Exploring Phonological Relationships between Babbling and Early Word Productions

by

© Kayla Day

A Thesis submitted to the

School of Graduate Studies

in partial fulfillment of the requirements for the degree of

Master of Arts

Department of Linguistics

Memorial University of Newfoundland

August 2014

St. John's Newfoundland

Abstract

In this research, I set out to uncover relationships between the phonological composition of the babbled utterances and early word productions. I track segmental development in onset position across both babbled utterances and early word productions of two English-learning children (Cameron and Georgia) from the English-Davis corpus, available through CHILDES/Phonbank (http://childes.talkbank.org/phon). Both children display a very strong tendency to produce sounds in babbled utterances before attempting them in meaningful words. Also, these children show very little variation away from English phonemes in their babbled utterances, which suggests that these children have a good level of awareness of the native phonological system from a young age. However, a close examination of the treatment of [l] in Cameron's babbles and early word productions suggests that at least certain segments receive different treatment at different stages of the child's phonological development. I also perform a formal analysis of the productions of both children using descriptive features and Feature Co-occurrence Constraints (FCCs). Both children's phonological development can be can be captured using this model. However, many of the differences in their developmental paths remain unaccounted for given this type of analysis. Addressing this issue, I conduct an analysis of both children's substitution patterns to determine what factors (e.g. perceptual or articulatory) influenced their productions of unacquired segments. As we will see, many of the substitution patterns displayed by both children appear to have strong articulatory influences. The knowledge gained from each of these analyses highlights the benefits of using a multi-faceted approach to phonological acquisition.

Acknowledgements

This research was made possible thanks to the support of numerous people. I want to thank everyone within the Department of Linguistics at Memorial University for giving me both the theoretical and practical knowledge required to complete this research. You prepared me not only for this thesis, but also gave me a solid foundation to continue my studies at the doctoral level. I especially want to thank my supervisor, Dr. Yvan Rose, who put in countless hours guiding me through this process. I am grateful for your patience and effort in teaching me, among many things, how to write, and more importantly think, like a linguist.

I also want to thank my friends and family for providing encouragement throughout the last three years. Especially my parents, who have sacrificed so much to help me get to this point, your constant love and support have taught me to always persevere. And last, but not least, Paul, for giving me constant motivation, and for often serving as my sounding board, during this entire journey.

Table of Contents

Chapter 1: Introduction

1. Objectives

In this thesis, I address current theoretical issues in light of the phonological development paths of two English-learning children, Cameron and Georgia, whose data are available through CHILDES/Phonbank (http://childes.talkbank.org/phon). To attain this goal, I track the segmental development of both children across babbles and early word productions. Following these empirical descriptions, I perform a formal analysis of both children's segmental acquisition, along with an examination of the substitution patterns found in their productions. All of these analyses provide valuable information about the phonological development of these two children. However, in order to successfully analyze one element of the children's development each approach excludes other aspects. This research aims to create a more complete developmental picture by exploring multiple facets of the children's phonological development.

2. Thesis Overview

I begin with a survey of current approaches to phonological development, which offers the necessary background to my empirical study. I then describe, in detail, the development of each phoneme attempted by Cameron and Georgia in onset position (including both singleton and branching onsets), along with each consonantal segment produced in both children's babbled utterances.

Comparing the segmental development of these two children, I observe many differences in their respective developmental paths. The children's data show differences in orders and ages of acquisition, the manifestation of natural class effects, and the treatment of unacquired phonemes. As we will see, Cameron begins producing meaningful words at a slightly younger age than Georgia, as well as displaying natural class effects in her productions. Georgia, by comparison, displays fewer such effects. Cameron also displays a tendency to develop substitution patterns for unacquired segments, while Georgia tends to either delete or not attempt unacquired segments.

Despite these differences in their early word production patterns, the two children display many segmental similarities in their babbled utterances. Both children's babbles contain predominantly voiced stops (oral and nasal) from a very young age, yet seem to lack a voicing preference in continuant segments. Interestingly, both children's babbled utterances also contain very few non-native segments. The non-native segments which are present in the children's babbles tend to contain novel combinations of features found in English, their ambient (target) language. Further, there is a strong tendency in both children's productions for segments to appear in babbles before they are attempted in words. However, there are also certain segments which behave differently in babbles compared to early word productions.

Building on these observations, I conduct an analysis of both children's segmental inventories in produced words using contrastive features and Feature Co-occurrence Constraints (FCCs; Levelt & van Oostendorp 2007). This analysis successfully describes the segmental development of both children, despite their developmental differences. However, many of the differences between them are lost, as this type of analysis fails to capture the children's treatments of unacquired segments.

Addressing this issue, I examine the substitution patterns in both children's productions, in order to determine the possible factors influencing each pattern. I consider articulatory factors, perceptual factors, or a combination of both, as likely influences for these substitution patterns. As we will see, both children's substitution patterns primarily relate to articulatory factors. Representational factors are not considered separately because, as I discuss throughout this thesis, phonological representations are interpreted as the connection between identifiable dimensions in acoustic space and the related articulatory/motor plan (following e.g. Stevens 1972; Stevens 1989; Lin & Mielke 2008). Under this view, any articulatory difficulty or perceptual error present in the child's linguistic system has implications for phonological representations.

Before we explore the details of this investigation, I survey four current approaches to phonological development in the following chapter. I then overview the analytical approach I embrace throughout the analysis.

Chapter 2: Background

1. Current Theories

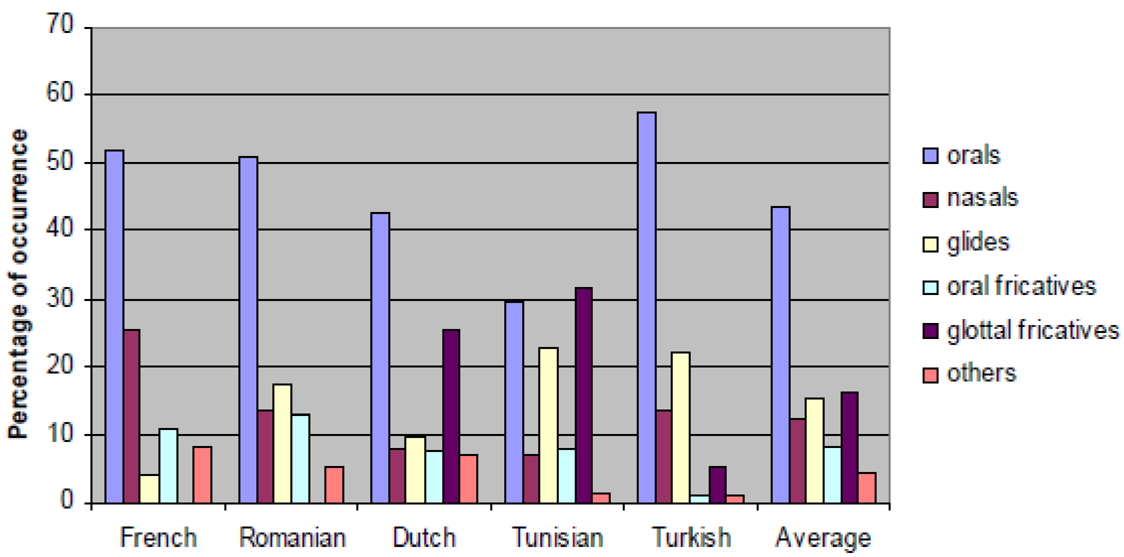
Within the field of language acquisition many approaches have been formulated in order to explain how children transition from the babbling stage to the word production stage and acquire the phonological system(s) of their mother tongue(s). In this chapter, I summarize four current theoretical approaches: a bio-mechanical approach, a perceptual approach, a templatic approach, and a representational approach. The bio-mechanical approach emphasizes the child's articulatory abilities and limitations. The perceptual approach focuses on properties of the ambient language such as frequency and acoustic salience. The templatic approach combines articulatory and perceptual factors as they relate to the child's formation of word templates (word-level representations). Finally, the representational approach emphasizes the types of units that compose the child's phonological grammar.

1.1 Bio-mechanical Approach

Proponents of bio-mechanical approaches, for example Kern & Davis (2009), argue that babbling is essentially a bio-mechanical process which governs the level of command that the child has over his/her vocal tract (Davis & MacNeilage 1990; MacNeilage & Davis 1990). This suggests that children's vocalizations are limited by their physical (e.g. physiological and/or motoric) capabilities at each relevant developmental stage. Building on this prediction, the phonetic content of babbled utterances should, therefore, be determined by the articulatory properties of the speech sounds. Following from this, more abstract phonemic properties of the target language should have little impact on the phonetic content of babbles and early word productions.

The notion of the child's articulatory capabilities limiting the content of their vocalizations is supported by seemingly universal properties of babbling. These universal properties can be related to the basic, bio-mechanical forms and functions of infants' speech organs. Kern & Davis (2009) conducted a cross-linguistic study of the babbles produced by 20 infants from five languages across four language families: Tunisian Arabic (Semitic), Turkish (Ural-Altaic), Dutch (West-Germanic), French, and Romanian (both Romance). Kern & Davis show that the infants' babbles look more similar to one another across languages than to the infant's own native language (Kern & Davis 2009:386). Some of these cross-linguistic commonalities include: oral stops being more common than other manners of articulation (as can be seen in Figure 1), and coronal and labial being more common places of articulation than dorsal and glottal.

Figure 1: Consonant Manner of Articulation (Kern & Davis 2009:361)



Kern & Davis propose that only the bio-mechanical hypothesis can explain the commonalities observed, stating that these "results suggest that common tendencies based on characteristics of the production system predominate during the babbling period. Observable characteristics appear to be based less on learning than on intrinsic self-organizing propensities of the system" (Kern & Davis 2009:370). Also offering support to this approach is the fact that previous longitudinal studies of the transition between babbling and word production (Oller 1980; Stoel-Gammon & Cooper 1984; Stark 1980; Vihman, Ferguson & Elbert 1986) have found similarities between "pre-linguistic vocalizations and earliest speech forms" (Kern & Davis 2009:353). However, the higher presence of glottal fricatives (e.g. [h]) in the Dutch and Tunisian infants (seen in Figure 1), and the fact that these two languages contain more glottal phonemes than the other languages examined, suggests that the ambient/input language does have some effect on the segmental inventory produced in babbles.

The bio-mechanical approach thus provides an account for both phonological similarities between babbled utterances and early words, and phonetic gaps in the consonantal inventories observed in babbled utterances. It is also helpful in explaining certain patterns in linguistic development data, for example difficulties in acquiring particular sounds. However, this approach has little to say about the possible analyses involved in grammatical development. It offers no theoretical notion of how a child will acquire language beyond mastering the articulatory requirements. Since there is much more involved in language acquisition than simply learning how to produce and combine sounds, as will be discussed further Chapter 7, this approach can only explain a small portion of the behaviours attested in child language phonological productions.

1.2 Perceptual Approach

Proponents of the perceptual approach place significant emphasis on how acoustic properties of the ambient language may influence speech development. This emphasis on perception predicts that phonetically salient or otherwise frequently perceived properties of the target language should manifest themselves in early productions, since they constitute the most accessible material the infant can grasp from the ambient language (Lintfert 2009). For example, frequent sibilant fricatives in English should be acquired early since they are both salient and frequent in the ambient language. Essentially, for this approach, babbling is associated with a stage in the child's development when his/her perception is not yet accurate, and early word production begins when (s)he has developed accurate perception. This explanation of the babbling stage accounts for why the phonetic content of babbled utterances is often similar to the phonetic inventory of the target language. However, this approach would suggest that babbles should contain the most frequent sounds of the target language. This is not always the case, as will be demonstrated in Chapter 6. Among other details, both children studied in this thesis display significantly fewer voiceless stops than voiced stops in the onsets of babbled utterances, even though both voiced and voiceless stops are extremely frequent in English.

1.3 Templatic Approach

Building on both articulatory and perceptual considerations, Vihman & Croft (2007) suggest a WYSIWYG (*What You See Is What You Get*) approach to language development. They propose that development takes place via word templates, which are preferred word shapes that the child acquires based on ambient language properties and articulatory limitations. Essentially, templates emerge based on the acoustic characteristics of words perceived and produced by the child. Vihman & Croft (2007) derive these templates from the very early word productions of infants. Word shapes that occur frequently across the data are proposed to represent a word template in the child's linguistic system, as can be seen in Table 1.

