashed potatoes

20. a refrigerator*

21. a plate of spaghetti

22. a tomato

23. a stack of tortillas*

24. an umbrella*

25. a bowl of vanilla ice cream

26. a violin*

All sessions were recorded with a small, unobtrusive Olympus VN-5200PC digital voice recorder with an ME15 electret condenser microphone. The resulting audio files were later analyzed on an Apple MacBook computer.

2.3. Procedure

Before any interviews were conducted, both involved child care centers agreed to support the project, and full approval was obtained from UTEP's Internal Review Board (IRB). Their letter of approval is included in Appendix A.

A very simple, casual elicited production task was used so that the 16 target vocabulary items could be observed and recorded in natural speech. Sometime prior to the experimental session, a parent or guardian was instructed to complete a parental permission form and a short language questionnaire about their child. Only those children who met the criteria outlined in Section 2.1 were interviewed.

Each interview took place in the participant's child care facility, as far away from the other children as possible in order to minimize distraction. The full battery of 26 photo printouts was shuffled and presented to the participant one by one along with a simple question such as: "What's this?" For a few of the items, one or more follow-up questions were also needed. For example, if a participant was asked to identify the bowl of vanilla ice cream, he or she would probably respond simply: "Ice cream." The experimenter would then ask, "What kind?" which would hopefully elicit the desired vocabulary item: "Vanilla." If the participant produced the targeted word on the first pass through the battery, then this photo would be set aside. Once all the photos had been presented to the participant at least once, the successfully identified items were presented once more in an attempt to elicit additional utterances of the targets without losing the young child's interest. Throughout the testing session, the experimenter was careful not to model any of the targeted vocabulary items either before or after they were produced by the participant. Each interview proceeded at a leisurely pace and took somewhere between 10 and 20 minutes.

Once an interview was recorded, its audio was reviewed by the experimenter, and all instances of target vocabulary items were transcribed using the International Phonetic Alphabet. A fairly narrow transcription was attempted so as to avoid coloring the data with a theoretical bias. A complete listing of these raw phonetic forms is available in Appendix B. These data were subsequently classified by the experimenter according to several criteria but with a primary focus on the initial syllable of each target word, both its level of stress and the nature of its onset.

A great deal of individual variation is expected, given the age range of the participants. With a sample size of only 20 children amounting to a fairly small number of response tokens, there is little point in pursuing a true quantitative analysis. Any attempt to make statistically valid generalizations would be premature and probably not particularly revealing. Therefore, the results of this study are meant to be only suggestive.

Chapter 3: Results of Study

3.1. Overview of Responses

As was mentioned in Section 2.2, several of the original target vocabulary items did not conform to the specific metrical template under investigation. Some of these words began with a syllable taking secondary lexical stress (i.e. *tortillas*, *umbrella*, *kangaroo*, and *violin*), and some contained a secondary stress later in the word (i.e. *chihuahua*, *orangutan*, and *refrigerator*). All these words were left out of the present study in order to prevent this extra variable of secondary stress from clouding the data.

Of the remaining 16 vocabulary items, 14 were produced by at least one participant. The words *apartment* and *dessert* conformed to the targeted stress pattern, but the two- and three-year old participants were apparently unfamiliar with these terms, or at least not comfortable enough with them to use them during the interview. The following table shows which participants (listed on the left) produced which words (listed along the top) and how many times each word was uttered during the testing session. To facilitate reference to individual participants while maintaining their anonymity, each participant has been assigned a unique code indicating their gender and age group. Participants are arranged in ascending order by age, and vocabulary items in descending order by frequency of production.

Table 3.1. Tally of target word production by individual participants

	bal-loon	ba-nana	com-puter	giraffe	guitar	pa-jamas	piano	to-mato	potato	spa-ghetti	gorilla	fla-mingo	va-nilla	bur-rito
F1	2	5	2	3		3	2							
M1	3	4			5		2		1	2			2	
M2A	2	4	3					4						
M2B	2	2			3									
M2C	4	5	3	4		1		4						
F2A	3	6	2	2						1	5	2		
F2B	1	4	3	1	1									
M2D	6	5		2										
F2C	2	2	3	1	4		2		1	2				2
F2D	5	6	2	4					2					
F2E	7	4		2		3		6	5					
M3A	4	2	2	3		2	3							
F3	3	2	4	1	5	2	2	1					2	
M3B	2	4	2	1	6		2			3	2			
M3C	3				3									
M3D	2	3	1	2	2	1	2	2		1				
M4	3	2	1	1	2	2	4	3	1	3				
F4A	3	3	1			2			2					
F4B	2	2	1	3	3	1		3	2	1		2		
F4C	2	4	1	1	2									

Participants produced an average of 6.25 target vocabulary items each. For a given participant, each item produced was uttered an average of 2.65 times, yielding a total of 331 tokens overall. As expected, a strong relationship between the participants' age and either the number of items produced or the number of repetitions per item is not apparent.

Although a large number of the targeted vocabulary items were freely produced by the participants, their pronunciation of these items often diverged from adult standards quite a bit. In fact, these words were produced in an adult-like manner less than half the time. Because a given production of a word can diverge from the adult standard in so many different ways, the present analysis is focused solely on the first syllable of each target vocabulary item, and more specifically, its onset. In the table below, a check mark (✓) indicates at least one fully adult-like pronunciation of the target's word-initial onset, a plus sign (+) indicates an over-stressed first syllable (e.g. /ˈpiˌænʌw/ for *piano*), a minus sign (−) indicates a reduced schwa in first syllable (e.g. /ˈpjænʌw/ for *piano*), and an X (✗) indicates no adult-like production of the target's word-initial onset. In this way, the massive amount of nominal data collected can be quantified, and useful generalizations may be possible.

Table 3.2. Participants' accuracy in first syllable production

	bal-loon	**ba-nana**	**com-puter**	**giraffe**	**guitar**	**pa-jamas**	**piano**	**to-mato**	**potato**	**spa-ghetti**	**gorilla**	**fla-mingo**	**va-nilla**	**bur-rito**
F1	✓	✓	✓	✗		✓	✗							
M1	−	✗			✗		✗		−	✗			✗	
M2A	✓	✓	+					✓						
M2B	−	✓			✗									
M2C	−	✗	✗	✗		✗		✓						
F2A	✓	+	✗	✗						+	−	✗		
F2B	✓	✗	✗	−	✗									
M2D	−	✗		−										
F2C	✓	✓	✗	✗	✗		+		✓	✗				✓
F2D	✓	+	✗	✗					✗					
F2E	✓	✓		✗		✗		✓	✗					
M3A	✓	✓	✗	✗		✗	−							
F3	✓	✓	✗	✓	✗	✓	+	✗					✗	
M3B	✓	✓	✗	✓	✗		✓			✗	✓			
M3C	−				✗									
M3D	✓	✓	✓	−	✗	✓	✓	✓		✓				
M4	✓	✓	+	−	✗	✓	✓	✗	✗	+				
F4A	✗	✗	✗			✗			+					
F4B	✓	✓	✓	✓	✗	✓		✓	✗	✓		✗		
F4C	−	✓	✓	✓	✗									

Given the wide range of phonetic forms produced, the above table goes a long way toward making some sense of the observed variation. These data can be further distilled into simple percentages by generalizing across the targets produced by each participant, as shown below. The number of targets produced by a given participant seems to be a slightly better predictor of adult-like pronunciation than their age, but neither relationship is particularly strong.

Table 3.3. Proportions of response types by individual participant

Participant	Age	Targets Produced	Adult-Like (✓)	Over-Stressed (+)	Reduced Schwa (−)	Non-Adult-Like (✗)
F4A	3;7;27	5		20%		80%
M1	2;3;25	7			29%	71%
M3C	3;5;19	2			50%	50%
M2D	2;10;0	3			67%	33%
F2A	2;9;16	7	14%	29%	14%	43%
M2C	2;8;8	6	17%		17%	67%
F2B	2;10;0	5	20%	20%		60%
F2D	2;11;16	5	20%	20%		60%
M3A	3;1;13	6	33%		17%	50%
M2B	2;7;7	3	33%		33%	33%
M4	3;6;16	10	40%	20%	10%	30%
F2C	2;11;15	9	44%	11%		44%
F3	3;3;28	9	44%	11%		44%
F2E	2;11;22	6	50%			50%
F4C	3;11;27	5	60%		20%	20%
M3B	3;5;15	8	63%			38%
F1	2;2;12	6	67%			33%
F4B	3;11;26	10	70%			30%
M2A	2;6;5	4	75%	25%		
M3D	3;5;27	9	78%		11%	11%

The above table provides a loose ranking of the participants by their overall accuracy in the production of adult-like WISS onsets. The target vocabulary items can be similarly ranked by generalizing across participants. Because four of the target items were produced by only one or two participants, their response type proportions may not be a reliable measure comparable to those of the more frequently produced items. The items *gorilla, flamingo*, *vanilla*, and *burrito* have therefore been omitted from the following table.

Table 3.4. Proportions of response types by target vocabulary item

Vocabulary Item	**Occurrences**	**Adult-Like (✓)**	**Over-Stressed (+)**	**Reduced Schwa (−)**	**Non-Adult-Like (✗)**
tomato(es)	7	71%			29%
balloon(s)	20	65%		30%	5%
banana(s)	19	63%	11%		26%
pajamas	9	56%			44%
piano	8	38%	25%	13%	25%
spaghetti	7	29%	29%		43%
giraffe(s)	15	27%		27%	47%
computer	15	27%	13%		60%
potato(es)	7	14%	14%	14%	57%
guitar	11				100%

At present, only WISS onsets are under scrutiny, so the percentage of non-adult-like responses for a given vocabulary item is arguably a fair measure of the inherent difficulty of that item's onset. However, an over-stressed or reduced initial syllable may also be considered non-adult-like to some degree. Therefore, it seems prudent to present this type of difficulty rating as a range rather than an exact percentage. The following table lists the target vocabulary items in increasing order of the apparent difficulty they presented to participants.

Table 3.5. Relative difficulty ratings of the target vocabulary items' word-initial onsets

Vocabulary Item	Occurrences	Difficulty Rating
balloon(s)	20	5-35%
tomato(es)	7	29%
banana(s)	19	26-37%
pajamas	9	44%
piano	8	25-63%
spaghetti	7	43-71%
giraffe(s)	15	47-73%
computer	15	60-73%
potato(es)	7	57-86%
guitar	11	100%

3.2. Overall Tendencies

In the previous section, each of the target vocabulary items was assigned a difficulty rating based on participant performance and ranked relative to the other target items (excluding those items that were produced by only one or two participants). No clear pattern emerged as a result of this ranking. It was not obvious by any means why *balloon* should be the least difficult item (with a rating of 5-35%) and *guitar* should be the most difficult (with a rating of 100%). If the data presented in Table 3.4 are reexamined in terms of the initial onset of each word as opposed to the vocabulary item as a whole, then perhaps we can begin to make some sense of these facts. In the following table, the response data for *gorilla* and *burrito* have been included under /g/ and /b/ respectively, but *flamingo* and *vanilla* would each require their own category, so these words are still not usable.

Table 3.6. Relative difficulty ratings for word-initial onsets

Onset	Occurrences	Difficulty Rating
/b/	40	15-35%
/t/	7	29%
/p/	24	42-63%
/sp/	7	43-71%
/ʤ/	15	47-73%
/k/	15	60-73%
/g/	13	85-92%

By combining vocabulary items with like onsets in this way, we begin to see similar sounds clustering together. In the following tables, this abstraction is taken a step further as onsets are grouped according to whether they are voiced or voiceless (in Table 3.6) and simple or complex (in Table 3.7). Here, "complex" in used to mean either an affricate (such as /ʤ/) or a sequence of two or more consonants (such as /sp/).

Table 3.7. Relative difficulty ratings for voiced vs. voiceless onsets

Onset	Occurrences	Difficulty Rating
voiced	70	37-56%
voiceless	57	47-64%

Table 3.8. Relative difficulty ratings for simple vs. complex onsets

Onset	Occurrences	Difficulty Rating
simple	103	40-55%
complex	24	50-75%

The above tables show that voiceless onsets were found to be slightly more difficult than voiced and complex onsets a bit more difficult than simple. These findings are not particularly surprising, but they are a good basis for comparison, and they demonstrate the validity of the coding method used. In the following table, complex onsets have been eliminated, and only the three places of articulation for simple stop consonants are evaluated. Here we can see fairly noticeable differences between onset types.

Table 3.9. Relative difficulty ratings for stop onsets at three places of articulation

Onset	Occurrences	Difficulty Rating
alveolar	7	29%
labial	64	25-45%
velar	28	71-82%

The alveolar place of articulation seems to have presented the least difficulty to participants. Overall, their production was the most adult-like for stops of this type. Slightly more difficult were labial stops, and velar stops were by far the most difficult to produce in an adult-like manner. It is perhaps no coincidence that coronal consonants are the most common in the languages of the world, followed generally by labial and then guttural sounds (Maddieson, 1984). The data collected were only a small, synchronic sample, but it would not be at all surprising if these difficulty ratings corresponded to a typical order of acquisition for stops: coronal, then labial, and finally (perhaps after some delay) guttural. This was precisely the order observed for voicing distinctions in a longitudinal study of four American children between the ages of 1;4 and 2;4 conducted by Marlys Macken (1980). Most participants in the present study have likely mastered these stops in more canonical positions, but as the onsets of WISSs, their production seems to be lagging.

3.3. Individual Strategies

By generalizing across all 20 participants and lumping the target vocabulary items into the abstract categories of coronal, labial, and guttural, we have been able to lend support to the idea that some speech sounds are likely to be acquired before others. The earliest sounds to be acquired would seem to be more natural and objectively easier to produce than more marked sounds. As a very broad generalization, this seems to be true. Looking more closely at individuals, however, we can see that young children are not mere animals blindly following a biologically determined acquisition program. They are active mental beings hard at work, each with their own unique solution to the problem of non-canonical metrical structures (such as WISSs in English).