Table 1: Examples of templates in early word productions of German learning child between 8-10 months (Vihman & Croft 2007:695)

Child form	Adult target	Characteristic pattern (based on later template)
[da]	da 'there'	CV
[ba]	Buch 'book'	CV
[aɪ]	ei! (fondling expression)	Vi
[aɪ]	Ei 'egg'	Vi
[naɪn]	nein 'no'	Vi
[mama]	Mama 'mama'	CVCV: CH + VH
[baba]	Papa 'papa'	CVCV: CH + VH
[pɪpɪ]	pieppiep 'mouse'	CVCV: CH + VH
[dɛdɛ]	Teddy	CVCV: CH + VH
[data]	das da 'that one there'	CVCV: CH + VH
[bɪta]	bitte 'please'	lab C . . . alv C

CH = consonant harmony; VH = vowel harmony;

The notion of a template can be helpful in explaining why children attempt particular words, or even why many phonologically different words are produced by the child using similar word shapes. Vihman & Croft suggest that the shape of these word templates may also influence which words the child may attempt in spoken forms (Vihman & Croft 2007:692). The child can 'adapt' these templates to their word choices, which may at times vary greatly from the template itself, as shown in Table 2.

Table 2: Adapting templates by German learning child 10-12 months (adapted from Vihman & Croft 2007:695)

Child form	Adult Target	Template	Adaptation
[nana]	Zahn(bürste) 'thooth(brush)'	CVCV: CH	Metathesis & Reduplication
[gɪŋgɛ]	Trinken 'to drink'	CVCV: CH	---

One other important theoretical consideration within a templatic approach is the level of representation possible. Under the templatic approach set forth by Vihman & Croft (2007), the lowest level of possible representation is the word level; this approach does not allow (sub)segmental representations. As such, behaviours that affect a linguistic domain below the word level cannot be explained using this approach. One such example is the case of natural class effects, the oft-noted tendency of similar sounds to pattern, or be acquired, together (e.g. Smith 1973; Fikkert 1994; Levelt 1994), as these patterns occur at the segmental level.

1.4 Representational Approach

Within bio-mechanical and perceptual approaches, babbles evolve into speech in a continuous fashion. Representational approaches are more abstract in nature, and focus on the types of phonological units that compose word forms in the child's early mental lexicon. According to proponents of this view (e.g. Spencer 1986; Fikkert 1994), a child's linguistic system emerges from distributional analyses of sounds and sound combinations of the target language. Infants essentially begin by analyzing word forms and eventually segment these words into their individual sounds and sound combinations (Goad & Rose 2004; Fikkert & Levelt 2008). The babbling stage, in this analysis, may correspond to an early step during which the child has an incomplete analysis of the input. Babbling may also be indicative of the child engaging in vocal practice (Inkelas & Rose 2007). Following the babbling stage, the analysis of the input progresses in a gradual fashion until the word can be fully represented and produced. This analysis of babbling still explains why an infant's babbled utterances share common characteristics with the target language, as well as why non-native sounds sometimes appear in children's babbled utterances. If an infant draws his/her phonological analysis from the ambient language, then the sounds (s)he produces as a result of this analysis should be similar to those in the ambient language. However, the productions of babbled utterances are not governed by the phonological system, so they may, and often do, diverge in both structure and content from the phonology of the target language. This observation is illustrated Table 3 where we can see that the babbled utterances have drastically different structure than early words produced at the same stage.

Table 3: Cameron's babbled utterances and early word productions at 1;02.14

Babbled Utterances	Early Words
[ʤudʌʤʊweɪbebɪsbʌdʌdʌsbɪs]	'plate' |pleɪt| → [bwe]
[mbʌʌdʌ]	'pizza' |pi:tsə| → [bɪtsæ]
[gogowogogwægʌvʌ:ɸ]	'turtle' |tʌɹtəl| → [dəɹdʌ]
[wæhædæwæwæwæbæwæbwæwæbæʌ]	'bottle' |bɑtəl| → [bæwu]

1.4.1 Acquisition of Place Features

Focusing on the acquisition of place features in the CVC productions of five Dutch-learning children, Fikkert & Levelt (2008) posit a general three-stage process for linguistic development. At Stage I, a word has only one Place of Articulation (PoA) feature, representing an unsegmentalized portion of speech, essentially a string of sounds not yet analyzed into individual segments by the child. During Stage II, the vowel is segmentalized away from the consonants, and may thus have a PoA different from that of the consonants. Finally, at Stage III, the word is fully segmentalized, but consonant PoA combinations can be very restricted at first; they gradually become less restricted as the child's phonological system develops (Fikkert & Levelt 2008:257-8).

Within this analysis, Stage III may be broken down into more specific stages to account for language-specific patterns, as is shown in Table 4. Fikkert & Levelt (2008) provide a five stage development for children acquiring Dutch, which details how the children gradually acquire the different, fully segmentalized PoA patterns. However, to make this a cross-linguistically applicable proposal, Fikkert & Levelt (2008) condense Stages III-V for Dutch into the generic Stage III outlined above.

Table 4: Stages of Development of PoA structures in Dutch (adapted from Fikkert & Levelt 2008:243)

Stage	Development	Production Patterns (cumulative)
I	$C_1 = C_2 = V$ (or $V = A$)	POP, PAP, TIT, TAT, KOK, KAK
II	$C_1 = C_2$	PIP, TOT, KIK
III	$C_1 = P$, $C_2 = T$	PVT
IV	$C_2 = K$	PVK, TVK
V	$C_2 = P$, $C_1 = K$	TVP, KVT, KVP

* Where P represents all labial consonants, T represents all coronal consonants, and K represents all dorsal consonants; O represents rounded (labial and dorsal) vowels, I represents all front (coronal) vowels, and A represents low vowels.

This proposal offers a very effective analysis of the Dutch data where the child begins analyzing the ambient language at the word level and slowly breaks the word down into smaller and smaller units. This proposal, therefore, involves two tasks that the child must complete. First, (s)he must identify the relevant categories in order to begin acquiring a particular aspect of the phonology. For Fikkert & Levelt (2008) the relevant category would be place features. Once the child has identified the relevant categories, (s)he must then understand their distribution across the relevant domain of the language. In the acquisition of place features summarized here, the child must understand the distribution of different PoAs across different syllabic positions.

1.4.2 Feature-based Segmental Development

Another representational approach, which illustrates a similar learning process (identify relevant categories, then identify their distribution), is proposed by Levelt & van Oostendorp (2007). Levelt & van Oostendorp formulate a feature-based view to phonological acquisition through Feature Co-occurrence Constraints (FCCs). They posit that phonological acquisition can be described in terms of features, following Jakobson (1941), as opposed to approaches based on segmental frequency. They provide an FCC-style analysis using data from six children in the CLPF database (Fikkert 1994; Levelt 1994), also available through CHILDES/PhonBank. This analysis successfully accounts for the order of acquisition observed in virtually all the children's segmental development with the predicted inventory matching the child's productive inventory. The predicted inventory consists of the segments expected to appear in the child's productions based on the combination of features and FCCs proposed to be present in the child's phonological system, while the productive inventory consists of the segments the child actually produces.

Table 5: FCC analysis of Child 2 from CLPF database (adapted from Levelt & van Oostendorp 2007:168)

Features	FCC	Predicted Inventory
[voice], [labial], [coronal]	---	{p,b,t,d}
[nasal]	[nasal]⊃[labial]	{p,b,t,d,m}
[continuant]	[continuant]⊃[coronal]	{p,b,t,d,m,s,z}
---	Revoke [nas]⊃[lab] Revoke [cont]⊃[cor] (if [w] = /v/)	{p,b,t,d,m,n,s,z,f,v,}
[velar]	*[voice, velar] *[velar, nasal]	{p,b,t,d,m,n,s,z,f,v,k,x}
[lateral]	---	{p,b,t,d,m,n,s,z,f,v,k,x,l}
[rhotic]	---	{p,b,t,d,m,n,s,z,f,v,k,x,l,r}

Within an FCC analysis, as illustrated in Table 5, there are essentially two components used to describe the child's development: contrastive features and FCCs. Levelt & van Oostendorp (2007) remain agnostic regarding the origins of features. Regardless of their origin, features gradually become available within the child's linguistic system, where they encode natural classes of segments. FCCs are constraints on particular featural combinations (either mandating or prohibiting a combination), and as such, they encode gaps in natural classes predicted by the pressure of given factors, for example articulatory difficulty. This allows an account for both segmental acquisition patterns following natural classes, as well as segmental acquisition involving paradigmatic gaps (Levelt & van Oostendorp 2007:163).

Within the analysis presented by Levelt and van Oostendorp (2007), the predicted inventory is limited to phonemic sounds present in Dutch. They exclude from their analysis potential FCCs which are not required to describe the system of phonological contrasts in Dutch, but which would rule out phonemic segments present in other languages." For instance, since laterals and rhotics do not contrast in the place or voicing dimension, constraints such as *[lateral, velar] or [rhotic]⊃[voice] are excluded from consideration." (Levelt & van Oostendorp 2007:171) However, lateral segments do display phonemic place and voicing contrasts in other languages. The set of segments considered by Levelt & van Oostendorp is thus limited to the phonetic inventory of segments to which the child has been exposed (the original CLPF corpus documents monolingual learners only). I maintain their stance in my discussion of the English data below, and only consider segments which are part of the phonetic inventory of (North American) English.

2. Limitations to Current Theories

As we can see, each approach highlights important aspects of phonological development. However, none of these approaches can fully account for the behaviours observed in the linguistic development of a typically developing child. With the exception of the templatic approach, each proposal emphasizes a single factor (either articulatory, perceptual or representational) and none of these factors can singlehandedly explain the variation observed between children. Even though the templatic approach emphasizes a combination of articulatory and perceptual factors, it is unable to explain patterns which pertain to units smaller than the segmental level, itself largely de-emphasized in the context of word-level, template representations. While each approach can effectively explain certain aspects of linguistic development, none can fully encompass the processes involved in the acquisition of language. Even within a single language, there is a considerable amount of variation among children, for example considering rates of development and timing of developmental stages, both segmentally and prosodically, as well as strategies for dealing with difficult or unacquired phonological forms (Fikkert 1994; Bernhardt & Stemberger 1998; Levelt et al. 1999; Menn & Vihman 2011; Vihman 2014); as such, any approach which focuses on only one type of influencing factor, or level of representation, has limited options to explain the source of the variation observed (Rose 2009).

3. Current Proposal

Instead of attempting to explain phonological development using the mono-dimensional or word-level approaches outlined above, I propose working toward a more comprehensive theory of linguistic development which would allow for the relationships between various factors to become apparent, as in the approach outlined by Rose (2009). Rose (2009) emphasizes the importance of both perceptual and articulatory factors in phonological analysis, and provides a transparent and concise explanation of apparent chain shifts, building on earlier work by Macken (1980). A chain shift is a sequence of two substitution patterns where the output segment from the first substitution is the input for the second substitution (A→B, B→C). An example is provided in (1), where the child produces [d] for target |z|[1], but then produces [g] for target |d|.

1 For the purposes of this thesis, || will be used to denote the English adult target phone and [] for actual forms, e.g. Rose & Inkelas (2011) for a similar notation.

(1) Apparent chain shifts (data from Smith 1973)

a)	Chain shift 1: z → d → g				
i)	|z| → [d]	'puzzle'	|pʌzl|	→	[pʌdɫ̩]
ii)	|d| → [g]; *[d]	'puddle'	|pʌdl|	→	[pʌgɫ̩]
b)	Chain shift 2: s → θ → f				
i)	|s| → [θ]	'sick'	|sɪk|	→	[θɪk]
ii)	|θ| → [f];*[θ]	'thick'	|θɪk|	→	[fɪk]

Chain shifts in child language are extremely difficult to explain using mono-dimensional approaches such as those outlined in Section 1 above. Indeed, if a child is capable of producing sound B in one context, A→B, then (s)he should be able to produce this segment as target-like, instead of substituting it with another segment (B→C).

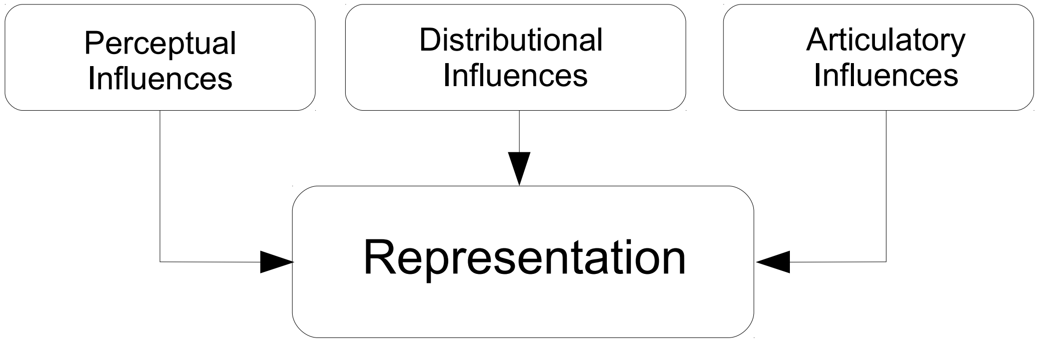
The apparent grammatical opacity of chain shifts has been the subject of many theoretical discussions in the past (e.g. Smith 1973; Smolensky 1996; Bernhardt & Stemberger 1998; Hale & Reiss 1998; Dinnsen 2008). However, Macken (1980) and Rose (2009) offer a straightforward explanation for the apparent paradox seen in chain shifts, which is outlined below.

If we first consider the data in (1a), each substitution can be easily explained. The stopping of |z| to [d], seen in (1ai), is a commonly observed pattern in child language (Bernhardt & Stemberger 1998) and is likely caused by articulatory factors. The pattern in (1aii) is likely related to perceptual factors which cause the child to create a faulty lexical representation: the velarity of [ɫ] influences the child's perception of the previous |d|, causing it to instead be perceived as the velar stop [g]. This faulty perception leads to the child building an incorrect lexical representation of 'puddle' as |pʌgɫ̩|, with a word-medial |g| instead of the target |d|.

Turning to the data in (1b), it seems that perceptual and articulatory factors again conspire. In (1bi), the child has likely not mastered the precise articulation required for |s| and therefore realizes it as [θ]. The substitution observed in (1bii) can be explained through perceptual factors. While this merger may seem articulatorily unlikely because the two sounds have different places of articulation, the fact that [θ] and [f] are extremely similar acoustically (e.g. Levitt et al. 1987) can account for this behaviour. A learner cannot produce, or represent, a distinction which (s)he cannot perceive. Therefore, |θ| would be encoded as |f| in the lexical representation of words such as 'thick'.

I adopt this type of multi-pronged approach throughout this thesis. As we will see, this will prove useful in the analysis of the English data below, where aspects of the data which elude one source of explanation can be explained through another source. This approach also enables a better understanding of how internal and external factors interact with one another throughout the acquisition process. Key factors such as articulatory limitations, distributional facts of the target language, and perceptual biases/faulty perceptions provide explanations for patterns of linguistic development. This multi-dimensional approach, schematized in Figure 2 below, situates phonological (e.g. featural) representations in direct relation with identifiable acoustic dimensions of speech and their corresponding articulatory/motor plans (e.g. Stevens 1972; Halle & Stevens 1979; Stevens 1989; Mielke 2005; Lin & Mielke 2008; Mielke 2008; Stevens & Keyser 2010; Mielke 2011; Rose to appear). Therefore, this is a representational approach substantiated by articulatory, distributional and perceptual factors/influences.

Figure 2: Multi-dimensional Approach to Featural Development (e.g. Rose to appear)



I return these theoretical considerations in Chapter 7, during my analyses of the current data. A detailed description of these data begins in Chapter 4, following an overview of the methodology adopted for this research in the next chapter.

Chapter 3: Method

1. Overview

In this chapter, I describe the methodology adopted for my research. First, I explain the source and nature of the data addressed in my analyses. Second, I address the work which was required to format my data in such a way as to allow me to perform the necessary analyses. Finally, I outline the steps involved in my analyses of these data.

2. Source of Acquisition Data

The data used for this research were obtained from the English-Davis corpus, available from the PhonBank database (http://childes.talkbank.org/phon). The English-Davis corpus contains transcribed productions of 21 children recorded at various ages. I chose data from two children whose recordings covered approximately the same age range, and which included both babbles and early word forms. The first dataset examined in this research comes from child Cameron, whose corpus spans from 00;07.11 to 02;11.24 and contains 52 recording sessions. Cameron's dataset contains 10,537 meaningful word productions and 4,680 babbled utterances, with the first documented word productions occurring at the age of 0;09. The second dataset is from Georgia, whose corpus spans from 00;08.25 to 2;11.05 and contains 45 recording sessions. Georgia attempts 12,015 meaningful words and produces 4,593 babbled utterances in her corpus, with the first documented word productions occurring at 0;10.

3. Data Preparation

I used the specialized Phon program to conduct my analysis. Phon is a software program that greatly facilitates a number of tasks required for the analysis of phonological development.

Phon supports multimedia data linkage, utterance segmentation, multiple-blind transcription, automatic labelling of data, and systematic comparisons between target and actual phonological forms (Rose et al. 2006; Rose & MacWhinney in press).

Before I began my analysis, there were multiple tasks that needed to be completed with the data obtained from PhonBank. First I syllabified the children's productions (both babbled utterances and meaningful words) following rules of English syllabification encoded within Phon. Following this, I inserted IPA target forms using the Auto-transcribe function in Phon. I then checked each record to ensure that all meaningful words had a target form transcribed, and manually inserted a target form when necessary. Each new target form was then added to the Phon dictionary for future reference. After each meaningful word had a target form, I checked the alignment of the IPA target and IPA actual forms, and made any necessary adjustments. Figure 3 and Figure 4 provide an example of this process.

Figure 3: Original alignment of characters in Phon

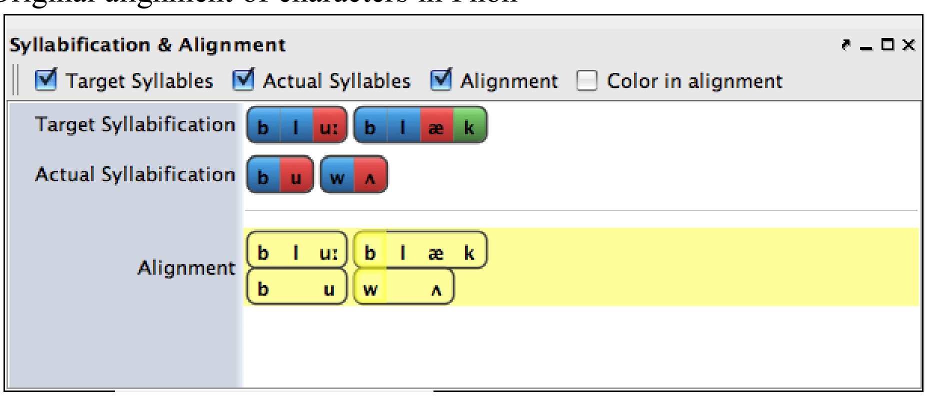
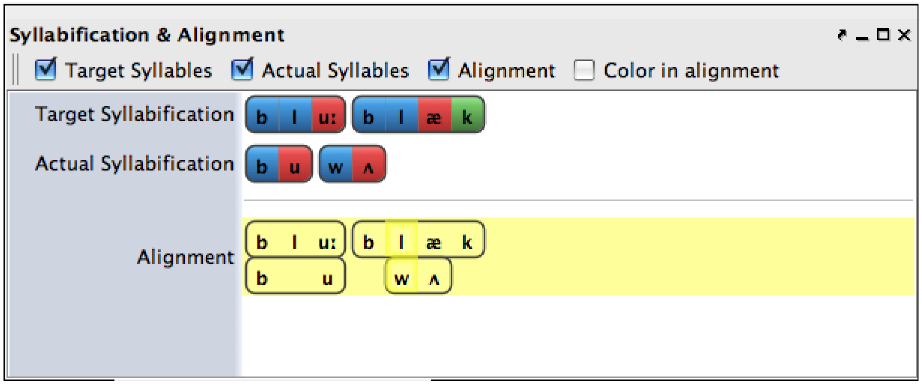


Figure 4: Corrected alignment of characters in Phon

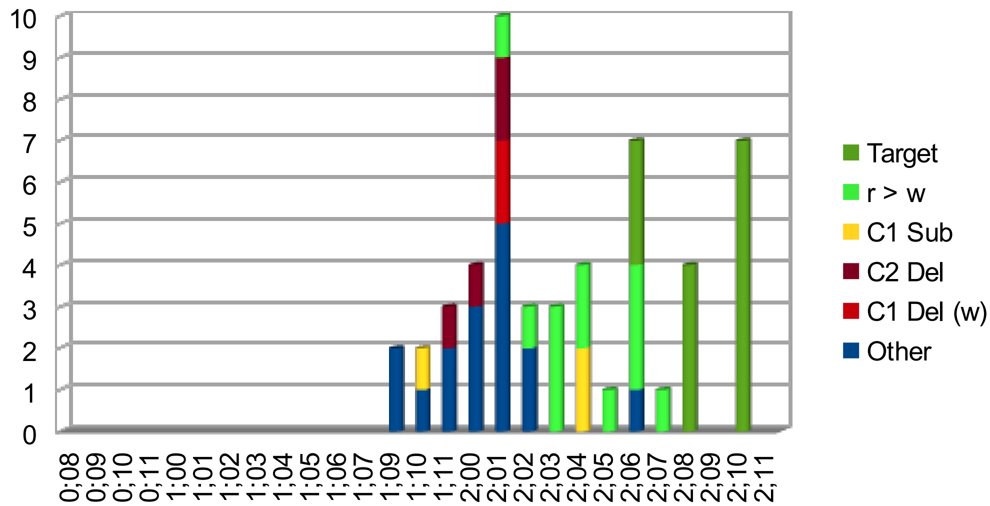


This particular example of alignment adjustment also demonstrates that deciding on the correct alignment is not always a simple task. In this particular case, the original alignment of [w] with |b|, as in Figure 3, is possibly correct since both segments share labial articulation. However, this would not be an optimal alignment since Cameron displays a tendency to produce [w] for |l| in both singleton and branching onsets while she generally produces [b] in a target-appropriate manner (as will be discussed in Chapter 4 and Chapter 7).

After all the IPA target forms were transcribed and aligned, it was necessary to make adjustments to certain target forms to reflect a particular dialectal property of North American English, which often displays [ɾ] allophones for the coronals |t,d|. This adjustment simply involved manually changing the IPA target transcriptions from |t,d| to |ɾ| in all relevant cases. This change in IPA target transcriptions was deemed necessary because of a stark contrast in Georgia's treatment of coronal stops in singleton onsets of initial or stressed syllables, if compared to those in medial, unstressed syllables (i.e. in non-flapping versus flapping contexts). Also, note that the same coronals in branching onsets were produced in a different way by the child, as these consonants are not realized as flaps in this contexts either. In fact, within all |tɹ|

and |dɹ| branching onsets throughout Georgia's dataset, there are only two coronal deletions as is illustrated in Figure 5 as "C1 Del."

Figure 5: Coronal + |ɹ| Branching Onsets (Georgia)

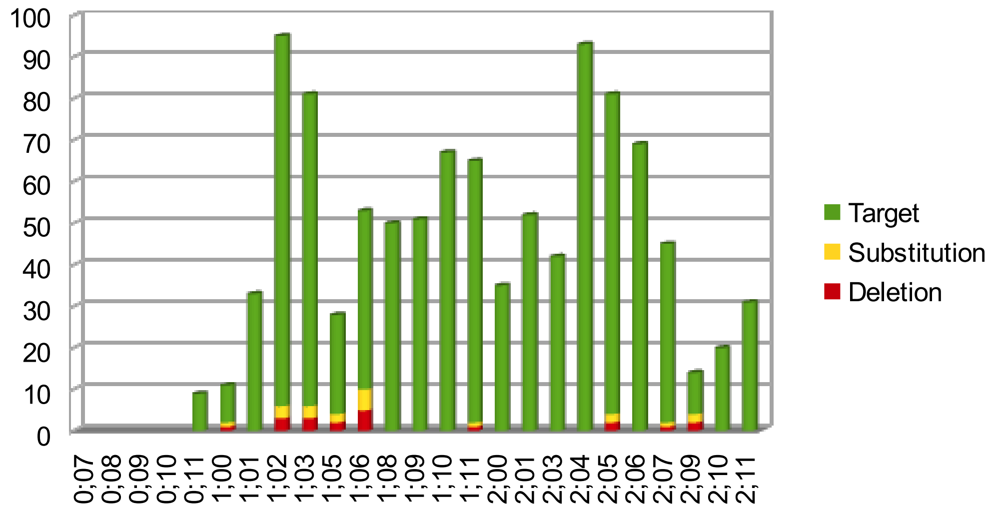


4. Data Analysis

Following data preparation, I performed queries of Cameron and Georgia's segmental development focusing on segments occurring in onsets. I used Phon's report generator to output the query results for analysis within spreadsheets. I then condensed the data to make it more manageable, grouping both children's sessions in one-month increments. I subsequently sorted the data by target phone and grouped the results by the nature of the production (whether the target segment was deleted, substituted, or produced in a target-like fashion). Recurring substitution patterns were treated separately from one-time substitutions. Substitution patterns which recurred across multiple sessions were given their own category. Following this data categorization, it was necessary to implement a standard criterion for acquisition. Throughout this thesis, in order for a sound to be considered acquired the child must achieve and maintain a 75% mastery level.