At this point, it may be enlightening to examine the production data of individual participants and look for evidence of regular, systematic deviations from adult norms. Such deviations should not be considered errors per se but may in fact be the result of the individual's developing system of phonological representation. Given time, each of these systems will come to approximate that of an adult speaker of American English, but the individual paths taken to arrive at this endpoint may vary noticeably. A complete listing of each participant's individual production data is available in Appendix C along with a single hypothesized phonological form for each target vocabulary item they produced and a brief statement on the nature of their phonological innovations. What follows is a general commentary on these data.

Two of the most common strategies participants used for adapting the target words into their grammar were syllable reduction and stress reassignment. Because the deletion of a syllable necessarily affects the metrical structure of a word, these two strategies are often difficult to tease apart. To gauge the frequency of WISS reduction in an objective manner, the number of syllables reduced must be considered alongside the level of stress assigned to a given target's first syllable. In the following table, a value of *2* indicates primary lexical stress, *1* indicates secondary or weak stress, and *0* indicates no stress whatsoever. Bear in mind that completely adult-like pronunciation of all targets would render a value of 0 in both columns. Instances of unusually strong tendencies toward syllable reduction and/or initial-syllable stress assignment have been highlighted below.

Table 3.10. Average syllable reduction and initial syllable stress for individual participants

Participant	Syllables Reduced	Initial Stress Level
M3C	0.33	2.00
M2B	0.33	1.11
M2D	0.39	0.78
M2A	0.06	0.69
F2B	0.60	1.02
F2D	0.83	1.92
F4A	0.20	1.43
F4C	0.20	0.45
F1	0.25	0.50
M2C	0.31	0.68
F2E	0.25	0.72
M3A	0.53	1.11
M1	1.00	2.00
F2A	0.38	1.38
M3B	0.21	0.46
F2C	0.11	0.74
F3	0.00	0.11
M3D	0.17	0.39
M4	0.10	0.62
F4B	0.05	0.15
Average	**0.32**	**0.91**

It seems that at least 8 of the 20 participants were generally intolerant of WISSs as they eliminated them (either by reduction or stress reassignment) more often than not. In the above table, participants are listed in ascending order by the number of target items they produced (ranging from 2 to 10) and secondarily by age (ranging from 2;2 to 3;11). Although the present study is lacking any longitudinal data for individual participants, this arrangement is intended to provide at least a very loose characterization of individual development over time. A very gradual drift toward adult-like pronunciation is apparent, but this is by no means reliable. Individual preference seems to be a bigger factor than developmental stage.

In addition to the weak syllable deletion and stress reassignment (presumably to a more canonical position), many other phonological simplifying processes have also been observed in young children, especially those under the age of four. A few of the most commonly cited processes are as follows (Dyson & Paden, 1983; Bowen, 1998; McIntosh & Dodd, 2008):

- **Sporadic voicing**: A voiceless segment is replaced by its voiced counterpart, often word-initially (e.g. /pɪg/→[bɪg]). This tends to be corrected by around 3;0.
- **Final devoicing**: A voiced segment is replaced by its voiceless counterpart word-finally (e.g. /pɪg/→[pɪk]). This tends to be corrected by around 3;0.
- **Final consonant deletion**: A consonant is deleted word-finally (e.g. /pɪg/→[pɪ]). This tends to be corrected by around 3;3.
- **Velar fronting**: A velar segment is replaced by its dental or alveolar counterpart (e.g. /kɑɹ/ →[tɑɹ]). This tends to be corrected by around 3;6.
- **Stopping of fricatives**: A fricative is replaced by its stop counterpart (e.g. /væn/→[bæn]). This tends to be corrected for *most* fricatives by around 3;6.
- **Consonant harmony**: Consonants within a word share a single place of articulation (e.g. /væn/ →[væm]). This tends to be corrected by around 3;9.
- **Cluster reduction**: Sequences of two or more consonants are reduced to one (e.g. /stɑɹ/→[tɑɹ]). This tends to be corrected by around 4;0.

- **Palatal fronting**: A palatal or postalveolar segment is replaced by its dental or alveolar counterpart (e.g. /ʃu/→[su]). This tends to be corrected by around 4;6.
- **Gliding of liquids**: The liquids /l/ and /r/ are confused with the glides /j/ and/or /w/. (e.g. /lɛg/→[jɛg]). This tends to be corrected by around 5;0.

These are only rough characterizations of the phonological adjustments children appear to be making. The motivation for these processes and the exact nature of their mental representation is still largely unknown. In the following table, an attempt is made to capture these processes in more rigid terms. Additional processes such as backing and nasalization were frequently observed in the present study and so are included below.

For the first five columns of the following table, a value of plus (+) or minus (−) is listed when a participant showed at least one instance of inappropriately adjusting the feature in question for some segment in a target word. Where a feature was both added and deleted by a single participant, a check mark (✓) is listed instead, indicating somewhat free variability between both values of this feature. It must be noted that only segmental *modifications* were considered, not deletion. Therefore, a rendering of *balloon* as [bu] would not trigger a listing under "±Nasal" or "±Continuant" because the entire segments containing these attributes were lost. In the two rightmost columns, capital letters are given to indicate the destination of the shift in question (i.e. to labial position, to coronal, or to guttural). Palatal and alveolar sounds are considered to have the same major place of articulation (coronal), so differences in palatalization do not trigger a listing in either of these columns. Again, a check mark is listed where both possible values (either "L" and "C" or "C" and "G") are applicable.

Participants are again listed in order of their apparent stage of acquisition. However, in viewing the following table as a possible indication of developmental order, it must be noted that participants listed near the top produced fewer target vocabulary items and so had less opportunity to demonstrate the phonological processes in question. The data for participants who produced fewer than five target items have been grayed out as a reminder of this important consideration.

Table 3.11. Tally of phonological simplifying processes used by individual participants

	±Voice	±Nasal	±Continuant	±Friction	±Palatal	Fronting	Backing
M3C	−						
M2B	−		+			L	
M2D	−	−	+		−		
M2A	+	✓	+		+		
F2B	−	+	✓	✓	−		
F2D	−		+	✓	✓		C
F4A	−	+	+	−	−		✓
F4C	−						
F1	✓	✓	+	✓	−	C	
M2C	✓	+	+	✓		✓	✓
F2E	✓	+	+	−	−		C
M3A	−		+		+	C	
M1		+		+	+	✓	
F2A	✓	−	+	−	✓	C	C
M3B	−					✓	
F2C	✓	+		−	−	✓	
F3	✓		✓	✓		C	
M3D	✓		+			L	
M4	✓	+	✓			L	G
F4B	✓	✓	✓	−		C	G

In reality, the column headings above represent overlapping, interrelated differences from adult norms, not discrete all-or-nothing processes. This is apparent when you consider that adding the feature [+nasal] to a non-nasal segment necessarily implies that the segment should be [+voice]. If this segment started off as a fricative, then its features [+continuant] and [+friction] would also have to change. Fricatives are necessarily [+continuant], but the reverse is not true as liquids and glides are also considered [+continuant]. Affricates are considered [+friction] but [-continuant]. Therefore, a setting of [+palatal] typically implies [+friction], but nothing is implied about [continuant]. A change from [+palatal] to [-palatal] often implies [-friction] (as in /ʤɑɹ/→/dɑɹ/) but the change in [friction] is probably best analyzed as secondary to the change in [palatal]. Obviously, these descriptive features are related in intricate ways which are perhaps not well understood at this point. Accordingly, great care must be taken in interpreting the data in Table 3.10.

(De)voicing was the most commonly observed process, occurring in all but one of the participants. Taken together with the closely related process of (de)nasalization, confusion among voiceless obstruents, voiced obstruents, and nasals may be interpreted as the most ubiquitous feature of the production data collected. In a similar fashion, non-adult-like settings of [continuant] and/or [friction] may be interpreted as uncertainty about the duration and/or stricture of sounds (i.e. whether they should be stop consonants or longer elements such as fricatives, glides, and vowels). These processes featured prominently in the production data but were not observed quite as often as voicing/nasalizing issues. These findings would suggest that contrasts of duration and stricture (e.g. /t/ vs. /s/) may be acquired earlier than contrasts of voicing or nasality (e.g. /t/ vs. /d/ or /d/ vs. /n/). That said, voiced sonorants and voiceless obstruents are rarely confused, so some sort of distinction between these basic segment types is probably made first.

The three remaining processes boil down to an inappropriate place of articulation, but (de)palatalization seems to pattern a bit differently from both fronting and backing. (Recall that a change in the setting of [palatal] is not considered a *type* of either fronting or backing, so these three processes can be teased apart.) While instances of (de)palatalization tends to decrease as production increases, fronting (to either a labial or a coronal position) seems to do just the opposite. Backing shows less consistency, but it was observed (along with fronting but not (de)palatalization) in the two most advanced participants (i.e. those who produced the greatest number of targets). As a very general observation, the coronal place of articulation seems to be the most popular destination for both fronting and backing in the early stages, but then labial and guttural consonants begin to gain ground with the last few participants.

In Appendix C, a single plausible phonological representation of each vocabulary item for each individual participant was postulated in order to facilitate description of WISS onsets as having one of three rough places of articulation: *labial* (i.e. bilabial or labiodental), *coronal* (i.e. dental, alveolar, or palatal), or *guttural* (i.e. velar, pharyngeal, or glottal). For a given participant, if an item's WISS onset place of articulation was the same as in the adult standard pronunciation of the word (e.g. /kɪn(tɑr)/ for *guitar*), then this item was considered to have been *selected* for its place of articulation. If, on the other hand, the participant's version of an item's WISS onset did not have an adult-like place of articulation (e.g. /kɪ(nejdʌw)/ for *potato*), then this item was considered to have been *adapted* to a new place of articulation. This characterization of phonological innovation in terms of selection and adaptation proved useful in describing and comparing the phonological representations of individuals, but it is equally suited to describing the strategies of the group as a whole.

Numerical values below are given in pairs indicating first the number of WISS onsets selected for a given place of articulation and second the number adapted to that same place of articulation. All instances of adaptation have been highlighted.

Table 3.12. Total instances of WISS onset selection and adaptation for individual participants

Participant	Labial Selected, Adapted	Coronal Selected, Adapted	Guttural Selected, Adapted
M3C	0, 0	0, 0	0, 0
M2B	1, 0.25	0, 0	0.25, 0
M2D	0, 0	1, 1	0, 0
M2A	2, 0	0.5, 0	0.5, 0
F2B	1, 0	0, 0	1, 0
F2D	0, 0	0, 1	0, 0
F4A	0, 0	0, 1.5	0, 0
F4C	1, 0	1, 0	2, 0
F1	4, 0	0, 1	0, 0
M2C	1, 0	2, 2	0, 0
F2E	2, 0	2, 2	0, 0
M3A	2, 0	1, 1	0, 0
M1	0, 0	0, 0	0, 0
F2A	0, 0	0, 2	1, 0
M3B	3.5, 0	1, 1	1, 0
F2C	4.5, 1	0.5, 0	0, 0
F3	4.5, 1	1, 2	0, 0
M3D	4.5, 1	1.5, 0	1, 0
M4	4.5, 1.5	0, 0	0.5, 1
F4B	4.5, 0	2.5, 0	2, 1
Total	**39, 4.75**	**21.25, 14.5**	**9.25, 2**

A few very interesting observations can be made regarding these data. First, there seems to be a loose relationship between the number of selections made for a given place by a given participant and the number of adaptations made by that participant to the same place. This would indicate that the more words a participant uses beginning with the same type of WISS, the more likely it is that he or she will generalize this WISS type to other words inappropriately. Second, where adaptation occurs, it is most likely to only one place of articulation for a given participant. In the present study, there were only two exceptions to this rule (F3 and M4) and no recorded cases of adaptation to all three places of articulation by a single participant. Perhaps most interesting of all is the way these instances of adaptation cluster together into what would appear to be three distinct developmental stages: overgeneralization to coronal (M2D through F3), then to labial (F2C through M4), and finally to guttural (M4 through F4B). Without true longitudinal data, this is impossible to verify, but it is an exciting finding nonetheless.

When all instances of selection and adaptation are tallied up, labial onsets appear to be the most likely candidates for selection (with a total of 39 occurrences), and coronal onsets are clearly the most likely outcome of adaptation (with 14.5 occurrences). However, these results are hardly fair since roughly half of the targeted vocabulary items happen to begin with labial onsets in their adult pronunciation. A word can't be selected for its coronal onset of the adult form doesn't *have* a coronal onset. Conversely, a word can't be adapted to a labial onset if its adult form already begins this way. In order to get a more accurate picture of the participants' true preferences, these raw numbers must be converted to percentages of the total *possible* occurrences of selection or adaptation for each place of articulation. In the following table, we see a very familiar pattern emerging yet again. Coronal onsets are favored most, followed by labial, and finally guttural.

Table 3.13. Adjusted WISS onset selection and adaptation figures

Place	Selected	Adapted
coronal	21.25 / 26.5 = **80.2%**	14.5 / 98.5 = **14.7%**
labial	39 / 70.5 = **55.3%**	4.75 / 54.5 = **8.7%**
guttural	9.25 / 28 = **33.0%**	2 / 97 = **2.1%**

3.4. Usage of Dummy Syllables

When a child's production of a WISS in a given word differs from the adult standard in a way that is not easily explained as simply phonetically inaccurate (e.g. [zə'tɑɹ] for *guitar*), it may be the case that this initial syllable is nothing more than a place-filler used to preserve the metrical structure of the word. When this sort of dummy syllable is employed, it may either replace the adult WISS completely (e.g. [tə 'n̲ænə] for *banana*), or the adult WISS may be reduced so that its onset becomes the onset of the following (stressed) syllable in the child's form (e.g. [tə'b̲ænə] for *banana*). These two strategies for dummy WISS application will henceforth be referred to as *swapping* and *squishing*, respectively.