I performed a separate query for branching onsets by searching for instances of an obstruent followed by a liquid, with both consonants occurring in onset position. This returned all branching onsets in each corpus, but also returned instances of sCC clusters (a branching onsets preceded by [s], as in the word 'string'). The sCC clusters were manually eliminated from the query results list, in order to avoid potential complications related to the initial [s] in these clusters, which are both phonetically and formally different from non-[s]-initial complex onsets (Goad & Rose 2004). Once this process was completed, I used Phon's report generator to compile the results into a spreadsheet and followed the same procedure outlined above for singleton onsets to format the spreadsheet and generate summary graphs. These summary graphs, as illustrated in Figure 6, allow for visual assessment of the main trends in the data, for example, at what point in the corpus the child begins producing a majority of attempts as target-like.

Figure 6: Nasals in Singleton Onsets (Cameron)[2]



This methodology led to detailed information on the segmental development of both children, to which I now turn. The next chapter provides a detailed description of Cameron's segmental development in word production, first in singleton onsets, then in branching onsets.

2 In all graphs throughout this thesis, the horizontal axis represents the child's age, and the vertical axis the number of attempts at the particular segment.

Chapter 4: Cameron's Consonantal Development

1. Introduction

In this chapter I summarize Cameron's segmental development in word productions. I begin with a description of the data for segmental development in singleton onsets, then move on to her development of branching onsets. Each target segment and branching onset attempted by Cameron is discussed, despite some of these having rather low frequencies of occurrence within the corpus. As we will see, Cameron's development unfolds in a systematic fashion, with many early segments appearing in natural classes. Further, the development of her branching onsets displays similarities with the development of the corresponding segments in singleton onsets.

2. Singleton onsets

In this section, I will describe Cameron's phonological development of singleton onsets across all word positions (i.e. word initial and word medial onsets). I focus first on her development of obstruents, then nasal stops, and, finally, approximants.

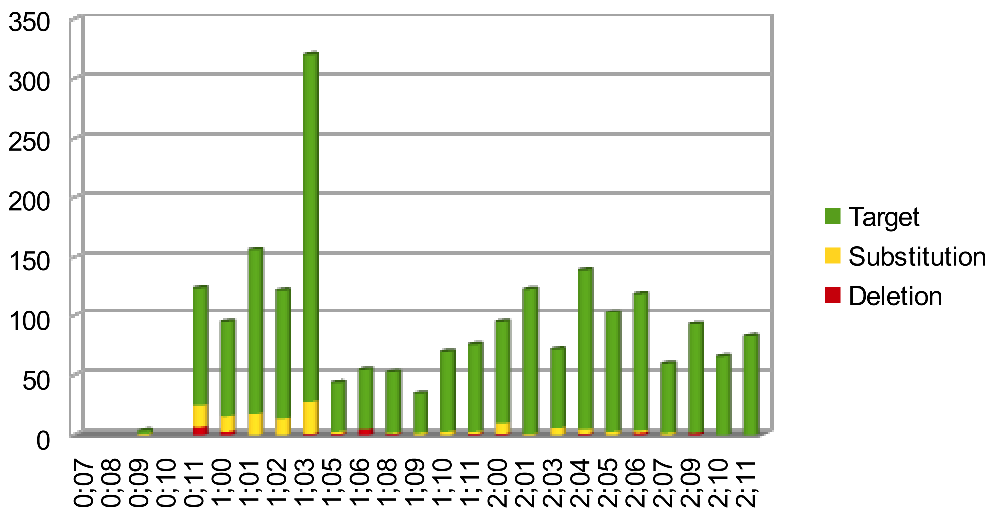
2.1 Stops

Cameron acquires both voiced and voiceless stops with relative ease, and displays some very systematic behaviours. However, there are striking differences between the development of voiced and voiceless stops, which I address in two separate sections. In Section 2.1.1, I present the data regarding voiced stops, which I compare to voiceless stops in Section 2.1.2. This order of presentation highlights the fact that voiceless stops behave similarly to voiced stops during the early months of Cameron's phonological development.

2.1.1 Voiced Stops

Cameron acquires the set of voiced oral stops (|b,d,g|) with ease at 0;11, as can be seen in Figure 7. This is similar to the pattern observed for nasal stops, as we will see in Section 2.5.

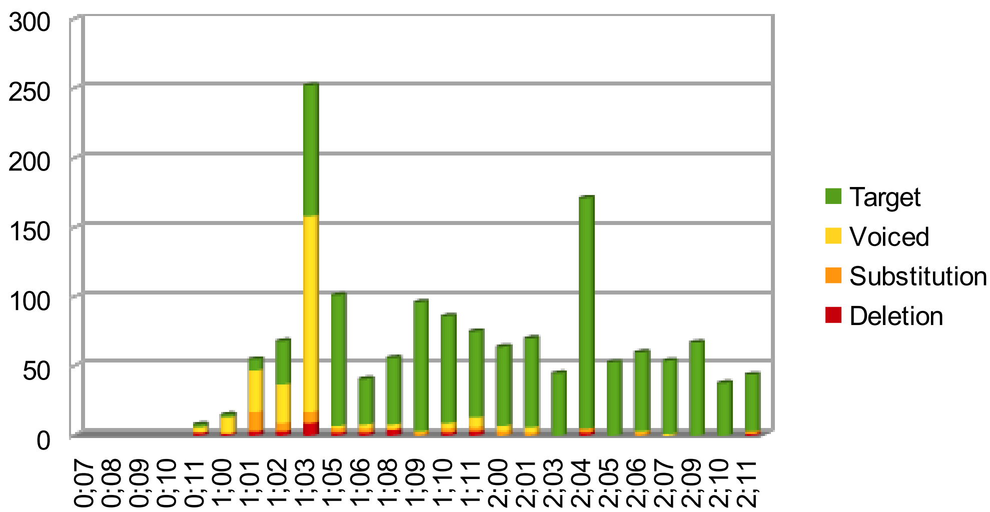
Figure 7: Voiced Oral Stops in Singleton Onsets



2.1.2 Voiceless Stops

The voiceless stops (|p,t,k|) are also first attempted at 0;11. However, Cameron consistently produces them as voiced until 1;05 when all three stops are suddenly produced as target-like, as Figure 8 illustrates.

Figure 8:   Voiceless Oral Stops in Singleton Onsets



This suggests that, at 1;05, Cameron acquired Voice Onset Time (VOT) across all three places of articulation for voiceless stops. The minor variation observed at 1;01 relates to occurrences of progressive assimilation, with |k| being assimilated by a preceding labial, as illustrated in (2).

(2)   Progressive assimilation substitutions at 1;01

a)   'pocket' |pɑkət| → [pɑpʊ]

b)   'basket' |bæskət| → [babʊ]

2.2 Flap

In most dialects of North American English, |ɾ|, an allophone of |t,d|, occurs in singleton onsets of unstressed, non-initial syllables (Chomsky & Halle 1968; Giegerich 1992), as illustrated in (3).

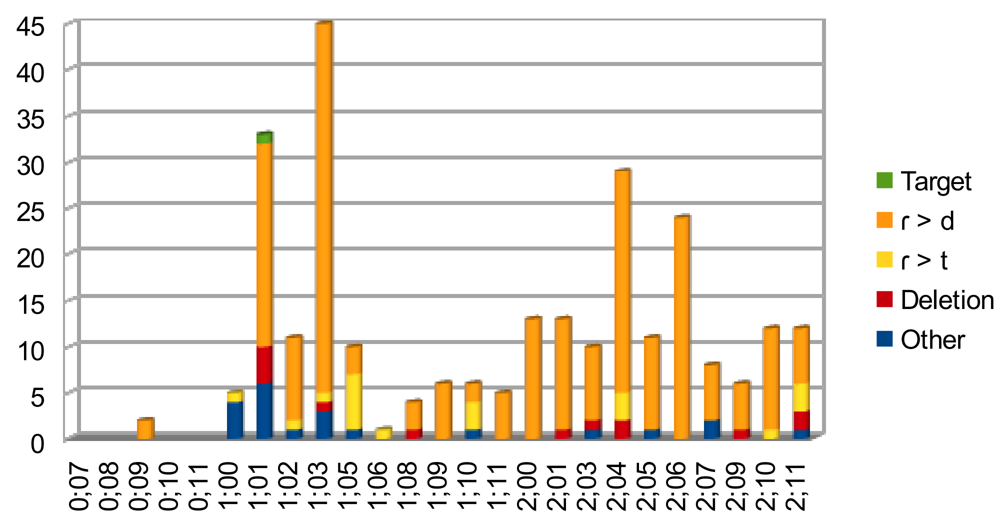
(3) Allophonic variation of |t,d|→[ɾ]

a) 'water' |ˈwɒtəɹ| → [ˈwɒɾəɹ]

b) 'ladder' |ˈlædəɹ| → [ˈlæɾəɹ]

Throughout the corpus, the main pattern observed is |ɾ| being produced as [d]. This pattern accounts for the majority of attempts made by Cameron in 15 of the 18 sessions between 1;01 and 2;10, as can be seen in Figure 9. This substitution maintains both place of articulation and voicing with the target |ɾ|. A second marginal pattern appears with [t] being produced for |ɾ|, which generally occurs in words where the underlying target phoneme for |ɾ| would be |t|. There are 107 instances of |ɾ| where the underlying phoneme would be |t|, with only 18 of these instances resulting in the substitution of |ɾ| with [t].

Figure 9: |ɾ|

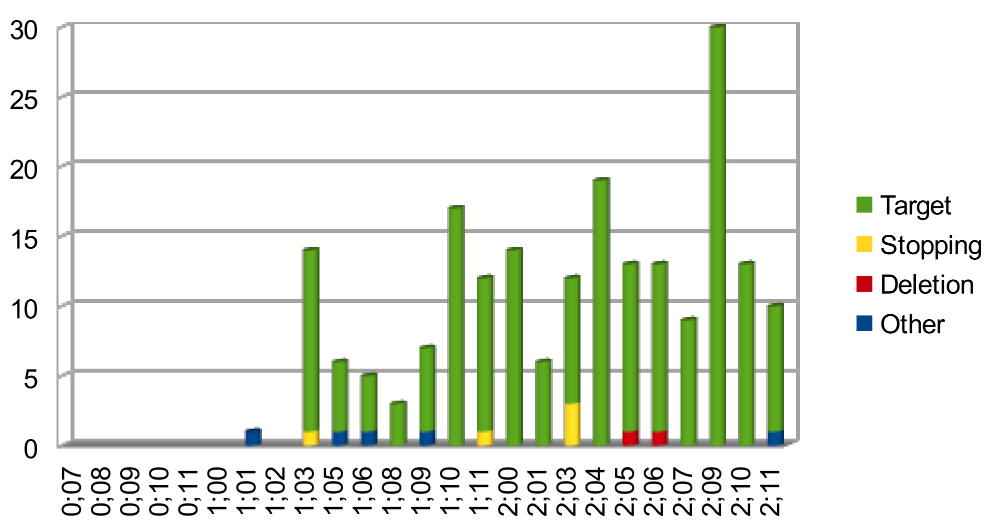


While Cameron fairly systematically substitutes [d] for |ɾ|, the target is transcribed as |ɾ| in her data to ensure comparability with Georgia's data. As we will see in Chapter 5, Section 2.2, Georgia displays a stark contrast in her treatment of coronal stops in flapping versus non-flapping environments. This difference suggests that coronal stops may be represented in different ways by the child, across the relevant positions.