Since it impossible to know with certainty when a dummy syllable is being applied and when the WISS onset is being modified for some other reason, it will be assumed for the time being that a dummy syllable is being used if and only if the child's WISS onset differs from that of the adult standard by major place of articulation. For example, if *guitar* is rendered [pə'tɑɹ], then [pə] will be considered a dummy syllable, but if *giraffe* is rendered [də'ɹæf], then [də] will be considered a phonological simplification of /ʤə/. Using this criteria, the following table gives an overview of dummy syllable application method by participant and vocabulary item. An X (✗) is used to indicate WISS swapping, and a check mark (✓) to indicate squishing.

Table 3.14. Usage of dummy syllables by participant, item, and method of application

	balloon(s)	banana(s)	computer	guitar	pajamas	tomato(es)	potato(es)	flamingo
M2B				✗				
M2D		✓						
F2D		✗						
F4A	✗	✗			✗			
M2C	✓		✗					
F2E					✓		✓	
M3A	✗							
F2A		✓	✗					
M3B				✗				
F2C			✗	✗				
F3			✗	✗		✓		
M3D				✗				
M4				✗		✓	✗	
F4B								✗

Judging by the above data, some participants apparently favor the use of dummy syllables more than others, and some vocabulary items seem to trigger dummy syllable application (as we have defined it). As we have already established, guttural onsets are the last to be acquired, so the apparently frequent use of dummy syllables for *computer* and *guitar* may be nothing more than segmental modification of `/k/` and `/g/`, respectively. It is perhaps telling that these are the only words where swapping happened several times, but no squishing occurred at all. Discounting these anomalies, there seems to be no way to predict with any accuracy when a given participant will choose to apply a dummy syllable and which method of application they will use.

According to Gnanadesikan's (2004) analysis of this phenomenon (based on a single subject), immature rankings of universal (but violable) phonological constraints are responsible for the modification of essentially adult-like phonological representations. She found that an approximant in onset position of the word's second syllable was the conditioning factor for use of the squishing method of dummy syllable application. In the current set of vocabulary items, *balloon* is the only word to which a dummy syllable was applied at least once. For this word, the squishing method was used by only one out of three participants. This does nothing to validate Gnanadesikan's claim. Just one vocabulary item (*flamingo*) was modified only by means of swapping, and just one item (*tomato*) was modified only by means of squishing. Both of these words begin their stressed syllable with /m/, so there is no way to differentiate them on that basis alone. To sum up, no strong counter-evidence was found to refute Gnanadesikan's analysis, but neither was it supported.

Looking at the apparent instances of dummy syllable application in Table 3.14 in terms of swapping and squishing, only one clear pattern emerged: the general non-occurrence of the squishing method in words containing guttural WISS onsets (i.e. *computer* and *guitar*). At this point, it may be revealing to take the general phonological processes of consonant harmony and metathesis into account. If a word's WISS onset is affected by a process of harmony with the following syllable, then both onsets will be made to share a single place of articulation (e.g. [d̲əˈn̲ænə] for *banana*). If the process of metathesis is instead employed, then the place of articulation for the first and second syllables will be switched (e.g. [d̲əˈm̲ænə] for *banana*).

Given three major places of articulation (labial, coronal, and guttural) and looking only at WISSs produced with a non-adult-like place of articulation, each possible dummy WISS is expected to fit the pattern of either harmony or metathesis *by chance* around half the time. Therefore, the presence of an H or an M in the following table is meant to indicate only the *possibility* of onset harmony or metathesis, respectively. Where neither process is even a possibility, a representative instance of the apparent dummy syllable is listed between slashes.

Table 3.15. A process approach to dummy syllable usage

	balloon(s)	banana(s)	computer	guitar	pajamas	tomato(es)	potato(es)	flamingo
M2B				/wɑs/				
M2D		M						
F2D		H						
F4A	H	H			/ɔkɔ/			
M2C	M		/dɪ/					
F2E					M		M	
M3A	H							
F2A		M	/də/					
M3B				H				
F2C			H	/pʰɑ/				
F3			/zʌ/	H		M		
M3D				/pʰʌ/				
M4				/pɪˀkt/		M	/kʰɪ/	
F4B								/kʰə/

As consonant harmony is a possibility in less than half of the observed instances of WISS swapping, it does not appear to play as major role in dummy syllable selection. In fact, if harmony is assumed as a causative factor, then some otherwise obvious generalizations are obscured. In the above table, it seems an inconsistency that participants F2C and F3 make use of harmony sometimes and not others. A cleaner analysis would suggest that F2C converts guttural WISS onsets to labial and F3 converts them to coronal. Consonant harmony therefore appears to be largely an epiphenomenon of WISS onset overgeneralization.

Metathesis, on the other hand, does seem to play a role in WISS modification. For every single observed instance of dummy syllable squishing, an alternative explanation of metathesis is also possible. It should be noted, however, that in each of these instances, only labial and coronal onsets are involved. Therefore, it may be that this finding merely recapitulates the earlier generalization that guttural WISS onsets are uncommon.

In short, there do seem to be idiosyncratic phonological templates at work here (cf. Vihman & Croft, 2007; Vihman, in press), but when and where such templates are employed is partly determined by very general principles and processes (cf. Dyson & Paden, 1983; Preisser, Hodson, & Paden, 1988; McIntosh & Dodd, 2008).

3.5. Summary

The results of the present study seem to confirm Macken's (1980) findings that coronal stops are typically acquired first in English, followed by labial, and then guttural. In Section 3.2, it was shown that the participants' production data was the most adult-like for target items beginning with an alveolar stop, next for targets beginning with a labial stop, and least of all for those beginning with a velar stop. In Section 3.3, it was tentatively put forward that a contrast between sonorants and obstruents precedes a contrast in duration/stricture, which in turn precedes voicing/nasality.

Additionally, it was found that the adaptation of WISS onsets to different places of articulation seems to indicate three developmental stages: overgeneralization to coronal onsets, followed by an allowance of labial onsets with concomitant overgeneralization, eventually extending to guttural onsets. The totals from Table 3.11 were then put together and weighted appropriately in Table 3.12 to show that both selection and adaptation were most common with coronal onsets, followed by labial onsets, and then guttural onsets. In the context of English WISSs at least, coronal onsets are clearly somehow more natural than labial onsets, and labial onsets are in turn more natural than gutturals. One thing that still remains unclear is exactly *why* this should be the case.

Chapter 4: Discussion

4.1. The Need for Emergent Features

In the preceding chapter, it was argued that in the acquisition of English phonology, there exists a noticeable preference for coronal consonants over labials (likely corresponding to an earlier addition of such sounds into the phonemic inventory) and a strong bias toward both of these places over gutturals. The typical order of acquisition for consonants (independent of manner contrasts) can therefore be predicted as coronal→labial→guttural. This prediction has been borne out by a longitudinal study in the acquisition of voicing contrasts in stop consonants at these positions (Macken 1980).

However, this generalization does not hold for Spanish. In a very similar experimental design carried out by the same researcher, contrasts in voicing/spirantization were found to begin with *labial* stops, only followed by velars and dentals after a delay of several months. These findings were attributed to the heavy concentration of word-initial labial stops in the children's production corpora. The proportions of word-initial stops at different places of articulation are given below. To isolate place of articulation for comparison, values for voiced and voiceless stops have been combined (Macken 1980).

Table 4.1. Distribution of word-initial stops in the vocabulary of Spanish-speaking children

Place	**2-Year-Olds**	**4-Year-Olds**
labial	23.2 + 24.2 = **47.4%**	18 + 24.8 = **36.8%**
velar	5.2 + 25.8 = **31.0%**	14.2 + 23.5 = **37.7%**
dental	5.5 + 16.1 = **21.6%**	7 + 12.5 = **19.5%**

It would seem that there is a connection between the number of words in a lexicon exemplifying a given feature and the rate of acquisition of that feature. In order to investigate this issue, two corpora of spoken English were examined, and the most common words possessing the metrical structure under investigation in the present study were extracted (i.e. words beginning with a stressless syllable, followed by a primary stress, and optionally ending with another stressless syllable). These 79 words are listed in Appendix D. Nearly half begin with a vowel, but the distribution of the onsets for the remaining 42 words is given below.

Table 4.2. Distribution of common WISS onsets by major place of articulation

Place	Proportion of Total
coronal	44% (18.5 words)
labial	36% (15 words)
guttural	20% (8.5 words)

Fractional values are possible above because of complex onsets (in this case, /pɹ/) and segments with an ambiguous place of articulation, as described in Appendix C. With all onset types eliminated besides simple stops, the following distribution was found.

Table 4.3. Distribution of common WISS stop onsets by place of articulation

Place	Proportion of Total
alveolar	44% (12 words)
labial	37% (10 words)
velar	19% (5 words)

Given the different methods used to evaluate place of articulation and the different number of words involved, the similarities between Tables 4.2 and 4.3 are quite striking. It now seems clear that the frequency of structures possessing a given feature (whether in the child's productive lexicon or in the adult input) probably does have an effect on the order in which that feature is acquired and/or generalized. Though the phonological systems of the world's languages are similar in important ways, they are not *identical*. The acquisition process reflects this. Indeed, if all children acquired exactly the same contrasts in exactly the same order, then the productive sound systems of all the world's languages would logically *be* identical.

Though the acquisitional order established for Spanish differs significantly from that of English, the findings for both languages are generally consistent with the universal contrastive hierarchy first proposed by Roman Jakobson in 1941 (Dresher, 2009). For consonants, the opposition of "grave" (e.g. [p, k]) and "acute" (e.g. [t, c]) sounds is taken as primary and probably the first to be acquired. The opposition of "compact" (e.g. [k, c]) and "diffuse" (e.g. [p, t]) follows close behind (Jakobson & Waugh 2002). Jakobson's hierarchy predicts that the first phonemic place opposition to be acquired is between labial and coronal, but it merely suggests that [p] would be phonetically expressed before [t] (Jakobson & Halle, 1954). The only strong prediction on the ordering of these places of articulation is that no phonemic contrast will be made between either labials and gutturals or coronals and gutturals before a contrast is made between labials and coronals (Dresher, 2009). While exceptions to this prediction are rare, they do exist (Macken, 1980), which calls the purported universality of such a hierarchy into question.

In fact, there is good reason to doubt the universal nature of distinctive features. In an exhaustive analysis of 628 language varieties (comprising around 549 distinct languages), Jeff Mielke (2008) found that at least three of the most notable feature sets were unable to account for more than 71% of the phonologically active classes (i.e. groups of phonemes implicated in phonological processes) in these languages. Jakobson et al.'s *Preliminaries to Speech Analysis* (1952) characterized 59.9% of these classes, Chomsky and Halle's *Sound Pattern of English* (1968) characterized 71.0%, and Clements and Hume's (1995) Unified Feature Theory characterized 63.7% of the classes. If the best a universal feature set can do is account for around two thirds of the demonstrably phonologically active classes in a typical human language, then some extra mental machinery is clearly necessary for the acquisition and representation of these classes. If young children can learn and automatize a full third of the necessary classes without any innate features to help them along, then why not the remaining two thirds as well?

Descriptive adequacy of existing feature sets aside, the very notion that a small set of acoustically- and/or articulatorily-grounded distinctive phonological features *could* be innate is flawed for one simple reason: *signed languages*. The distinctive features required to describe sign phonology are rooted in gestural and/or visual contrasts and bear no strong resemblance to the sort of features proposed for spoken language (Brentari, 1993; Hulst, 2000). That humans as a species would evolve *two* sets of universal distinctive features for two distinct language modalities is unlikely in the extreme. A more obvious explanation is that the distinctive features of sign phonology are not inborn but are acquired gradually. If this is possible for signed languages, then why not spoken?

An approach that posits no innate distinctive features but instead provides a mechanism for such features to be learned and applied gradually is clearly preferable (e.g. Vihman & Croft, 2007). It may be the case that many of the features that come to be acquired are virtually the same across speakers of any given language and perhaps even across the languages of the world. Such similarity among features can easily be explained by our physiological, cognitive, and perceptual similarities as humans without recourse to an innate feature set or other such language-specific device. The segment [t] whether produced in English, Japanese, or German is very similar both acoustically and gesturally. Even its representation in the minds of speakers as the phoneme /t/ is undoubtedly very similar. But similarity, however extreme, does not imply identity. "The upside of confusing similarity with identity is that it allows more sweeping generalizations to be made. The downside is that they are often wrong," (Mielke, 2008).

Recent work in Element Theory looks promising (e.g. Nasukawa, 2005; Harris, 2006; Bellem, 2007; Nasukawa & Backley, 2008) but is somewhat hampered by a commitment to universality. Most versions of Element Theory use a very small set of elements, perhaps as few as five (Jensen, 1994) or even just *two* (Hulst, 2000), and rely on complex grammatical structures to provide phonemic contrast. This is not ideal because while a small inventory of elements simplifies the substance of the sound system, an increase in grammatical structure would seem to cancel out any benefit that might be derived from this simplification. Besides this, it is unclear that a handful of innate phonological elements are really capable of capturing all the phonologically active classes of every possible human language.

If on the other hand, these elements were not assumed to be genetically determined but instead simply *likely* to develop in the minds of *nearly* all speakers of *most* languages, then such a theory would have the potential to account for not only the phonemic contrasts of the world's languages but also their allophonic alternations and morphologically conditioned processes, however diachronic their motivation may be. Sound change over time could be plainly characterized as the under-acquisition (or perhaps *mis*-acquisition) of language-particular distinctive features.

Given such an approach, the most common phonological elements across languages and dialects could be considered somewhat *natural* but not truly universal. Even within the phonological system of a single individual, acquired features are subject to change as new distinctions are added and the system becomes increasingly adult-like. In the related domains of morphology and syntax, the features necessary to describe grammatical processes are even more abstract and specific to the languages in which they operate (Croft, 2001). Accordingly, the concept of emergent features should not be limited to phonology but should extend to all levels of grammatical representation.