2.3 Fricatives

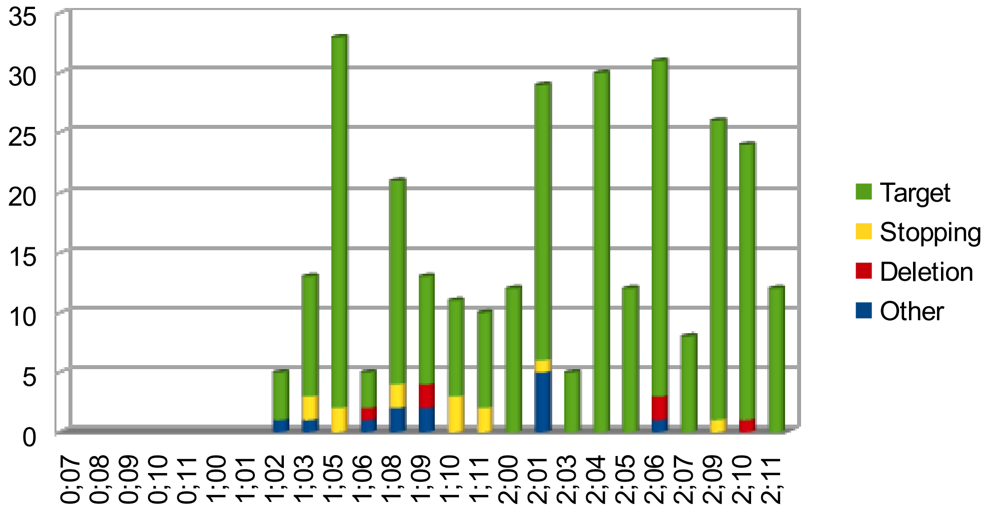
Moving on to fricatives, between 1;02 and 1;03 Cameron acquires |f,s,h|. Their voiced counterparts |v,z| are acquired later, at 1;09 and 2;03, respectively. Note, however, that the data available for these voiced fricatives are much more limited. The development of |f| is illustrated in Figure 10. Cameron acquires this sound at 1;03.

Figure 10: |f| in Singleton Onsets



Turning to |s|, Figure 11 illustrates that Cameron acquires this sound upon her first recorded attempts, at 1;02.

Figure 11: |s| in Singleton Onsets



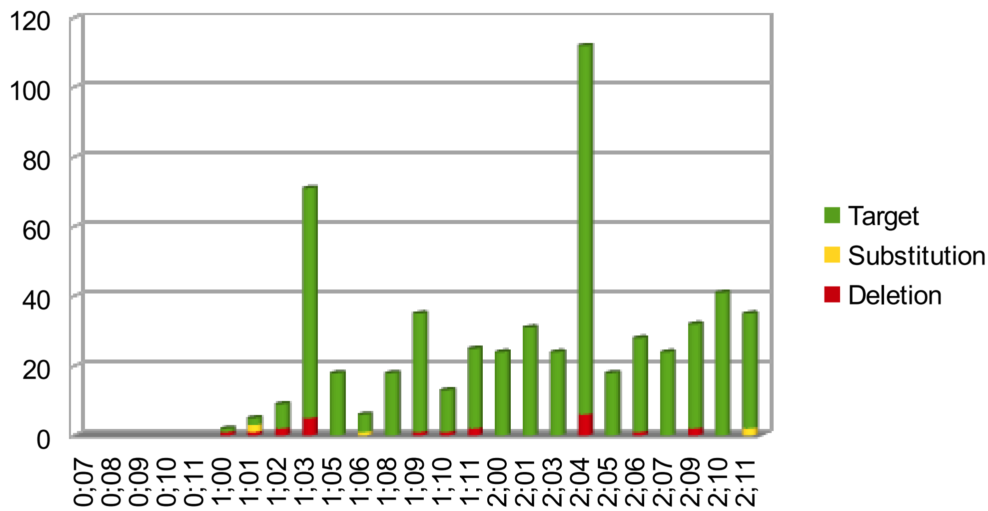
The small amount of variation occurring at 2;01 for |s| is essentially caused by one word. At 2;01, Cameron displays a variation where |s| is produced as [w] three times in 'some' when it follows 'want' and once 'something', as can be seen in (4).

(4) Cameron's |s|→[w] variation at 2;01

a)	Orthography	want some more
	IPA Target	|'wɑnt| |'sʌm| |'mɒɹ|
	IPA Actual	[wʌ] [wʌm] [moɹ]
b)	Orthography	and something to eat
	IPA Target	|'ænd| |'sʌmθɪŋ| |'tuː| |'iːt|
	IPA Actual	[ɛn] [wʌmtɪŋg] [tu] [it]

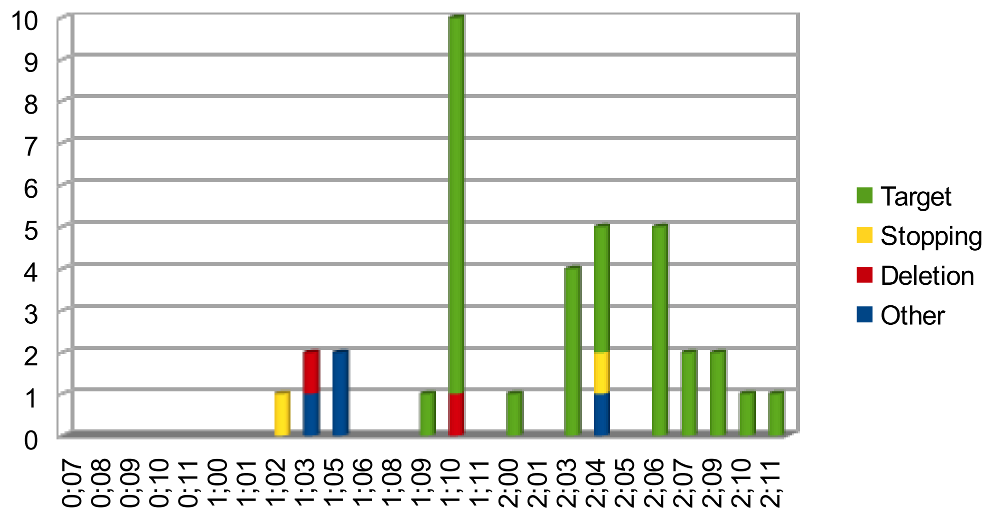
Focusing now on |h|, Cameron acquires this sound by 1;02, after two months of limited attempts, as can be seen in Figure 12.

Figure 12: |h| in Singleton Onsets



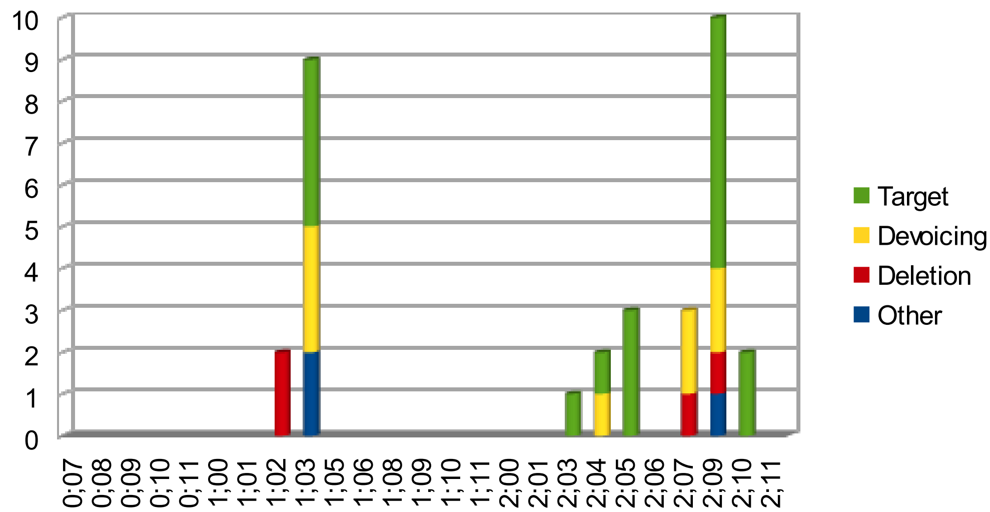
Turning to the voiced fricatives |v,z|, the later acquisition and sparsity of occurrence of these two consonants is not surprising given the limited number of English words with |v,z| in onset position. As Figure 13 illustrates, Cameron begins producing the majority of her attempts at |v| as target-like beginning at 1;09, as opposed to 1;03 for |f|.

Figure 13: |v| in Singleton Onsets



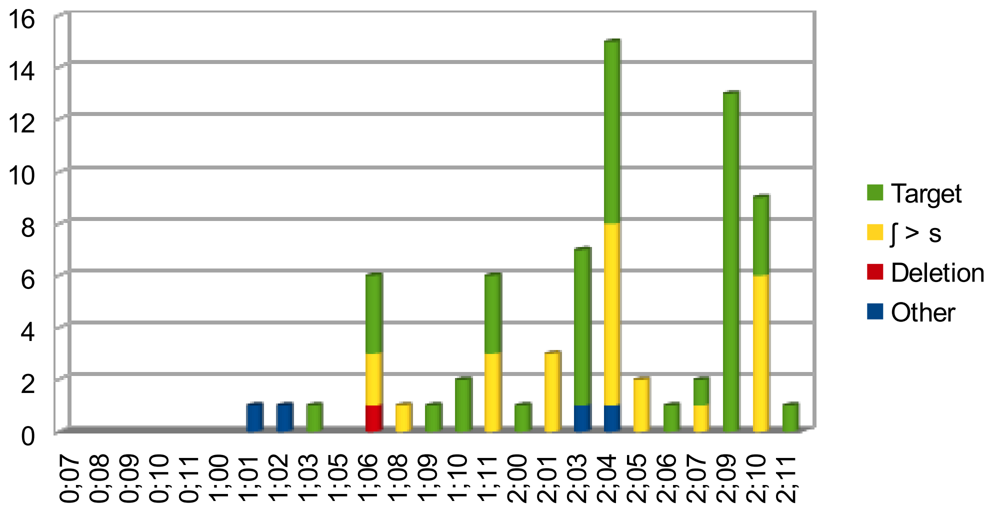
In contrast to this, Cameron is much less accurate at producing [z], illustrated in Figure 14. This lower accuracy is in large part due to what appears to be an optional devoicing of |z|, observed between 1;03 and 2;09. If we consider both the target-like and devoiced productions of |z|, then the majority of attempts in each session are produced as an alveolar fricative starting at 1;03.

Figure 14: |z| in Singleton Onsets



Turning now to |ʃ|, we can see in Figure 15 that Cameron makes her first attempt at this consonant at 1;01 with 'shoe' |ʃuː|→[tju]. At 1;06 Cameron begins substituting [s] for |ʃ|, a pattern that persists until 2;10, however not in a consistent way.

Figure 15: |ʃ| in Singleton Onsets



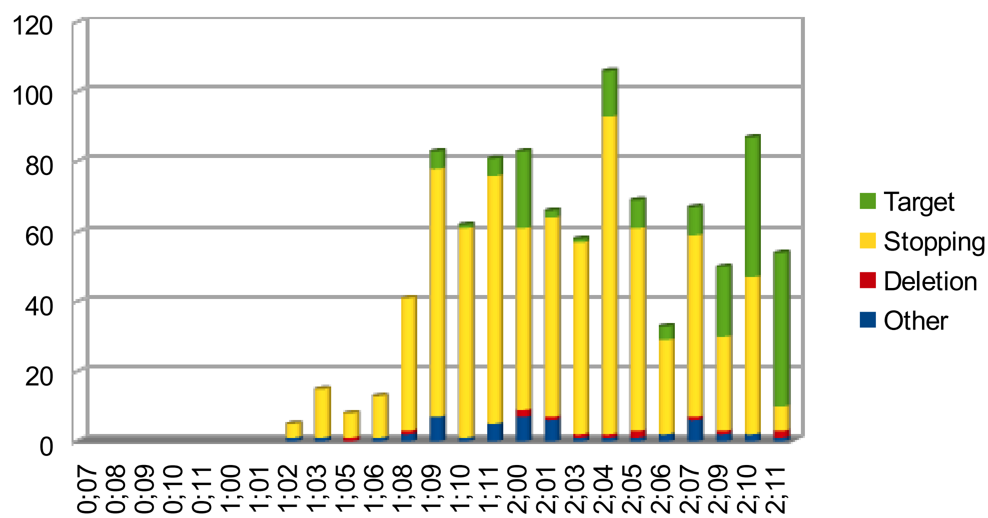
A closer look at the data in fact reveals that the |ʃ|→[s] variation is attested in only a handful of words. Only six words display this variation, listed in (5), and three of these words, *fishing*, *shop* and *she('s)*, account for 88.0% of the total occurrences of this pattern (22/25 occurrences). While interesting, such lexical effects are beyond the scope of the present phonological analysis. I thus leave this discussion for further research. Nonetheless, this |ʃ|→[s] pattern is significant in that it is not reciprocated in the data recorded for |s|: Cameron never produces |s| as [ʃ].