Adopting the basic tenets of Autosegmental Phonology (Goldsmith, 1990; Zoll 1998), the current analysis aims to incorporate the ideas of combinable, fully-interpretable phonological elements (Harris, 1996; Harris & Lindsey, 2000) and ordered feature acquisition (Jakobson & Waugh, 2002; Dresher, 2009), but unfettered by a commitment to the notion of an innate, universal feature set (cf. Chomsky & Halle, 1968).

4.2. Building an Inventory with Emergent Elements

As a first attempt to put the idea of emergent phonological elements into practice, it may be helpful to consider a language with a somewhat simpler phonemic inventory than English. With unusual phonemes like /θ/, /ð/, /æ/, /ʒ/, and /ɹ/, English is notoriously hard to pronounce, even for many native speakers. A language with a smaller inventory of sounds is likely to contain many of the same contrasts made by very young speakers of English who haven't yet learned to make all the distinctions present in the adult system.

As an example of a simple, natural, and fairly symmetrical system of phonemic contrasts, the Gikuyu language of Kenya seems to be a perfect candidate. Alice Mwihaki (2001) describes Gikuyu's phonemic inventory as comprising the sounds listed in Table 4.4 below. Marginal phonemes that may be accounted for either as an allophone of another phoneme or as a combination of two or more existing phonemes are listed in gray.

Table 4.4. Traditional taxonomy of the phonemic inventory of Gikuyu

	Labial	**Dental**	**Palatal**	**Guttural**
Voiceless Stops		t		k
Prenasal Stops	mb	nd		ŋg
Prenasal Affricate			ɲʤ	
Nasals	m	n	ɲ	ŋ
Voiceless Fricatives	ɸ	θ	ʃ	h
Voiced Spirants	w	r	j	ɣ
High Vowels			i	u
Mid-High Vowels			e	o
Mid-Low Vowels			ɛ	ɔ
Low Vowel				a

With only around 21 phonemes (excluding the pre-nasal obstruents, which may be analyzed as complex segments), Gikuyu makes roughly the same number of phonemic contrasts as might be expected of a typical English-speaking three-year-old. Although it cannot be assumed at this point, it may be possible that the elements proposed here for Gikuyu are also applicable to English. While not all languages make the exact same contrasts in the same order, such contrasts are undoubtedly rooted in human biology, whether as language-specific mechanisms of the sort proposed in Generative Phonology (Chomsky & Halle, 1968) and Optimality Theory (Prince & Smolensky, 2004) or as general limitations on perception and articulation (Bybee, 2001; Vihman & Croft, 2007; Mielke, 2008). As such, there are bound to be more similarities than differences among the sound systems of the world.

In the present framework, prosodic structure is assumed to be somewhat independent from the basic elements responsible for contrast at the phonemic level. Therefore, features such as [syllabic] and [stress] are not treated here (cf. Fant, 1971; Kehoe & Stoel-Gammon, 1997). What follows is a listing of five distinctive features (and their corresponding elements) that capture the phonemic inventory of Gikuyu quite economically in terms of natural classes.

Table 4.5. Emergent elements proposed for Gikuyu

Feature	Element	Description
[obstruent]	{!}	Indicates obstruents (stops, fricatives, etc.) as opposed to sonorants.
[coronal]	{D}	Produced with the tip or blade of the tongue. Indicates frontness in vowels.
[low]	{B}	Produced with the lips and/or teeth. Indicates a low tongue body in vowels.
[strict]	{*}	Indicates contact between articulators for consonants and tension (i.e. an advanced tongue root and/or lip rounding) for vowels.
[nasal]	{N}	Indicates nasality in sonorants or simply voicing in obstruents.

The feature [obstruent] is easily motivated by the input an infant receives, as relatively straightforward acoustic cues are available to distinguish sonorants from obstruents (Pruthi & Espy-Wilson, 2003). [coronal] is an articulatory feature, but it corresponds quite closely to the acoustic feature [acute] (Jakobson et al., 1952). This distinction is again well motivated by the acoustic input. [low] is very much an articulatory feature corresponding to a lack of dorsal stricture. Its corresponding element {B} may be identified as either compact or diffuse, depending on its status as a vowel or a consonant. With [strict], the feature set grows a bit more abstract, as identification of the relative stricture of a given sound is heavily dependent on context.

The element {N} is actually not actually necessary for phonemic contrast in Gikuyu if pre-nasal stops are analyzed as sequences of nasal+stop (or perhaps nasal+fricative). Therefore, [nasal] should probably not be considered an *element* of Gikuyu phonology, just a *feature* added to help regulate allophonic variation and organize some of the language's most common clusters (i.e. the pre-nasal stops). In actuality, there is no clear-cut distinction between elements and features; they are really one and the same thing. It is simply a matter of convenience to deal with these most basic phonological features as if they were themselves distinct segments because they typically are expressed as such. Without making any strong cross-linguistic predictions, each of these features could be considered *marked* in that its presence cannot be assumed by default (cf. Trubetzkoy, 1939). In this sense, more complex segments (i.e. those comprising several elements) may be considered more marked than simpler segments.

What follows is a listing of the predicted phonemic contrasts available in Gikuyu at five distinct stages of acquisition, with each stage corresponding to the addition of one new element. These stages are intended to determine the organization of the phonemic/phonetic inventory but also to be psychologically plausible predictors of the typical stages of phonological acquisition. Elements that seem to be present but cannot be easily explained in terms of some necessary contrast between sounds are grayed out of the element specifications below. In fact, there are only two instances of this happening in the Gikuyu inventory, and both involve the somewhat unnecessary feature [nasal].

1. {} = [m, n, ɲ, ŋ, w, r, j, ɣ, i, u, e, o, ɛ, ɔ, a]

   {!} = [t, k, mb, nd, ɲdʒ, ŋg, ɸ, θ, ʃ, h]

2. {} = [m, ŋ, w, ɣ, u, o, ɔ, a]

{!} = [k, mb, ŋg, ɸ, h]

{D} = [n, ɲ, r, j, i, e, ɛ]

{!D} = [t, nd, ɲʤ, θ, ʃ]

3. {} = [ŋ, ɣ, u, o]

{!} = [k, ŋg, h]

{D} = [ɲ, j, i, e]

{!D} = [ɲʤ, ʃ]

{B} = [m, w, ɔ, a]

{!B} = [mb, ɸ]

{DB} = [n, r, ɛ]

{!DB} = [t, nd, θ]

4. {} = [ɣ, o]

{!} = [h]

{D} = [j, e]

{!D} = [ʃ]

{B} = [w, a]

{!B} = [ɸ]

{DB} = [r, ɛ]

{!DB} = [θ]

{*} = [ŋ, u]

{!*} = [k, ŋg]

{D*} = [ɲ, i]

{!D*} = [ɲʤ]

{B*} = [m, ɔ]

{!B*} = [mb]

{DB*} = [n]

{!DB*} = [t, nd]

5. {} = [ɣ, o]

{!} = [h]

{D} = [j, e]

{!D} = [ʃ]

{B} = [w, a]

{!B} = [ɸ]

{DB} = [r, ɛ]

{!DB} = [θ]

{*} = [u]

{!*} = [k]

{D*} = [i]

{B*} = [ɔ]

{!DB*} = [t]

{*N} = [ŋ]

{!*N} = [ŋg]

{D*N} = [ɲ]

{!D*N} = [ɲʤ]

{B*N} = [m]

{!B*N} = [mb]

{DB*N} = [n]

{!DB*N} = [nd]

Given the above feature specifications, the sounds of Gikuyu can be represented in a table whose rows and columns correspond precisely to the proposed manner and place contrasts. Three of the four lax vowels have tense counterparts, but /ɛ/ does not. This would seem to be a gap in the inventory, but the present mode of analysis does offer an explanation of sorts. /ɛ/ is the only vowel composed of two overlapping place elements. No other vowel in the language is composed of more than two elements, so perhaps the situation is more symmetrical than it seems at first glance.

Table 4.6. The phonemic inventory of Gikuyu recast in terms of emergent elements

	B	**DB**	**D**	
!*		t		k
!*N	mb	nd	ɲdʒ	ŋg
***N**	m	n	ɲ	ŋ
!	ɸ	θ	ʃ	h
*****	ɔ		i	u
	a, w	ɛ, r	e, j	o, ɣ

It seems that the phonemic inventory of Gikuyu, as well as a plausible account of its acquisition, can be described quite parsimoniously within the proposed framework. The entire inventory can be broken down into just four or five distinctive elements, which can be articulated alone or in combination. No internal structure is proposed for these elements or the combinations they form (cf. Schane 1984; Kaye, Lowenstamm, & Vergnaud 1985; Harris & Lindsey, 1995; Hulst, 2000). Only the most basic syllable constituents of onset and rhyme are assumed.

4.3. Application of the Framework to English

Now that the proposed approach has demonstrated its viability with a very simple sound system, it is time to move on to that of American English. In the following table, all rounded vowels are listed under the place heading of "Labial" (as opposed to "Velar") because at least one of these sounds (i.e. /ɔ/) contrasts phonemically with a non-front unrounded counterpart (i.e. /ʌ/ or /ɑ/). More sounds are included in the following table than are commonly considered phonemes, but these additional clusters and allophonic variants do figure prominently into the sound system. These marginal phonemes are listed below in gray.

Table 4.7. Traditional taxonomy of the phonemic inventory of English

	Labial	Dental	Alveolar	Palatal	Velar	Glottal
Voiceless Stops	p		t		k	ʔ
Voiced Stops	b		d		g	
Voiceless Afficate				ʧ		
Voiced Affricate				ʤ		
Nasals	m		n		ŋ	
Voiceless Fricatives	f	θ	s	ʃ		h
Voiced Fricatives	v	ð	z	ʒ		
Flap			ɾ			
Laterals		l			ɫ	
Approximants	w		ɹ	j		
High Tense Vowels	u			i		
High Lax Vowels	ʊ			ɪ		
Mid Tense Vowels	o			e		
Mid Lax Vowels	ɔ			ɛ	ʌ, ə	
Low Vowels				æ	ɑ	

Although the inventory of English is much larger than that of Gikuyu with much finer contrasts, only one additional element is required to represent all the phonemic contrasts of American English. This element {G} is described below. Interestingly, a very economical and explanatory description of the sounds of English is possible using basically the same features proposed for Gikuyu, emerging in the exact same order.

Table 4.8. Emergent elements proposed for English

Feature	Element	Description
[obstruent]	{!}	Indicates obstruents (stops, fricatives, etc.) as opposed to sonorants.
[coronal]	{D}	Produced with the tip or blade of the tongue. Indicates frontness in vowels.
[low]	{B}	Produced with the lips and/or teeth. Indicates a low tongue body in vowels.
[strict]	{*}	Indicates contact between articulators for consonants and tension (i.e. an advanced tongue root and/or lip rounding) for vowels.
[nasal]	{N}	Indicates nasality in sonorants or simply voicing in obstruents.
[close]	{G}	Indicates a raised and/or retracted tongue body, possibly with lip rounding.

As noted above, the proposed feature set equates nasality in sonorants with voicing in obstruents (cf. Nasukawa, 2005). This innovation is instrumental in allowing the relatively large segmental inventory of English to be generated from a set of only six basic elements. The additional feature [close] is articulatory in nature, but its precise realization is highly dependent on context. For example, {G} alone might be identified acoustically as *diffuse* (i.e. high), but in combination with {!}, it would be *compact* (i.e. velar). When combined with {B}, {G} might be described as *flat* (i.e. rounded, retracted, and/or retroflex). In this way, elements acquired later may be parasitic on those acquired earlier.

The predicted stages below correspond very closely to the generalizations made in Chapter 3. Of course, these are only generalizations, not strict universals. Every child acquiring English is not expected to formulate exactly the above features and apply them in exactly the above order with no need for reformulation along the way. What is outlined here may be the most efficient path to an adult-like system of contrasts, but it is certainly not the *only* path.

It is predicted that after Stage 1, sonorants and obstruents should rarely, if ever, be confused. It should be noted, however, that voiced obstruents may initially be identified as sonorants, causing confusion of voiced stops with nasals and voiced fricatives with approximants in the early stages. In Stage 2, confusion between consonants should abound, but the processes of stopping, fricativizing, gliding, and sonorant nasalization are expected to predominate. There are essentially two places of articulation in this stage (coronal and labial/guttural), and a two-vowel system is possible (likely realized as /ɪ/ and /ɑ/). In Stage 3, consonantal simplifying processes involving manner are expected to persist while further place contrasts are made. In Stage 4, stopping and fricativizing should be corrected, but (de)voicing is expected to persist. All major place contrasts are possible at this point, but a distinction between alveolar and palatal sounds is still expected to be lacking. The vowel system should be fairly adult-like in this stage, but confusion between the following pairs is predicted: /ʊ:ʌ/, /ɪ:ɛ/, and /ɔ:ɑ/. In Stage 5, these mergers are expected to persist while voicing errors are eliminated. In Stage 6, a fully adult-like inventory is predicted.

As with the analysis of Gikuyu, elements that seem to be present but cannot be easily explained in terms of contrast are grayed out of the specifications below. Only one indisputable phoneme is affected (/g/), and again only the last element added (in this case, {G}) is in question.

1. {} = [m, n, ŋ, ɾ, w, l, ɫ, ɹ, j, u, i, ʊ, ɪ, o, e, ɔ, ɛ, ʌ, ə, æ, ɑ]

   {!} = [p, t, k, ʔ, b, d, g, ʧ, ʤ, f, θ, s, ʃ, h, v, ð, z, ʒ]

2. {} = [m, ŋ, w, u, ʊ, o, ɔ, ʌ, ə, ɑ]

   {!} = [p, k, ʔ, b, g, f, h, v]

   {D} = [n, ɾ, l, ɫ, ɹ, j, i, ɪ, e, ɛ, æ]

   {!D} = [t, d, ʧ, ʤ, θ, s, ʃ, ð, z, ʒ]

3. {} = [ŋ, u, ʊ, ʌ, ə]

   {!} = [k, ʔ, g, h]

{D} = [n, ɾ, j, i, ɪ, e, ɛ]

{!D} = [t, d, ʧ, ʤ, s, ʃ, z, ʒ]

{B} = [m, w, o, ɔ, ɑ]

{!B} = [p, b, f, v]

{DB} = [l, ɫ, ɹ, æ]

{!DB} = [θ, ð]

4. {} = [ʊ, ʌ, ə]

{!} = [h]

{D} = [j, ɪ, ɛ]

{!D} = [s, ʃ, z, ʒ]

{B} = [w, ɔ, ɑ]

{!B} = [f, v]

{DB} = [ɹ, æ]

{!DB} = [θ, ð]

{*} = [ŋ, u]

{!*} = [k, ʔ, g]

{D*} = [n, ɾ, i, e]

{!D*} = [t, d, ʧ, ʤ]

{B*} = [m, o]

{!B*} = [p, b]

{DB*} = [l, ɫ]

5. {} = [ʊ, ʌ, ə]

{!} = [h]

{D} = [j, ɪ, ɛ]

{!D} = [s, ʃ]

{B} = [w, ɔ, ɑ]

{!B} = [f]

{DB} = [ɹ, æ]

{!DB} = [θ]

{*} = [u]

{!*} = [k, ʔ]

{D*} = [ɾ, i, e]

{!D*} = [t, ʧ]

{B*} = [o]

{!B*} = [p]

{DB*} = [l, ɫ]

{!DN} = [z, ʒ]

{!BN} = [v]

{!DBN} = [ð]

{*N} = [ŋ]

{!*N} = [g]

{D*N} = [n]

{!D*N} = [d, ʤ]

{B*N} = [m]

{!B*N} = [b]

6. {} = [ʌ, ə]

{!} = [h]

{D} = [ɛ]

{!D} = [s]

{B} = [ɑ]

{!B} = [f]

{DB} = [æ]

{!DB} = [θ]

{!*} = [ʔ]

{D*} = [ɾ, e]

{!D*} = [t]

{!B*} = [p]

{DB*} = [l]

{!DN} = [z]

{!BN} = [v]

{!DBN} = [ð]

{D*N} = [n]

{!D*N} = [d]

{B*N} = [m]

{!B*N} = [b]

{G} = [ʊ]

{DG} = [j, ɪ]

{!DG} = [ʃ]

{BG} = [w, ɔ]

{DBG} = [ɹ]

{*NG} = [ŋ]

{*G} = [u]

{!*G} = [k]

{D*G} = [i]

{!D*G} = [ʧ]

{B*G} = [o]

{DB*G} = [ɨ]

{!DNG} = [ʒ]

{!*NG} = [g]

{!D*N} = [ʤ]

Such a limited inventory of elements allows for a compact representation of the sounds of English based less on the physical space involved in the articulation of these sounds and more on their distinctive features. The following chart shows a great deal more symmetry than the more traditional taxonomy presented in Table 4.7.

Table 4.9. The phonemic inventory of English recast in terms of emergent elements

	B	DB	D	DG	G	BG	DBG	
!*	p		t	ʧ	k			ʔ
!*N	b		d	ʤ	g			
*N	m		n		ŋ			
!	f	θ	s	ʃ				h
!N	v	ð	z	ʒ				
*		l	e, ɾ	i	u	o	ɨ	
	ɑ	æ	ɛ	ɪ, j	ʊ	ɔ, w	ɹ	ʌ, ə

As was noted for the Gikuyu inventory, the number of elements allowed to overlap does seem to be somewhat constrained. Although six elements are postulated for English, no single phoneme requires more than four of these. It is possible to imagine how additional phones might be realized (e.g. /q/ for {!B*G} and /ɖ/ for {!DB*NG}), but such sounds would likely resemble existing phonemes such that their phonetic interpretation would be somewhat difficult. Still, it may be considered a strength that the current mode of analysis is capable of not only describing existing contrasts but predicting possible contrasts that might be phonemicized in the future. Perhaps more importantly, potential mergers of existing phonemes can be predicted on the basis of feature loss, either in specific contexts or across the board.

4.4. Analyses of Observed Alternations

The system of contrasts outlined in Section 4.3 is capable not only of predicting which speech sounds will be frequently confused early in the acquisition process but also of representing common phonological processes known to exist in adult phonology (e.g. reduction, assimilation, metathesis). To illustrate this potential, several phonological innovations observed in the present study will be analyzed here. In each of the following examples, a standard adult pronunciation of the word in question is listed alongside the phonetic form(s) recorded for a given participant. All syllabic nuclei carry a mark directly above them: A plus sign (+) indicates primary lexical stress, a minus sign (−) indicates secondary stress, and a dot (.) indicates no stress whatsoever. Below each segmental transcription, all applicable elements are listed on successive lines. Very slight structural improvements that would not change the phonetic output in any major way are indicated below as light gray elements (which could possibly be added to the representation) and dark gray elements (which could possibly be removed).

The following pair illustrates feature loss in the onset of the first syllable, resulting in devoicing and spirantization. These are very common processes in adult phonology as well. For example, Spanish tends to apply *both* processes to word-final stops. In the current framework, the loss of [nasal]/{N} is responsible for devoicing, and the loss of [strict]/{*} is responsible for spirantization. The presence or absence of [close]/{G} in this first syllable is not particularly important for contrast, but in any case, it seems to have migrated from onset to rhyme position. [coronal]/{D} also appears to have spread to this position from the onset of the next syllable, but it is perhaps more likely that the vowel is represented as /ɪ/ in its underlying form.

(1) F2B's production of *guitar*:

```
  .  +         .  +
[gəthaɑɹ] vs. [hɪthaɹ]
 ! !!         ! !!
   D  D        DD  D
     BB           BB
 * *            *
 N
 G    G        G   G
```

As a more clear-cut example of feature migration consider the problem of nasal debuccalization. This is another common process in adult phonology. By any account, the feature [nasal] (or some equivalent) spreads to the preceding vowel and subsequently (or perhaps simultaneously) detaches from the syllable's coda. In many cases, this results in complete loss of the coda with its only remnant being the nasalization of the vowel. The current framework provides a very simple explanation for this process in the example shown below: The timing of the elements is adjusted such that there is no distinct space for [ŋ] to occupy between the end of [coronal]/{D} and the start of [obstruent]/{!}. This could be restated in terms of the segments [ĩ] and [g], but segments such as these are not responsible for the existence of their associated elements; it seems to be the other way around (cf. Goldsmith, 1990; Harris & Lindsey, 1995).

(2) F2A's production of *flamingo*:

```
  .  +  .         + .
[fləmĩŋgəw] vs. [mĩgʌw]
 !     !            !
  D  D            D
 BB B    B       B   B
  * ****         ***
    NNNN         NNN
     GGG G        GG G
```

Now that a few of the more mundane processes have been illustrated, we can begin to examine situations where there seems to be no explanation for phonological innovation other than simply a different representation in the lexicon. This may be the case, but it would be ideal if phonological processes could be identified to *motivate* these alternative representations. In (3) below, what appears to be a straight substitution of /gə/ with /kɪn/ may actually be better characterized as a mutation of the former *into* the latter. If the descriptive features [voice] and [nasal] are taken to be two realizations of the same thing (cf. Nasukawa, 2005), then this process can be described quite simply as a migration of the feature [nasal]/{N} from the onset of the first syllable to its rhyme. As in (1), the vowel of this syllable may be characterized as /ə/ affected by feature spreading or simply /ɪ/ at the underlying level.

(3) F4B's production of *guitar*:

```
  .  +          .   +    .   +
[gəthaɹ] vs. [khɪnthaɹ, kɪnthaɹ]
 ! !!         !!  !!    !  !!
   D  D         DDD  D   DDD  D
     BB            BB       BB
 * *          *  **     * **
 N              NN       NN
 G    G       GGG    G  GG    G
```

A similar example of feature migration is shown in (4) below. In this case, the heterotropic element is [close]/{G}. Likely due to a metrical restriction disallowing WISSs, {G} is unable to appear word-initially. Perhaps as a strategy for preserving the overall featural content of the word, {G} instead surfaces word-finally. The last phonetic form listed in (4) below appears to include an attempt to reposition {G} in the WISS, though in its rhyme instead of its onset. Still, the word-final [k] remains.

(4) M3B's production of *guitar*:

```
  .  +          +      +      .   +
[gəthaɹ] vs. [thaɹk, thaɹkh, dʊwthaɹk]
 ! !!         !!  !  !!  !!  !  !!  !
   D  D       D  D   D  D    D  D  D
     BB         BB     BB      B  BB
 * *          *   *  *   *   *  *   *
 N                           N
 G    G           GG     GG    GG   GG
```

As a classic example of metathesis, consider the innovations made in the following example. [sp] is allowed as an onset when it occurs as part of a stressed syllable (as in the third form listed), but in a

WISS, it must be reduced to [b] or [p]. This leaves [s] without a home, so [s] pushes past the onset position to find one. If each of the lines following the phonetic forms below is considered to be a separate phonological tier, then the movement of an element within one tier really indicates nothing more than a timing adjustment. In terms of the phonological elements involved, the overall shape of the forms below remains fairly similar despite such adjustments.

(5) M4's production of *spaghetti*:

```
   . + .        .  + .    .  + .    + - .
[spəgɛɾi] vs. [bəskɛɾɪj, pəskɛɾi, spɛgɛɾi]
 !! !          ! !!      ! !!     !! !
 D   DDD         D DDDD    D DDD  D D DDD
  B            B         B         B
  * * **       *  * *    *  * **   * * **
    N          N            N        N
    G  G          G  GG     G  G     G  G
```

Most of the preceding examples were chosen to illustrate well-attested phonological processes. For the most part, they could be described just as well in a more traditional framework (e.g. Chomsky and Halle, 1968; Prince & Smolensky, 2004). The following alternation, on the other hand, would be quite difficult to tackle. Stated in terms of emergent elements, the three phonological representations given below are all strikingly similar despite their wildly divergent phonetic forms. There are at least two plausible motivations for this innovation, perhaps working in tandem. First, the combination of {!D*N} with {G} may be disallowed in this child's inventory. This could force {G} to spread leftward in an attempt to find phonetic realization. Where {!B*} and {G} overlap, an English speaker (not possessing /q/ in their inventory) will likely produce [k], basically ignoring the element [low]/{B}. Instead of forming a single WISS (perhaps [kɔ]), the four elements prior to the main stress make up *two* syllables, allowing the word to consist of two metrical feet (both trochees) with no un-footed syllables. The end product is a phonological representation that fits with the rest of the child's phonological grammar and is still identifiable with the adult equivalent.

(6) F4A's production of *pajamas*:

```
   .  + .        - . + .   -  .  + -
[phədʒãməz] vs. [ɔkɔdãmas, ɔwkaɹdamas]
 !! !!   !        ! !   !    !  !   !
    DD   D          D   D      DD   D
 B    BB         BBB BBB   BBBBB BBB
 *  *  *          * * *      *  * *
    NNNN N          NNN N       N N
    GG           GGG       GGGGG
```

When the above phonological innovations are stated in terms of overlapping elements, their regularity becomes more apparent, although no specific mechanisms have been proposed to motivate them here. A thorough, formal analysis of such alternations is beyond the scope of this project. However, the proposed feature set and related theoretical framework clearly show promise in this regard.

Chapter 5: Conclusion

5.1 Overall Findings

In the present study, phonemic distinctions were found to be made gradually throughout development based primarily on the notion of maximal contrast (cf. Jakobson & Waugh, 2002). Such distinctions and their order were found to be fairly equivalent across participants, though individual strategies certainly played a role in observed variation. Phonemic contrasts were not applied equally in all structural positions. In particular, distinctions between different types of WISS onsets seemed to lag behind distinctions made for the onsets of stressed syllables. This suggests that metrical structure has the authority to license available phonemic contrasts and that such contrasts are licensed only where they are likely to provide *lexical* contrast. Early in the acquisition of English, this is not the case for WISSs, a relatively infrequent syllable type.

The phonemic contrasts observed did not take the shape of a contrastive hierarchy but were instead particularly amenable to description as emergent elements which can be combined exactly like privative distinctive features to create more complex segments. A tendency was observed toward combining these elements only to provide contrast with other speech sounds (whether phonemic or allophonic). The proposed distinctive features [obstruent], [coronal], [low], [strict], [nasal], and [close] were found to apply in a fairly rigid order to the sounds systems of both American English and the unrelated Bantu language Gikuyu (which was not found to need the feature [close] or perhaps even [nasal] for phonemic contrast). Whether these features and their order of application are truly universal remains to be seen.

5.2. Limitations of Study

The experimental design of the present study was very loose, which allowed for a great deal of naturalistic data to be collected, but these data were very much open to interpretation. Several very interesting trends were observed, but no firm conclusions can be drawn at this point without a statistically viable sample size. While it is true that 20 participants were interviewed, none of them actually produced all the target forms. Only a single target (*balloon*) was produced by all 20 participants.

Perhaps the biggest limitation of the present study is its lack of diachronic data. Diachronic predictions were made from synchronic data such as the frequency of innovations involving particular types of segments and metrical positions, but these predictions cannot be verified without a true longitudinal study.

5.3. Recommendations

The theoretical implications of the framework proposed here are vast. In order to provide support for the claims made here, a longitudinal study involving both production and perception would be ideal. A forced choice task involving segmental variations in structurally similar words (e.g. *tomato* and *potato*) might lend support for the idea that some featural contrasts are acquired before others, both in production *and* perception. Even a latitudinal study of this type could provide support for a particular acquisitional order in the sense that some contrasts may be found to *imply* others.