(5) |ʃ|→[s] optional substitution examples

a) 'dalmatian' |dælˈmeɪʃən|→[nesɪns] at 1;06
b) 'brushing' |ˈbɹʌʃɪŋ|→[bɹʌsʌ] at 1;06
c) 'shirt' |ˈʃʌɹt|→[dusəɹt] at 1;08
d) 'fishing' |ˈfɪʃɪŋ|→[fɪsɪŋg] at 1;11
e) 'shop' |ˈʃɑp|→[sap] at 2;01, 2;04, 2;05
f) 'she('s)' |ˈʃiː(z)|→[si(z)] at 2;07, 2;10

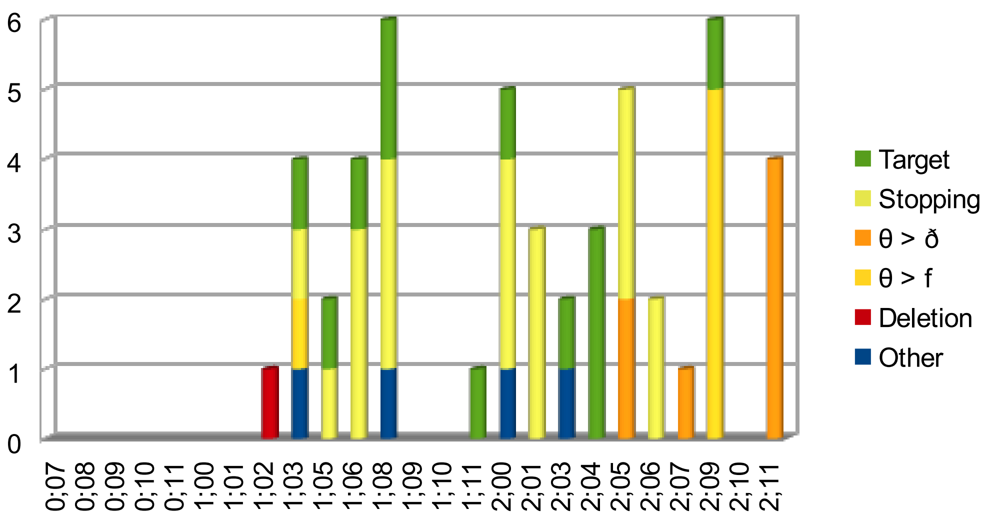
Looking now at |ð|, as shown in Figure 16, Cameron's substitution pattern of producing |ð| as [d] emerges at 1;02. This stopping pattern is fairly categorical from 1;02 until 2;09. At this point, Cameron begins to produce more target-like forms until she successfully acquires |ð| at 2;11 with an 81.5% accuracy rate (44/54 attempts).

Figure 16: |ð| in Singleton Onsets



While Cameron's development of the voiced interdental fricative |ð| follows a straightforward pattern from start to finish, her development of the voiceless counterpart |θ| does not, as can be seen from the limited number of examples illustrated in Figure 17.

Figure 17: |θ| in Singleton Onsets



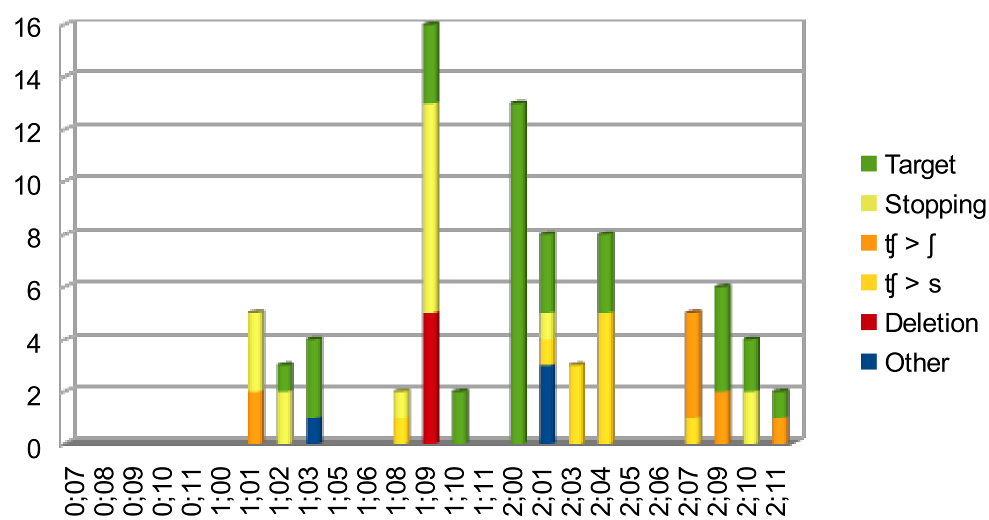
Cameron makes her first attempt at |θ| at 1;02, which results in a deletion. The five attempts she makes between 1;02 and 1;03 each display a different strategy: one case of deletion, three different substitutions (|θ|→[j], |θ|→[f], |θ|→[t]), and one target-like production. From 1;05 to 2;06, [t/d] is the most common production for target |θ| (i.e. stopping). At 2;05, we see the emergence of the final substitution pattern for |θ|, with Cameron producing it as the voiced interdental fricative [ð]. While Cameron does have difficulty acquiring this sound, 34 of the 36 substitutions she chooses share common physical attributes with |θ|, an observation that I return to in Chapter 7.

2.4 Affricates

Focusing now on the development of affricates, Cameron first attempts |ʧ| at 1;01, as can be seen in Figure 18. Just as we saw with |θ| above, there is noticeable fluctuation present in Cameron's data for |ʧ|. Between 1;01 and 1;03, we see three of the four recurring variations for

|ʧ| emerge: |ʧ| gets produced as [t/d[3]] (stopping), [ʃ], and as target-like. At 1;08, when attempts at |ʧ| resume, the fourth recurring variation emerges: |ʧ| is produced as [s].[4] Cameron fluctuates between these four substitutions throughout the corpus, and with so few attempts at |ʧ| present, it is difficult to see any significant patterns in this fluctuation. While Cameron achieves |ʧ| productions with accuracy at 1;10 and 2;00, she is unable to maintain a high level of accuracy and therefore this segment cannot be considered to be acquired during the period covered by the corpus.

Figure 18: |ʧ| in Singleton Onsets



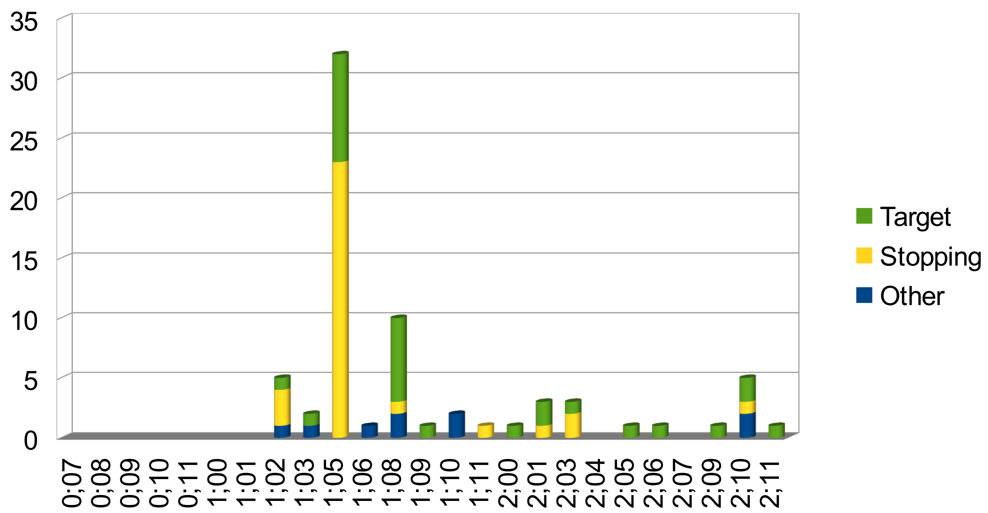
The data for |ʤ| is more sparse than the data for |ʧ|, but suggests that Cameron acquired this consonant at 2;05, as Figure 19 illustrates. However, with only nine attempts at |ʤ| after 2;05, it is very difficult to state decisively that acquisition has occurred. Prior to 2;05,

3 The substitution of [d] for |ʧ| at 1;01 and 1;02 is consistent with her production of voiceless stops as voiced until 1;05, as we saw in Figure 8.

4 Similarly, the production of |ʧ| as [s] follows Cameron's tendency to substitute [s] for |ʃ| beginning at 1;06.

Cameron attempts |ʤ| 61 times, with varying results. Generally, Cameron either produces |ʤ| as target-like or stopped to [d]. However, both production patterns display sizeable amounts of variability across sessions.

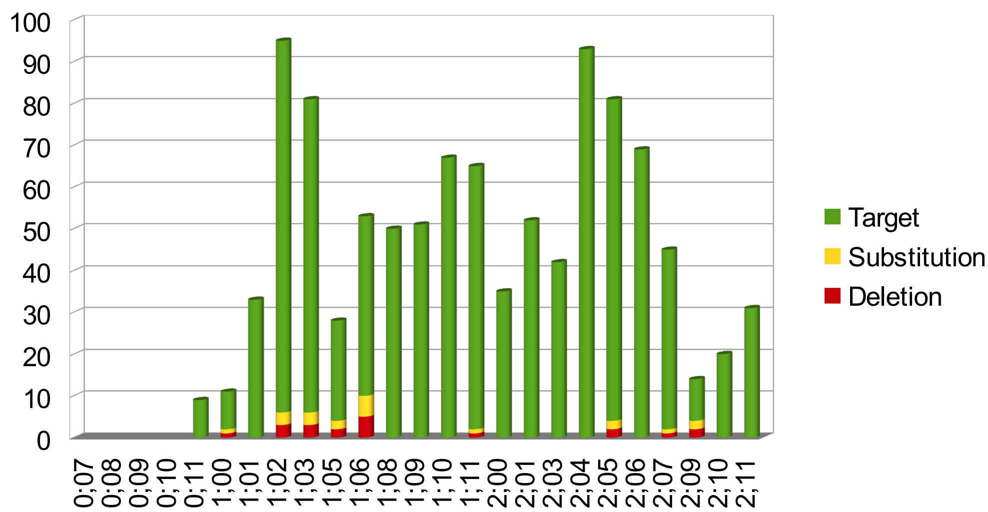
Figure 19: |ʤ| in Singleton Onsets



2.5 Nasal Stops

Considering the nasal stops |m,n|, illustrated in Figure 20, Cameron's development is parallel to her development of voiced oral stops (recall: Figure 7). Nasals are acquired upon Cameron's first attempt at 0;11.

Figure 20: Nasal Stops in Singleton Onsets



2.6 Approximants

Turning to approximants, Cameron acquires the English glides |j,w| at 0;11, as can be seen in Figure 21 and Figure 22, respectively. She makes her first attempt at both |l| and |ɹ| at 0;11 as well, with three attempts at |l| and one at |ɹ|. All four attempts at |l,ɹ| result in deletion.

Figure 21: |j| in Singleton Onsets

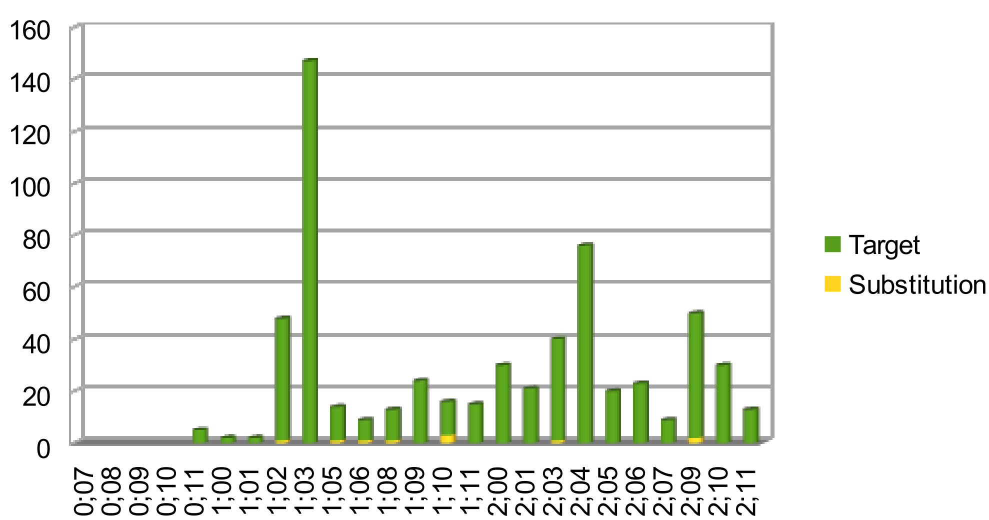
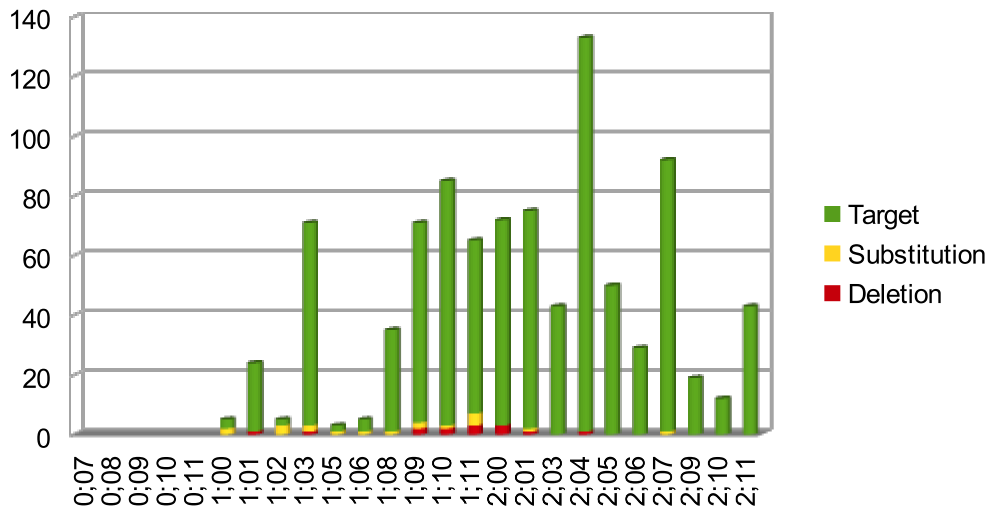
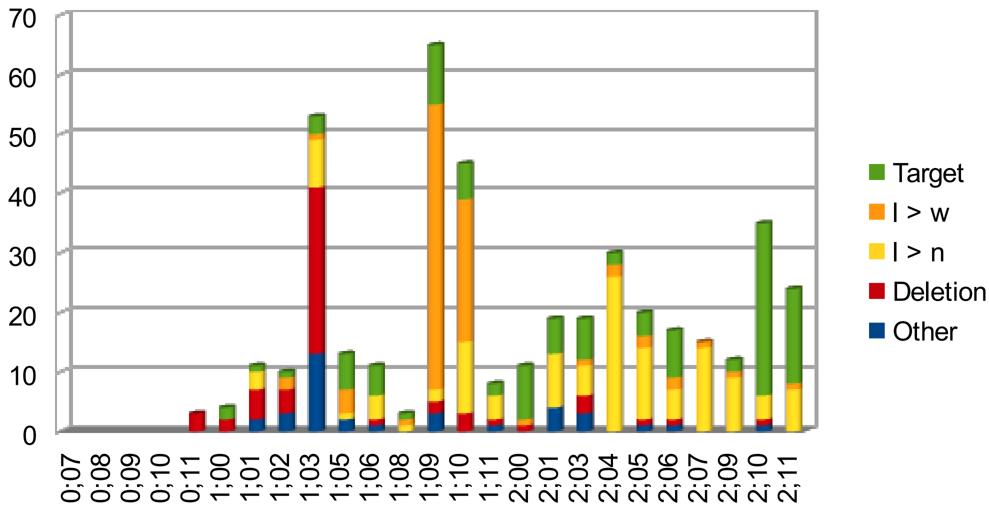


Figure 22: |w| in Singleton Onsets



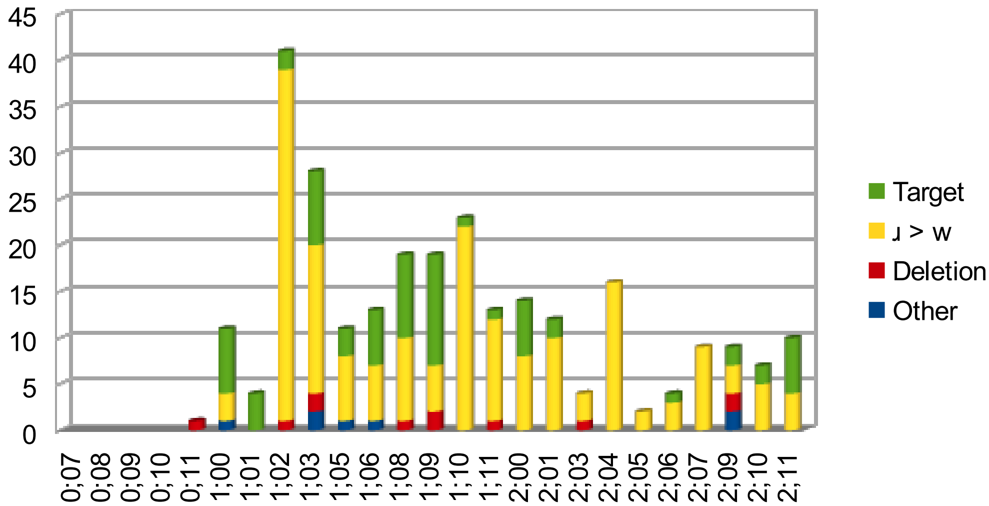
Turning now to |l|, we can see in Figure 23 that Cameron generally deletes |l| between 0;11 and 1;03. At 1;05, she begins substituting [w,n] for |l|. Cameron begins to produce |l| as [w], instead of as [n], at 1;09, with 73.8% of attempts resulting in |l|→[w] (48/65 attempts). At 1;11 the pattern is reversed and |l|→[n] becomes the dominant substitution pattern between 1;11 and 2;10. Both of these substitution patterns maintain common physical attributes with the target sound, as we saw with the substitutions affecting |θ|, an observation that we will revisit in Chapter 7. At 2;00, we begin to see the emergence of target-like productions, with acquisition finally taking place at 2;10, with an 82.9% accuracy rate (29/35 attempts).

Figure 23: |l| Singleton Onsets



If we look at |ɹ|, a different trend emerges regarding substitution patterns, as can be seen in Figure 24. Cameron substitutes [w] for |ɹ| throughout the data. However, this pattern is not uniformly representative. At 1;00 and 1;01, the majority of attempts are produced as target-like, while between 1;02 and 1;05 the majority of the attempts in each session result in |ɹ|→[w] substitution. We then see a slight increase of target-like productions between 1;06 and 1;09, followed by a re-emergence of the |ɹ|→[w] pattern, which remains dominant until 2;10. This behaviour may be indicative of the presence of a covert contrast (Scobbie et al. 1996; Gibbon 1999). This possibility will be further discussed in Chapter 7. Given this constant fluctuation, it is difficult to tell whether the increase in accurate productions at 2;11 is an indicator of acquisition or simply a new rotation of the established pattern.

Figure 24: |ɹ| in Singleton Onsets

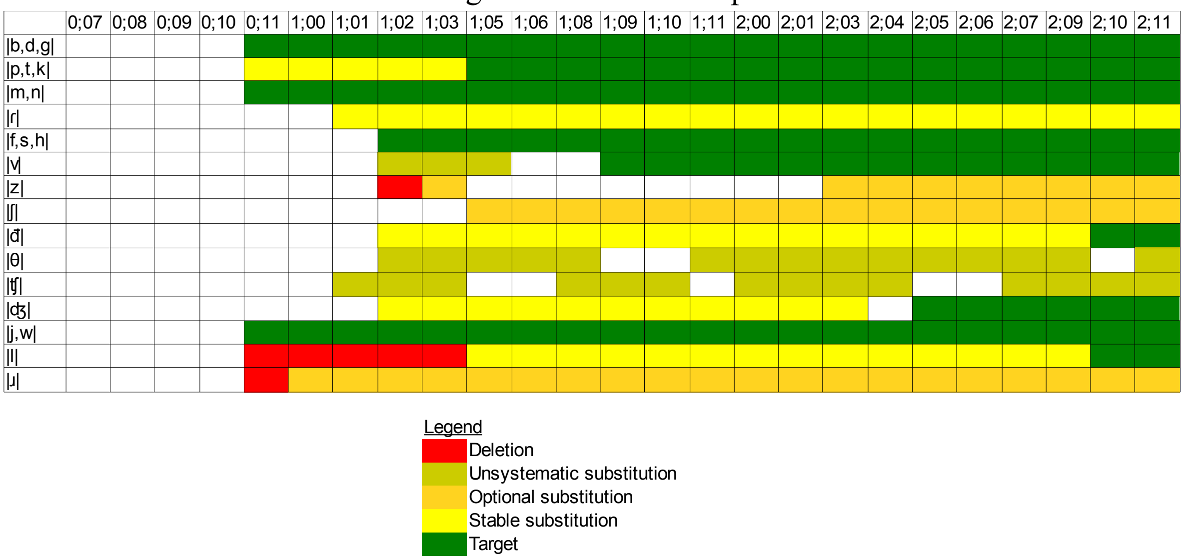


2.7 Summary of Observations for Singleton Onsets

With the exception of |ʃ,ɹ|, which will be discussed below, Cameron's development of singleton onsets can be summarized into three different behaviours: sounds which give her no difficulty and which she acquires easily (e.g. oral and nasal stops, glides and voiceless fricatives excluding |θ|); sounds that she is unable to produce as target-like but have a consistent substitution pattern (e.g. |ð| and |ɾ|); and sounds that she spends the majority of the corpus trying to acquire without consistent outcomes (e.g. |θ| and |ʧ|).

As can be seen in Table 6, Cameron also acquires her early sounds in broad natural classes: she acquires all her voiced stops (oral and nasal) and both the glides |j,w| at 0;11; her voiceless stops at 1;05; and the voiceless fricatives |f,s,h| between 1;02 and 1;03. The sounds which she acquires at a later time do not follow such a tidy pattern. They seem to be added to her system one by one, such as |ʤ|, acquired at 2;05, or |v|, which she acquires at 1;09. The fourth behaviour that Cameron exhibits, which, as mentioned above, applies to |ʃ,ɹ| only, involves fluctuations between target-like productions and systematic substitution patterns. (Recall that target-like productions of |ɹ| occur as early as 1;00, yet Cameron never maintains the necessary accuracy to acquire this sound.) This pattern is known as a U-shaped learning curve and is attested in numerous studies on child phonological development (e.g. Leopold 1947; Fikkert 1994; Fikkert & Levelt 2008).