While empirical support is being garnered for emergent phonological elements as they apply to English, attempts can be made to apply the mode of analysis outlined here to the sound systems of other languages. Certainly, the features proposed here could be used to *describe* the phonemic inventories of many languages, especially when augmented with additional features (perhaps [labial], [long], etc.), but only if they do this economically while making valid phonological and developmental predictions can they be considered likely analogues of the sort of representational structures which exist in the mind.

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Appendix A: IRB Letter of Approval

THE UNIVERSITY OF TEXAS AT EL PASO
Office of the Vice President for Research and Sponsored Projects
Institutional Review Board
El Paso, Texas 79968-0587
phone: 915 747-8841 fax: 915 747-5931

DATE: January 20, 2010

TO: Cliff Jones, BA
FROM: University of Texas at El Paso IRB

STUDY TITLE: [139098-2] Developmental Variation in Children's Acquisition of Metrical Structures
IRB REFERENCE #:
SUBMISSION TYPE: Amendment/Modification

ACTION: APPROVED
APPROVAL DATE: January 20, 2010
EXPIRATION DATE: January 20, 2011
REVIEW TYPE: Expedited Review

Thank you for your submission of Amendment/Modification materials for this research study. University of Texas at El Paso IRB has APPROVED your submission. This approval is based on an appropriate risk/ benefit ratio and a study design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

This study has received Expedited Review based on the applicable federal regulation.

Please remember that informed consent is a process beginning with a description of the study and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the study via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the signed consent document.

Please note that any revision to previously approved materials must be approved by this office prior to initiation. Please use the appropriate revision forms for this procedure.

All SERIOUS and UNEXPECTED adverse events must be reported to this office. Please use the appropriate adverse event forms for this procedure. All FDA and sponsor reporting requirements should also be followed.

Please report all NON-COMPLIANCE issues or COMPLAINTS regarding this study to this office.

Please note that all research records must be retained for a minimum of three years after termination of the project.

Based on the risks, this project requires Continuing Review by this office on an annual basis. Please use the appropriate renewal forms for this procedure.

If you have any questions, please contact Athena Fester at (915) 747-8841 or afester@utep.edu. Please include your study title and reference number in all correspondence with this office.

Appendix B: Overall Production Data

The following tables represent all the relevant production data collected for this study. Each participant's unique code is listed along the left side of the table. Due to spatial limitations, the seven most frequently identified target vocabulary items are presented first, and the remaining seven items follow. Within each cell, all of the participant's utterances of the given item have been phonetically transcribed. Those occurring more than once appear in bold. Several forms listed under "pajamas" appear in gray and are excluded from analysis because they seem to be instances of the word *jammies* and not actually *pajamas* at all.

Table B.1. Phonetic forms of participant utterances of the most frequently identified targets

	balloon(s)	banana(s)	computer	giraffe(s)	guitar	pajamas	piano
F1	bʊ'ʊ̃n bʊ'u	**mʌ'nanʌs** βʌ'nanʌ mʌ'nanʌz mʌ'nanəz	tʌ'piɔ cʌ'piɔ	**'dæf** 'daf		**pə'damis** bə'dami	bʌ'ɾãhʌ 'bãə
M1	'w̠ʊ̃m 'bʊ̃n 'bũm	**'ɲæɲʌ** 'ɲaɲa 'ɲɛɲʌ			**'tʰɑɹ** 'tʰɑ 'tʰaɹ		'ɲano 'ɲaˌnʌw
M2A	bə'nʊ̃w̃n ˌbu'nʊwn	bə'næ̃nʌ ˌbʌ'næ̃nʌ bʌ'næ̃n ˌbæl'jæ̃nʌ	**ˌkãm'piɚ** ˌkãm'pilɚ				
M2B	'blũn 'blũs	bə'næ̃nʌ bə'nãnʌ			ˌwʌʔs'tɑɹ 'wɑsˌtɑɹ ˌwʌh'tɑɹ		
M2C	'blũnts 'bũmts dɪ'bũb dɪ'bũs	mi'nanaz mi'naˌnʌz mi'nãʌ mi'nanʌ 'miˌnanas	'fɔˌdɔs də'pw̠uˌdɔs dɪ'pʊɾə	**də'w̠ʌf** də'w̠af də'laf		'tjaˌmʌz	
F2A	bə'lũz 'bũz 'bjũnts	**do'bɛdʌz** də'bɛdˌaz də'bɛɾʌz ˌdo'bæ̃nʌz ˌbæ̃'nʌz	tʰə̥'pʰejdɔ də'pʰeɾʌ	'dw̠aʔf 'dw̠af			

	balloon(s)	banana(s)	computer	giraffe(s)	guitar	pajamas	piano
F2B	bə̃'nũz	**'nanaz** ˌnɛ'nas	'pjerɚ pi'ɚ 'pjʊɚ	'dʝæf	hɪ'tʰɑɹ		
M2D	**'blũs** **ə'blũz** 'blʊw 'plũn	**ʌ'mæˌnæ** ə'mæ̃ˌnæh tə̥'bæˌnæs tə'mæ̃ˌnas		dɚ'ɹæf 'ʤɹæf		'dæ̃mis 'ʤæ̃ˌmiz ə'ʤæ̃miz	
F2C	bə'lũts ˌbʌ'nũn	bə'nãnəs ˌpʌ'nana	ˌpʰjʌ'pʰjɪwdɚ pʰʌ'pʰjɪwdɚ ˌpʰɑ'pʰjudɚ	ˌdʌ'wæf	**ˌpʰɑ'tʰɑɹ** ˌpʰʌʔ'tʰɑɹ ˌpʰʌ'tʰɑɹ	'ʤãmiz 'ʤãmis	**'pʰjãnʌw**
F2D	'blũn 'blʊ̃w̃n 'dlə̃w̃ bə'lə̃w̃n 'blə̃w̃	**'tʰʊˌnãna** 'nãnʌ 'bæ̃ˌnãna 'fəˌnana 'nãna	'pʰedɚ 'pʰerɚ	**'laf** 'daf		'ʤaˌβi 'daβi	
F2E	**'plĩw** 'pɪlĩn 'plũs 'lʊ̃w̃ bɪ'lĩw̃s pɪ'lʊ̃w	**bʌ'nãnʌs** pa'nãnas pʰa'nãnʌz		'dʌˌw˞æf tu'w˞æf		tə'pãə tu'amɪz 'twamɪz	
M3A	**bə'lʊ̃w̃nts** dɪ'lĩw̃nts pə'lĩw̃n	bə'nãnʌ bə'nãnas	'peˌtɚ 'pɛˌcɪ	'ʃw˞af ʃʊ˞'af 'ʧw˞af		'ʤamas tʰə̥'ʃamas	'pãˌnʌw 'pãnaw 'paˌnʌw
F3	bə'lũts bə'lũn bə'lũ	bə'næ̃nʌ βə'næ̃nʌ	sə'pʰɹudɚ zə'pʰʝudɚ zə'pʰjurɚ sʌ'pʰʝurɚ	ʤɚ'ɹæf	**sə'tʰɑɹ** **zə'tʰɑɹ** zɪ'tʰɑɹ	pə'ʤɑmʌz pʰə'ʤɑmʌz	**ˌpʰi'æ̃nʌw**
M3B	bə'lũn bʊ'lũn	pʊ'nanas bə'nanas bʊ'nana bə'nana	'pʰjurɚ 'pʰjɪwrɚ	ʤɚ'ɹæf	**'tʰɑɹk** dʊw'tʰɑɹk 'tʰɑɹkʰə̥	'ʤæ̃mis	pi'jænʌw pʰi'jãnʌw
M3C	'buh 'biʊɔʔs 'bɪʊʔ				'tæ 'tæʌ 'tʌɹ		
M3D	bə'lʊ̃w̃nts 'blu	bə'nænʌs bə'næ̃nʌs bə'næ̃nʌ	kʰə'pʰjurɚ	**'ʤɹæf**	pʰʌ'tʰɑɹ pʰə'tʰɑɹ	pʰə'ʤɑməz	**pʰi'æ̃nʌw**
M4	bʌ'lʊ̃w̃z bʌ'lʊ̃w̃n ˌbʌ'lʊ̃w̃n	bə'næ̃nʌz bʌ'næ̃nʌ	'kʰə̃mˌpʰirɚ	'ʤɹæf	'pʰɹiˌtʰɹaʝ ˌpɪˀkt'hɑɹ	bə'ʤɑməz pʊ'ʤɑmʌz	pʰɪn'læ̃nʌw pʰɪd'læ̃nʌw pʰ̃ĩ'nerow pʰʊ̃'læ̃nʌw
F4A	**'pʊ̃w̃n** ˌdʊ'lũts	ˌdene'nẽnʌ ˌdə̃˞mnlə̃m'nɛ̃na ˌde'nɛ̃na	'pʰiˌdɚ			ˌɔwkaɹ'daˌmas ˌɔkɔ'dãmas	
F4B	bə'lũnts ˌbaj'lʊ̃w̃n	bɪ'næ̃nʌz bə'næ̃nʌ	kʰə̃m'pʰjiwrɚ	ʤɚ'ɹæf ʤɚ'ɹæfɪz ʤɚ'apɪz	**kʰ̃ĩn'tʰɑɹ** kĩn'tʰɑɹ	pʰə'ʤãmiz	
F4C	'blʊ̃w̃n 'blə̃w̃n	ˌbi'nanʌ bə'næ̃nʌ bɪ'næ̃nʌ bɪ'nãna	kʰə̃m'pirɚ	ʤɚ'ɹæf	**kʰə'tʰɑɹ**		

Table B.2. Phonetic forms of participant utterances of the least frequently identified targets

	tomato(es)	potato(es)	spaghetti	gorilla	flamingo	vanilla	burrito
M1		ˈpɛɾʌ	**ˈʧʌˌʧʌ**			ˈneɔ ˈnɛɔ	
M2A	təˈmɛ̃nʌwz ˌnʌwˈmɛ̃nʌw ˌtoˈmelow ˌtʌwˈmejɾʌw						
M2C	tʰoˈmejʌwz toˈmejŋʌwz tʰəˈmɛjnʌws dɪˈmejˌnʌwz						
F2A			ˈspɑgəˌdɪdi	ˈgoˌʍala ˈʍɛla ˈgʍɪlʌ ˈkʍɪla ˈkʍɛlə	**ˈmĩgʌw**		
F2C		pʰəˈtʰejɾʌw	ˌbʌˈdʌdi pʰəˈdʌdi				bʌˈwiɾʌw ˌbʌˈwiɾʌw
F2D		ˈceɹˌtʌ ˈtʌtʌ					
F2E	**tʰəˈmɛjlɔwz** tʰəˈmɛjnʌwz tʰə̥ˈmɛjnʌwz tʰəˈmɛjŋɔws tʰəˈmɛjlɔws	**tʰəˈmɛjlʌws** ˈnejˌlʌws ˈmejˌlʌws ˈmɛjɾʌwz					
F3	pəˈtʰejɾʌwz					bʌˈnɪlə bəˈnɪlʌ	
M3B			**pəˈgɛɾi** pʊˈgɛɾi	gɚˈɹɛˌlʌ gɚˈwɪla			
M3D	ˌtʰuˈmejɾʌwz tʰuˈmejˌtʰʌwz		sbəˈgɛɾi				
M4	pʰʊˈtʰeɾʌw pʰəˈtʰejɾʌw pʰʊˈnedʌw	kʰɪˈnejdʌw	bəsˈkɛɾɪj ˈspɛˌgɛɾi pəsˈkɛɾi				
F4A		ˈpɛˀtˌdɛs ˌpɛˀtˈdɛs					
F4B	tʰʊˈmejɾowz tʰəˈmɛjɾʌwz tʰəˈmejɾowz	məˈtʰejɾoz ˈtʰejɾowz	spəˈgɛɾi		kʰəˈmẽɾo kʰə̃mˈbeɾow		

Appendix C: Individual Production Data

Based on the phonetic forms recorded for each participant, a single slightly more abstract phonological form will be postulated for each vocabulary item. Given the small amount of evidence available, this is nothing more than one plausible guess as to how the differing phonetic forms may be related to a single phonological form. However, this simplification will greatly facilitate analysis of the raw data by brushing aside performance issues for the time being. To keep the data theory-neutral, an attempt was made to posit forms requiring only very well attested and uncontroversial phonological processes.

Within each phonological form below (enclosed in slashes), metrical feet are indicated by the enclosure of constituent segments within parentheses. The first vowel of each foot receives stress, and any subsequent vowels (as well as any vowels appearing outside of a set of parentheses) are stressless. If more than one foot is present in a given phonological form, then the foot receiving primary lexical stress is marked with a subscript "S" (for *strong*) and all others are marked with a subscript "W" (for *weak*). Within each set of phonetic forms (enclosed in square brackets), forms occurring more than once are indicated by a superscripted number in parentheses indicating their number of occurrences.

In order to facilitate generalizations across participants, places of articulation have been limited to three: *labial* (bilabial or labiodental), *coronal* (dental, alveolar, or palatal), and *guttural* (velar, pharyngeal, or glottal). Where complex onsets exist or single segments do not fit neatly into just one of these categories (e.g. /w/ and /r/), onsets will be considered to span two or more categories. The term "selected" is used below to mean that a given adult form was incorporated into the child's grammar with no major structural change. Conversely, a form is "adapted" if it has undergone some sort of adjustment, probably to fit more neatly into the child's existing grammar. Because it is often difficult to differentiate between completely stressless syllables and those with weak stress, word-initial syllables with secondary stress will be analyzed, but they will be given half the weight of true WISSs.

In an attempt to provide the clearest developmental picture possible with a study of this type, participants have been listed below in ascending order of the number of targets they produced. Due to the immense variability among individuals, it is believed that this is a better indication of acquisitional stage than either biological age or accuracy rating.

C.1. M3C (3;5;19)

Table C.1. Production data for participant M3C

Item	Phonological Form	Phonetic Form(s)
balloon(s)	/(bɪʊ)+s/	[ˈbuh, ˈbiʊɔʔs, ˈbɪʊʔ]
guitar	/(tær)/	[ˈtæ, ˈtæʌ, ˈtʌɹ]

Although very little data is available, it seems likely that WISSs are not tolerated in this participant's sound system. There may well be complex onsets such as /bl/ and /gt/ in the underlying representations of these words, but no direct evidence for this was provided.

C.2. M2B (2;7;7)

Table C.2. Production data for participant M2B

Item	Phonological Form	Phonetic Form(s)
balloon(s)	/(blun)+s/	[ˈblũn, ˈblũs]
banana	/bə(nænʌ)/	[bəˈnæ̃nʌ, bəˈnãnʌ]
guitar	/(wɑs)$_W$(tɑr)$_S$/	[ˌwʌʔsˈtɑɹ, ˈwɑsˌtɑɹ, ˌwʌhˈtɑɹ]

1 labial onset selected, 0.25 adapted; 0.25 guttural onsets selected. This participant appears to favor labial onsets. In a theory-neutral description of the data, it is unclear whether the onset /w/ should be classified as "labial" or "guttural", so its use in place of the adult form /g/ for *guitar* has been considered half a labial adaptation and half a guttural selection. Because this first syllable was weakly stressed, these values were again halved, rendering values of 0.25.

C.3. M2D (2;10;0)

Table C.3. Production data for participant M2D

Item	Phonological Form	Phonetic Form(s)
balloon(s)	/ə(blʊwn)+z/	[ˈblũs(2), əˈblũz(2), ˈblʊw, ˈplũn]
banana(s)	/tə(mæ)$_S$(næ)$_W$+s/	[ʌˈmæˌnæ(2), əˈmæ̃ˌnæh, tə̥ˈbæˌnæs, təˈmæ̃ˌnas]
giraffe	/də(ɹæf)/	[dɚˈɹæf, ˈdʒɹæf]

1 coronal onset selected, 1 adapted; 1 null onset adapted. This participant seems to favor alveolar onsets and may in fact use them interchangeably with /ə/. At least, this seems to be the case for *banana*.

C.4. M2A (2;6;5)

Table C.4. Production data for participant M2A

Item	Phonological Form	Phonetic Form(s)
balloon	/bu(nʊwn)/	[bəˈnʊ̃w̃n, ˌbuˈnʊwn]
banana	/ba(njænʌ)/	[bəˈnæ̃nʌ, ˌbʌˈnæ̃nʌ, bʌˈnæ̃n, ˌbælˈjæ̃nʌ]
computer	/(kam)$_W$(piɾɚ)$_S$/	[ˌkãmˈpiɚ$^{(2)}$, ˌkãmˈpilɚ]
tomato(es)	/(tʌw)$_W$(mɛjnɾʌw)$_S$+z/	[təˈmɛ̃nʌwz, ˌnʌwˈmɛ̃nʌw, ˌtoˈmelow, ˌtʌwˈmejɾʌw]

2 labial onsets selected; 0.5 coronal onsets selected; 0.5 guttural onsets selected. This participant shows remarkably adult-like pronunciation for his age. The primary strategy seems to be to apply secondary stress to WISSs. It is unclear whether the apparent preference for labial onsets is accidental or genuine.

C.5. F2B (2;10;0)

Table C.5. Production data for participant F2B

Item	Phonological Form	Phonetic Form(s)
balloons	/bə(nunz)/	[bə̃ˈnũz]
bananas	/(nanaz)/	[ˈnanaz(3), ˌnɛˈnas]
computer	/(pjʊɾɚ)/	[ˈpjeɾɚ, piˈɚ, ˈpjʊɚ]
giraffe	/(drjæf)/	[ˈdɟ̟æf]
guitar	/hɪ(tɑr)/	[hɪˈtʰɑɹ]

1 labial onset selected; 1 guttural onset selected. This participant seems to employ a variety of strategies including dropping the first syllable (e.g. *bananas* and *computer*), dropping the first syllable's vowel (e.g. *giraffe*), and leaving certain initial syllables intact (e.g. *balloons*), though perhaps adjusted slightly (e.g. *guitar*). Brevity seems to be desirable as no trisyllabic words were recorded.

C.6. F2D (2;11;16)

Table C.6. Production data for participant F2D

Item	Phonological Form	Phonetic Form(s)
balloon	/(blʊwn)/	[ˈblũn, ˈblʊ̃w̃n, ˈdlə̃w̃, bəˈlə̃w̃n, ˈblə̃w̃]
banana	/tʊ(nana)/	[ˈtʰʊˌnãna(2), ˈnãnʌ, ˈbæ̃ˌnãna, ˈfəˌnana, ˈnãna]
computer	/(pedɚ)/	[ˈpʰedɚ, ˈpʰeɾɚ]
giraffe	/(laf)/	[ˈlaf(3), ˈdaf]
potato	/(tertʌ)/	[ˈceɹˌtʌ, ˈtʌtʌ]

1 coronal onset adapted. F2D shows a strong tendency to avoid WISSs but plays around with different possibilities in *banana*. Whenever an initial syllable like /bæ/, /fə/, or /tʊ/ is present, it is made to receive primary stress. In any case, [+anterior] onsets seem to be preferred for syllables of this type.

C.7. F4A (3;7;27)

Table C.7. Production data for participant F4A

Item	Phonological Form	Phonetic Form(s)
balloon(s)	/dʊp(lʊwn)+s/	['pũw̃n$^{(2)}$, ˌdʊ'lũts]
banana	/(demlem)$_W$(nɛna)$_S$/	[ˌdene'nẽnʌ, ˌdɚ̃mnlə̃m'nɛ̃na, ˌde'nɛ̃na]
computer	/(pi)$_S$(dɚ)$_W$/	['pʰiˌdɚ]
pajamas	/(ɔwkaɹ)$_W$(damas)$_S$/	[ˌɔwkaɹ'daˌmas, ˌɔkɔ'dãmas]
potatoes	/(pɛt)$_S$(dɛs)$_W$/	['pɛˀtˌdɛs, ˌpɛˀt'dɛs]

1.5 coronal onsets adapted; 0.5 null onsets adapted. Labial onsets are apparently disallowed, with preference given to /d/. More interesting is this participant's treatment of *pajamas*. Instead of beginning with /p/ (an apparently disallowed segment in this environment), she seems to split /p/ up into at least two separate components: a labial element (/ɔ/ or /w/) and a voiceless stop (/k/).

C.8. F4C (3;11;27)

Table C.8. Production data for participant F4C

Item	Phonological Form	Phonetic Form(s)
balloon	/(blʊwn)/	[ˈblʊ̃w̃n, ˈblə̃w̃n]
banana	/bi(nanʌ)/	[ˌbiˈnanʌ, bəˈnæ̃nʌ, bɪˈnæ̃nʌ, bɪˈnãna]
computer	/kəm(piɾɚ)/	[kʰə̃mˈpiɾɚ]
giraffe	/ʤɚ(ræf)/	[ʤɚˈɹæf]
guitar	/kə(tɑr)/	[kʰəˈtʰɑɹ(2)]

1 labial onset selected; 1 coronal onset selected; 2 guttural onsets selected. This participant seems to accept a variety of onsets, but no alveolars were recorded. Despite the presence of voiced onsets in both *banana* and *giraffe*, /k/ was preferred over /g/ in *guitar*. Also of interest is the high-front vowel (/i/) in the first syllable of *banana*.

C.9. F1 (2;2;12)

Table C.9. Production data for participant F1

Item	Phonological Form	Phonetic Form(s)
balloon	/bʊ(un)/	[bʊˈʊ̃n, bʊˈũ]
banana(s)	/mʌ(nanʌ)+z/	[mʌˈnanʌs^(2), βʌˈnanʌ, mʌˈnanʌz, mʌˈnanəz]
computer	/tʌ(piɔ)/	[tʌˈpiɔ, cʌˈpiɔ]
giraffe	/(dæf)/	[ˈdæf^(2), ˈdaf]
pajamas	/pə(damis)/	[pəˈdamis^(2), bəˈdami]
piano	/bʌ(ɾãhʌ)/	[bʌˈɾãhʌ, ˈbãə]

4 labial onsets selected; 1 coronal onset adapted. This participant seems to show a bias toward [+anterior] onsets, both labial and alveolar. Velars are unattested in the data, though the palatal /c/ seems to be present as an allophone of /t/.

C.10. M2C (2;8;8)

Table C.10. Production data for participant M2C

Item	Phonological Form	Phonetic Form(s)
balloon(s)	/dɪ(blum)+s/	[ˈblũnts, ˈbũmts, dɪˈbũb, dɪˈbũs]
banana(s)	/mi(nanʌ)+z/	[miˈnanaz, miˈnaˌnʌz, miˈnãʌ, miˈnanʌ, ˈmiˌnanas]
computer	/dɪ(pru)$_S$(dɔs)$_W$/	[ˈfɔˌdɔs, dəˈpw̴uˌdɔs, dɪˈpʊɾə]
giraffe	/də(raf)/	[dəˈw̴ʌf(2), dəˈw̴af, dəˈlaf]
pajamas	/(tja)$_S$(mʌz)$_W$/	[ˈtjaˌmʌz]
tomatoes	/to(mɛjnʌwz)/	[tʰoˈmejʎwz, toˈmejŋʌwz, tʰəˈmɛjnʌws, dɪˈmejˌnʌwz]

1 labial onset selected; 2 coronal onsets selected, 2 adapted. This participant has a strong tendency to use an alveolar onset. The default initial syllable seems to be /dɪ/, as applied to *balloon*, *computer*, and possibly *giraffe*.

C.11. F2E (2;11;22)

Table C.11. Production data for participant F2E

Item	Phonological Form	Phonetic Form(s)
balloon(s)	/pɪ(lɪwn)+s/	[ˈpl̃ɪw̃(2), ˈpɪl̃ɪn, ˈplũs, ˈl̃ʊw̃, bɪˈl̃ɪw̃s, pɪˈl̃ʊw̃]
bananas	/pa(nanaz)/	[bʌˈnãnʌs(2), paˈnãnas, pʰaˈnãnʌz]
giraffe	/tu(ræf)/	[ˈdʌˌɰæf, tuˈɰæf]
pajamas	/tup(amɪz)/	[təˈpãə, tuˈamɪz, ˈtwamɪz]
potatoes	/tə(mɛjlʌwz)/	[tʰəˈmɛjlʌws(2), ˈnejˌlʌws, ˈmejˌlʌws, ˈmɛjɾʌwz]
tomatoes	/tə(mɛjnɔwz)/	[tʰəˈmɛjlɔwz(2), tʰəˈmɛjnʌwz, tʰə̥ˈmɛjnʌwz, tʰəˈmɛjŋɔws, tʰəˈmɛjlɔws]

2 labial onsets selected; 2 coronal onsets selected, 2 adapted. This participant shows a strong preference for alveolar onsets, particularly /t/, but she tolerates /p/ as well. Somewhat surprisingly, where /b/ exists in the adult form, it is converted to /p/ (which may or may not be voiced as [b]), but where /p/ exists in the adult form, it is actually converted to /t/, as evidenced by this participant's treatment of both *pajamas* and *potatoes*. This seems to be the reason for the confusion between the words *potatoes* and *tomatoes*.

C.12. M3A (3;1;13)

Table C.12. Production data for participant M3A

Item	Phonological Form	Phonetic Form(s)
balloon(s)	/bə(lɪwn)+s/	[bəˈlʊ̃w̃nts(2), dɪˈlɪ̃w̃nts, pəˈlɪ̃w̃n]
banana(s)	/bə(nana)+s/	[bəˈnãnʌ, bəˈnãnas]
computer	/(pɛj)$_{S}$(tɚ)$_{W}$/	[ˈpeˌtɚ, ˈpɛˌcɪ]
giraffe	/ʧɚ(af)/	[ˈʃw˞af, ʃʊ˞ˈaf, ˈʧw˞af]
pajamas	/tə(ʃamas)/	[ˈʤamas, tʰə̥ˈʃamas]
piano	/(pa)$_{S}$(nʌw)$_{W}$/	[ˈpãˌnʌw, ˈpãnaw, ˈpaˌnʌw]

2 labial onsets selected; 1 coronal onset selected, 1 adapted. This participant tolerates /b/ as a WISS onset (e.g. *balloon* and *banana*) but not /p/ (e.g. *pajamas* and *piano*). Attempts are made to extend palatal onsets to this environment (e.g. *giraffe* and *pajamas*), but not consistently.

C.13. M1 (2;3;25)

Table C.13. Production data for participant M1

Item	Phonological Form	Phonetic Form(s)
balloon	/(bum)/	[ˈw̴ʊ̃m, ˈbʊ̃n, ˈbũm]
banana	/(ɲæɲʌ)/	[ˈɲæɲʌ$^{(2)}$, ˈɲaɲa, ˈɲɛɲʌ]
guitar	/(tɑr)/	[ˈtʰɑɹ$^{(3)}$, ˈtʰɑ, ˈtʰaɹ]
piano	/(ɲa)$_{s}$(nʌw)$_{w}$/	[ˈɲano, ˈɲaˌnʌw]
potato	/(pɛɾʌ)/	[ˈpɛɾʌ]
spaghetti	/(ʧʌ)$_{s}$(ʧʌ)$_{w}$/	[ˈʧʌˌʧʌ$^{(2)}$]
vanilla	/(nɛɔ)/	[ˈneɔ, ˈnɛɔ]

This participant requires primary stress to fall on the first syllable of the word. To achieve this, all WISSs have been eliminated. The first syllable's onset seems to have been preserved in only two out of seven items: *balloon* and *potato*.

C.14. F2A (2;9;16)

Table C.14. Production data for participant F2A

Item	Phonological Form	Phonetic Form(s)
balloons	/(blunz)/	[bəˈlũz, ˈbũz, ˈbjũnts]
bananas	/do(bænaz)/	[doˈbɛdʌz(2), dəˈbɛdˌaz, dəˈbɛɾʌz, ˌdoˈbæ̃nʌz, ˌbæ̃ˈnʌz]
computer	/tə(pejdɔ)/	[tʰə̥ˈpʰejdɔ, dəˈpʰeɾʌ]
giraffe	/(draf)/	[ˈdwa̰ʔf, ˈdwa̰f]
spaghetti	/(spɑgə)s(dɪdi)w/	[ˈspɑgəˌdɪdi]
flamingo	/(mĩgʌw)/	[ˈmĩgʌw(2)]
gorilla	/ko(rɛla)/	[ˈgoˌw̰ala, ˈw̰ɛla, ˈgw̰ɪlʌ, ˈkw̰ɪla, ˈkw̰ɛlə]

2 coronal onsets adapted; 1 guttural onset selected. This participant seems to have preference for alveolar WISS onsets, possibly in connection with the onset of the following syllable being a labial stop, as evidenced by her pronunciation of both *bananas* and *computer.*

C.15. M3B (3;5;15)

Table C.15. Production data for participant M3B

Item	Phonological Form	Phonetic Form(s)
balloon	/bə(lun)/	[bə'lũn, bʊ'lũn]
banana(s)	/bə(nana)+s/	[pʊ'nanas, bə'nanas, bʊ'nana, bə'nana]
computer	/(pjɪwɾɚ)/	['pʰjuɾɚ, 'pʰjɪwɾɚ]
giraffe	/ʤɚ(ræf)/	[ʤɚ'ɹæf]
guitar	/dʊw(tɑrk)/	['tʰɑɹk(4), dʊw'tʰɑɹk, 'tʰɑɹkʰə̥]
piano	/pi(jænʌw)/	[pi'jænʌw, pʰi'jãnʌw]
spaghetti	/pə(gɛɾi)/	[pə'gɛɾi(2), pʊ'gɛɾi]
gorilla	/gɚ(rɪlʌ)/	[gɚ'ɹɛˌlʌ, gɚ'wɪla]

3.5 labial onsets selected; 1 coronal onset selected, 1 adapted; 1 guttural onset selected. This participant appears to tolerate a variety of WISS onsets, but his treatment of *guitar* is puzzling. In one out of five instances, he prefixes /tɑrk/ with a stressless /dʊw/. He seems to be aware of metrical shape of the word but unsure of the first syllable.

C.16. F2C (2;11;15)

Table C.16. Production data for participant F2C

Item	Phonological Form	Phonetic Form(s)
balloon(s)	/bʌ(lun)+s/	[bə'lũts, ˌbʌ'nũn]
banana(s)	/pʌ(nana)+s/	[bə'nãnəs, ˌpʌ'nana]
computer	/(pɑ)$_W$(pjɪwdɚ)$_S$/	[ˌpʰjʌ'pʰjɪwdɚ, pʰʌ'pʰjɪwdɚ, ˌpʰɑ'pʰjudɚ]
giraffe	/(dʌ)$_W$(wæf)$_S$/	[ˌdʌ'wæf]
guitar	/(pɑ)$_W$(tɑr)$_S$/	[ˌpʰɑ'tʰɑɹ(2), ˌpʰʌʔ'tʰɑɹ, ˌpʰʌ'tʰɑɹ]
piano	/(pjanʌw)/	['pʰjãnʌw(2)]
potato	/pə(tejɾʌw)/	[pʰə'tʰejɾʌw]
spaghetti	/pʌ(dʌdi)/	[ˌbʌ'dʌdi, pʰə'dʌdi]
burrito	/bʌ(wiɾʌw)/	[bʌ'wiɾʌw, ˌbʌ'wiɾʌw]

4.5 labial onsets selected, 1 adapted; 0.5 coronal onsets selected. This participant shows a strong preference for labial WISS onsets, both in selection and adaptation. The only exception appears to be *giraffe*, where an alveolar onset was used. Actually, this syllable was pronounced with weak stress, so it may not be an exception at all.

C.17. F3 (3;3;28)

Table C.17. Production data for participant F3

Item	Phonological Form	Phonetic Form(s)
balloon(s)	/bə(lun)+s/	[bə'lũts, bə'lũn, bə'lũ]
banana	/bə(nænʌ)/	[bə'næ̃nʌ, βə'næ̃nʌ]
computer	/sə(prjudɚ)/	[sə'pʰɹudɚ, zə'pʰʄudɚ, zə'pʰjuɾɚ, sʌ'pʰʄuɾɚ]
giraffe	/ʤɚ(ræf)/	[ʤɚ'ɹæf]
guitar	/zə(tɑr)/	[sə'tʰɑɹ(2), zə'tʰɑɹ(2), zɪ'tʰɑɹ]
pajamas	/pə(ʤɑmʌz)/	[pə'ʤɑmʌz, pʰə'ʤɑmʌz]
piano	/(pi)W(ænʌw)S/	[ˌpʰi'æ̃nʌw(2)]
tomatoes	/pə(tejɾʌwz)/	[pə'tʰejɾʌwz]
vanilla	/bʌ(nɪlʌ)/	[bʌ'nɪlə, bə'nɪlʌ]

4.5 labial onsets selected, 1 adapted; 1 coronal onset selected, 2 adapted. This participant tolerates a variety of WISS onsets but displays a very interesting tendency to replace guttural onsets with /s/ or /z/ (e.g. *computer* and *guitar*). Her pronunciation is otherwise fairly adult-like.

C.18. M3D (3;5;27)

Table C.18. Production data for participant M3D

Item	Phonological Form	Phonetic Form(s)
balloon(s)	/bə(lʊwn)+s/	[bəˈlʊ̃w̃nts, ˈblũ]
banana(s)	/bə(nænʌ)+s/	[bəˈnænʌs, bəˈnæ̃nʌs, bəˈnæ̃nʌ]
computer	/kə(pjurɚ)/	[kʰəˈpʰjurɚ]
giraffe	/(ʤræf)/	[ˈʤɹæf(2)]
guitar	/pʌ(tɑr)/	[pʰʌˈtʰɑɹ, pʰəˈtʰɑɹ]
pajamas	/pə(ʤɑməz)/	[pʰəˈʤɑməz]
piano	/pi(ænʌw)/	[pʰiˈæ̃nʌw(2)]
spaghetti	/sbə(gɛri)/	[sbəˈgɛri]
tomatoes	/tu(mejtʌwz)/	[ˌtʰuˈmejrʌwz, tʰuˈmejˌtʰʌwz]

4.5 labial onsets selected, 1 adapted; 1.5 coronal onsets selected; 1 guttural onset selected. While a variety of onsets are tolerated, this participant seems to give preference to /p/, as demonstrated by his pronunciation of *guitar*. It is unclear whether other words containing a WISS beginning with /g/ (e.g. *gorilla*) would be subject to the same substitution.

C.19. M4 (3;6;16)

Table C.19. Production data for participant M4

Item	Phonological Form	Phonetic Form(s)
balloon(s)	/bʌ(lʊwn)+z/	[bʌˈlʊ̃w̃z, bʌˈlʊ̃w̃n, ˌbʌˈlʊ̃w̃n]
banana(s)	/bʌ(nænʌ)+z/	[bəˈnæ̃nʌz, bʌˈnæ̃nʌ]
computer	/(kəm)$_W$(piɾɚ)$_S$/	[ˈkʰə̃mˌpʰiɾɚ]
giraffe	/(ʤræf)/	[ˈʤɹæf]
guitar	/(pɪ)$_W$(gtɑr)$_S$/	[ˈpʰɹiˌtʰɹaɟ˞, ˌpɪˀktˈhɑɹ]
pajamas	/pə(ʤɑmʌz)/	[bəˈʤɑməz, pʊˈʤɑmʌz]
piano	/pɪn(lænʌw)/	[pʰɪnˈlæ̃nʌw, pʰɪdˈlæ̃nʌw, pʰ̃ĭˈneɾow, pʰʊ̆̃ˈlæ̃nʌw]
potato	/kɪ(nejdʌw)/	[kʰɪˈnejdʌw]
spaghetti	/pəs(gɛɾɪj)/	[bəsˈkɛɾɪj, ˈspɛˌgɛɾi, pəsˈkɛɾi]
tomato	/pʊ(tejdʌw)/	[pʰʊˈtʰeɾʌw, pʰəˈtʰejɾʌw, pʰʊˈnedʌw]

4.5 labial onsets selected, 1.5 adapted; 0.5 guttural onsets selected, 1 adapted. This participant seems to tolerate both labial and guttural onsets, but this picture is a bit over-simple. The initial onset of *guitar* is made to be labial, while that of *potato* is made to be guttural. In any case, alveolar WISS onsets seem to be disallowed, with preference given to /p/ (e.g. *tomato*).

C.20. F4B (3;11;26)

Table C.20. Production data for participant F4B

Item	Phonological Form	Phonetic Form(s)
balloon(s)	/baj(lʊwn)+s/	[bəˈlũnts, ˌbajˈlʊ̃w̃n]
banana(s)	/bɪ(nænʌ)+z/	[bɪˈnæ̃nʌz, bəˈnæ̃nʌ]
computer	/kəm(pjiwɾɚ)/	[kʰə̃mˈpʰjiwɾɚ]
giraffe(s)	/ʤɚ(ræf)+ɪz/	[ʤɚˈɹæf, ʤɚˈɹæfɪz, ʤɚˈapɪz]
guitar	/kɪn(tɑr)/	[kʰɪ̃nˈtʰɑɹ(2), kɪ̃nˈtʰɑɹ]
pajamas	/pə(ʤamiz)/	[pʰəˈʤãmiz]
potatoes	/mə(tejɾowz)/	[məˈtʰejɾoz, ˈtʰejɾowz]
spaghetti	/spə(gɛɾi)/	[spəˈgɛɾi]
tomatoes	/tʊ(mɛjɾowz)/	[tʰʊˈmejɾowz, tʰəˈmɛjɾʌwz, tʰəˈmejɾowz]
flamingo	/kə(mbẽɾow)/	[kʰəˈmẽɾo, kʰə̃mˈbeɾow]

4.5 labial onsets selected; 2.5 coronal onsets selected; 2 guttural onsets selected, 1 adapted. This participant accepts a variety of onsets but seems to give preference to /k/ (e.g. *flamingo*). Actually, an initial syllable resembling /kən/ could be posited for all three instances of guttural WISS onsets above (*computer*, *guitar*, and *flamingo*).

Appendix D: Common Words Fitting the WS(W) Pattern

In order to determine the frequency of different word-initial syllable types in English for words following a WS(W) stress pattern (i.e. words beginning with a stressless syllable followed by a syllable taking primary lexical stress and optionally ending with another stressless syllable), word frequency lists from two corpora were consulted: the spoken portion of the CELEX Corpus and the London-Lund Corpus of Spoken English (UWA Psychology). Words were considered if they fit the desired metrical template and recieved either a frequency score of at least 100 in the CELEX corpus or a score of at least 15 in the London-Lund corpus. All words meeting these criteria are listed below with their first syllable underlined. Due to their frequent pronunciation with at least secondary stress on the first syllable, four potential candidates were excluded: *abstract*, *cannot*, *inside*, and *record*.

1. about
2. accept
3. across
4. afraid
5. again
6. against
7. ago
8. agree
9. allow
10. allowed
11. along
12. amount
13. another
14. apart

15. apply

16. around

17. assistant

18. away

19. because

20. become

21. before

22. beginning

23. behind

24. believe

25. between

26. committee

27. complete

28. completely

29. computer

30. concerned

31. decide

32. decided

33. decision

34. degree

35. department

36. direction

37. director

38. discussion

39. effect

40. enormous

41. enough

42. exactly

43. example

44. except

45. expect

46. expensive

47. extent

48. extremely

49. forget

50. imagine

51. important

52. impression

53. indeed

54. instead

55. involved

56. machine

57. perhaps

58. police

59. position

60. prepared

61. produce

62. professor

63. provide

64. religion

65. remember

66. result

67. support

68. suppose

69. supposed

70. today

71. together

72. tomorrow

73. towards

74. united

75. unless

76. until

77. upon

78. within

79. without

Vita

Clifford S. Jones, Jr., was born in 1982 in Houston, Texas. He grew up in the nearby town of Magnolia with a strong interest in both writing and visual art. In high school, he developed a talent for web/software development and received the highest year-long average for Computer Science I, II, and III. During this time, he worked for a local software company where he wrote the better part of two instructional guides to Macromedia (now *Adobe*) Director Shockwave Studio and was a major contributor to a third. Clifford studied Computer Science at Texas A&M University for several semesters, but following a summer study-abroad program in Germany, he began to discover a passion for language education and linguistic analysis. In 2004, he transferred to the University of Texas at El Paso (UTEP) and soon graduated with honors, earning a Bachelor of Arts in Linguistics.

In 2007, Clifford accepted a teaching position at a small English conversation school in Kagawa, Japan. There, he developed curriculum and taught classes for both children and adults. A little over a year later, Clifford, his wife Tina, and their two-year-old daughter Mei moved back to Texas in order to be closer to family and receive further education. Clifford returned to UTEP, where he worked half-time as a teaching assistant in the ESOL program and volunteered in UTEP's Language Acquisition Research Lab (LAR Lab). As a teaching assistant, he was responsible for various tasks including grading, tutoring, website maintenance, software development, and teaching a low-intermediate level course. In the LAR Lab, he took part in the planning and execution of two research projects involving both adults and very young children. For several months, he accepted a paid position as the lab's student director. In the summer of 2010, Clifford received his Bachelor of Arts in Linguistics from UTEP. He graduated with a GPA of 4.0 and a certification for Teaching English to Speakers of Other Languages (TESOL).

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