Table 6: Timeline of Cameron's Singleton Onset Development



3. Branching Onsets

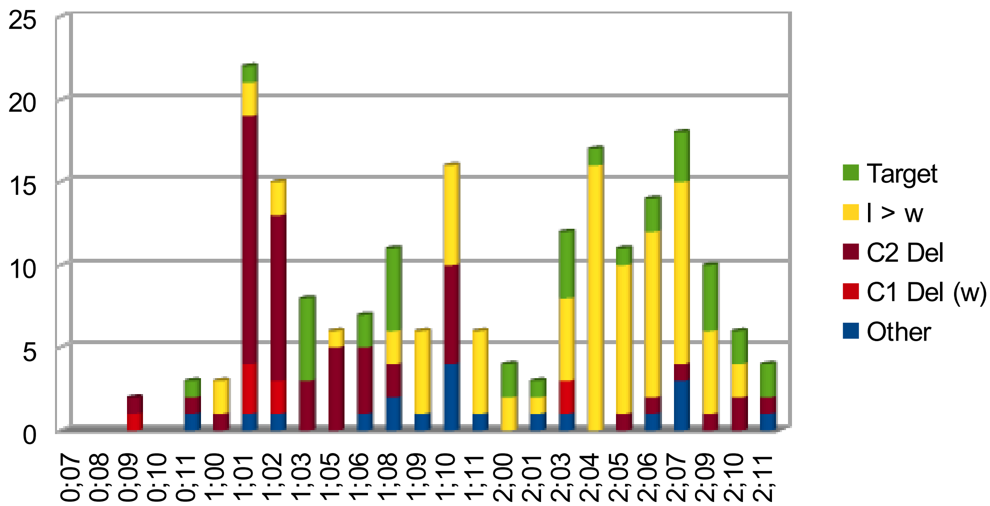
In this section, I focus on Cameron's phonological development of branching onsets. The data available for branching onsets are more sparse than the data for singleton onsets. It is, however, possible to draw meaningful conclusions based on these data. I begin with a description of the |Cl|[5] clusters, followed by |Cɹ| clusters and, finally, |Cw| clusters.

5 Where "C" represents any consonant in this position.

3.1 |Cl|

Figure 25, below, illustrates all of Cameron's attempts at |Cl| branching onsets throughout the corpus.

Figure 25: All |Cl| Branching Onsets Attempted by Cameron



Note that while Cameron begins to produce target-like |Cl| clusters as young as 0;11, at no point in the corpus is she able to consistently produce these clusters as target-like. While the target-like productions found in the corpus consist of a variety of clusters, in any particular session there may be only one branching onset produced as target-like. For example, the five target-like productions attested when the child is 1;03 occur across three separate sessions, with each session containing only one target-like lexical form, as seen in (6).

(6) Target-like |Cl| branching onsets at 1;03

a) 'cluck' |klʌk|→[klʌ] occurs twice during session recorded at 1;03.03

b) 'play' |ˈpleɪ|→[plɛɪ] occurs twice during session recorded at 1;03.18

c) 'plate' |ˈpleɪt|→[ple] occurs once during session recorded at 1;03.25

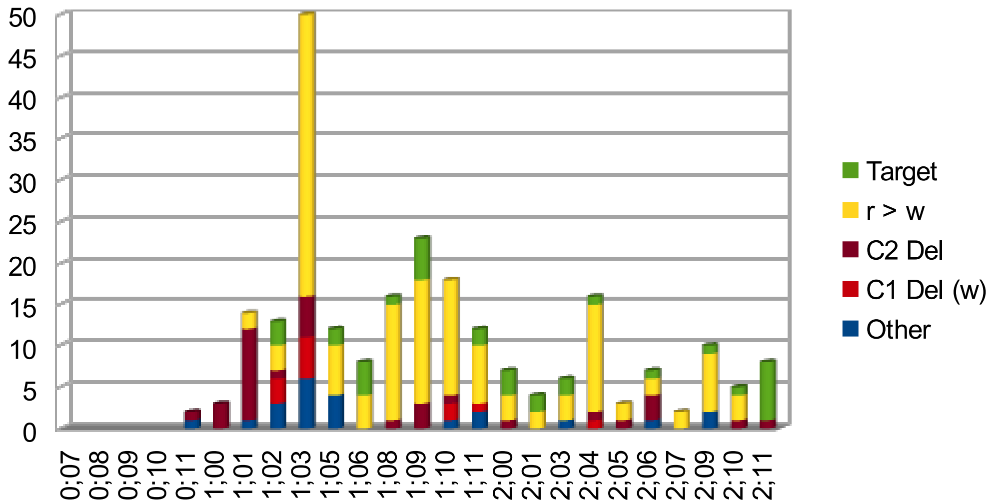
Turning to substitution patterns, note that [Cw] produced for |Cl| does not become a dominant pattern until 1;09, which corresponds to when the |l|→[w] pattern became dominant in singleton onsets, as was discussed in Section 2.6 above. Between 1;09 and 2;11, the |Cl| →[Cw] substitution combined with the number of target-like productions accounts for the vast majority of attempts in most sessions. During this period, Cameron was thus producing the vast majority of her |Cl| branching onsets as clusters. One exception to this generalization came at 1;10. This month contains a spike in C2 deletions, which is, however, related to only two words: four attempts at 'block(s)' and two attempts at 'blew'. Neither of these words are attempted in the recordings after 1;10.

3.2 |Cɹ|

I illustrate the data for |Cɹ| branching onsets in Cameron's corpus in Figure 26. Note that the |Cɹ| clusters are more systematic than |ɹ| in singleton onsets (recall: Figure 24) in that there is very little fluctuation between target-like productions and substitutions. Beginning at 1;03, Cameron produces |Cɹ| as [Cw]. Note that this is one month after the |ɹ|→[w] pattern emerges in her singleton onsets. Cameron follows the pattern of substituting [Cw] for |Cɹ| from 1;03 until 2;10, with this substitution pattern representing the majority of attempts in all but one session at 2;06. Combining target-like productions and |Cɹ|→[Cw] substitutions, the majority of Cameron's attempts at |Cɹ| branching onsets between 1;03 and 2;10 result in cluster production.

At 2;11, the majority of productions are target-like. It is, however, difficult to determine if she has acquired this cluster since this is also the last session recorded in the corpus.

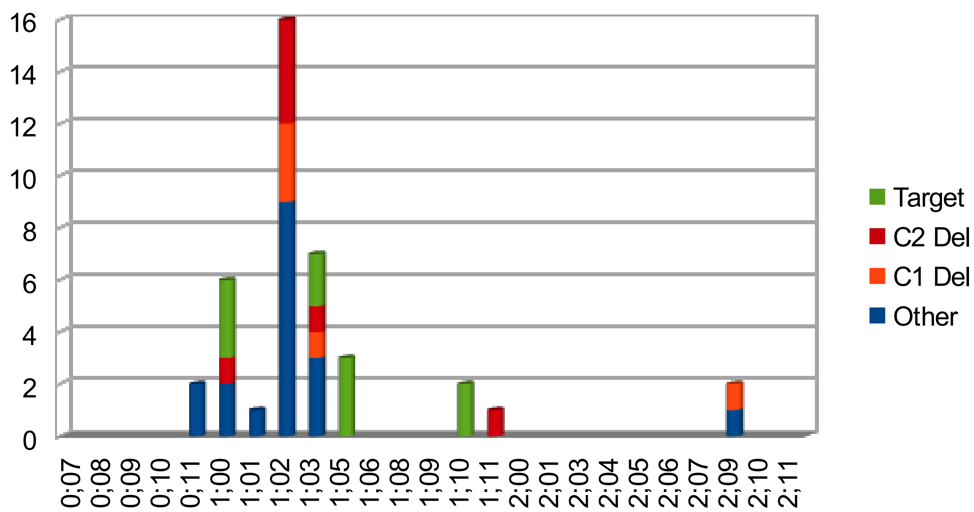
Figure 26: All |Cɹ| Branching Onsets Attempted by Cameron



3.3 |Cw|

The number of |Cw| branching onsets is very limited in Cameron's data. Figure 27 illustrates Cameron's few attempts at |Cw| branching onsets. Despite her tendency to substitute [w] for both |l,ɹ| in other branching onsets, she is unable to achieve any consistent accuracy in her attempts at |Cw| branching onsets. Also, all attempts between 0;11 and 1;03 come from the onomatopoeic forms "quack" |kwæk| and "tweet" |twiːt|, with the few non-onomatopoeic forms recorded appearing as of 1;05. With fewer than 40 forms attempted, it is extremely difficult to explain the non-acquisition of the |Cw| branching onset.

Figure 27: All |Cw| Branching Onsets Attempted by Cameron



3.4 Summary of Observations for Branching Onsets

If we compare the data for |Cl| and |Cɹ| branching onsets in Table 7, we can see that Cameron establishes a substitution pattern for the |Cɹ| branching onsets six months earlier than for the |Cl| branching onsets (1;03 for |Cɹ| versus 1;09 for |Cl|), similar to her treatment of |l| and |ɹ| in singleton onsets (Figure 23 and Figure 24, respectively). These trends do not hold true for |Cw| branching onsets however, which Cameron fails to acquire despite an early acquisition of |w| in singleton onsets. It is, indeed, surprising that she displayed a pattern of substituting [Cw] clusters for both |Cl| and |Cɹ| clusters, and yet was unable to successfully produce target-like |Cw| branching onsets.

Table 7: Timeline of Cameron's Branching Onset Development

	0;07	0;08	0;09	0;10	0;11	1;00	1;01	1;02	1;03	1;05	1;06	1;08	1;09	1;10	1;11	2;00	2;01	2;03	2;04	2;05	2;06	2;07	2;09	2;10	2;11
|Cl|																									
|Cɹ|																									
|Cw|																									

Legend
- C2 deletion
- unsystematic substitution
- transition between patterns
- stable substitution
- target

In the next chapter, I continue with data description focusing now on Georgia's word productions. I also highlight similarities and differences between the segmental development of these two children.

Chapter 5: Georgia's Consonantal Development

1. Introduction

In this chapter I summarize the segmental development of Georgia's word productions. First, I describe her development in singleton onsets, then I move on to her development in branching onsets. Each target onset attempted by Georgia is discussed in this chapter, even though some targets are represented by few attempts. As we will see, Georgia develops her segmental inventory in a somewhat segment-by-segment fashion, with different members of a natural class being acquired at different points in time. With respect to branching onsets, Georgia displays similar segmental patterns as observed in singleton onsets. However, she also displays some striking developmental similarities between different types of branching onsets.

2. Singleton Onsets

In this section, I describe Georgia's phonological development of singleton onsets. Just as in the preceding chapter, I begin with the development of obstruents, then nasal stops, and, finally, approximants.

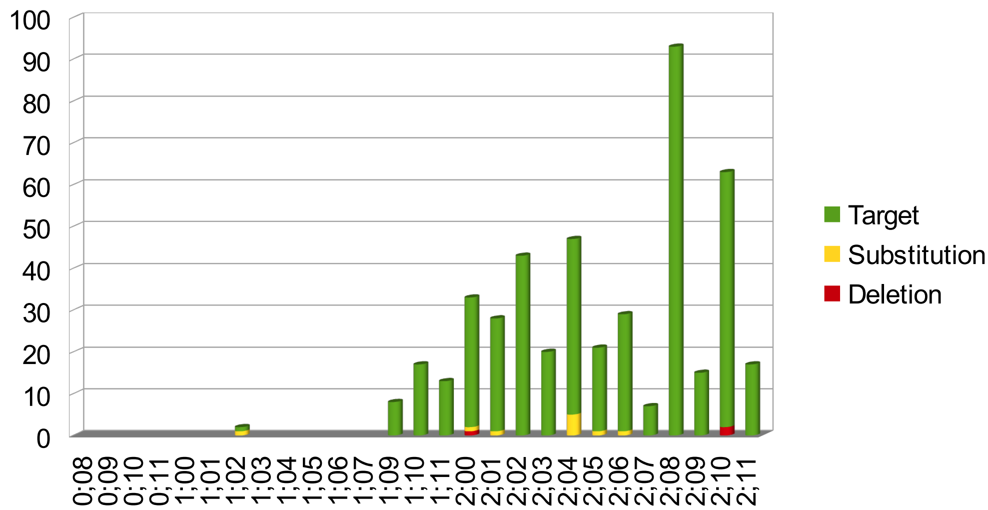
2.1 Stops

The data for oral stops in Georgia's corpus display a certain degree of variation among different places of articulation. This variation creates a stark contrast with the categorical treatment of stops we saw in Cameron's data. Because of this difference in behaviour, I will not condense Georgia's data into voiced and voiceless categories, as I did for Cameron; I discuss each sound individually, in order to properly highlight the relevant patterns.

2.1.1 Voiceless Stops

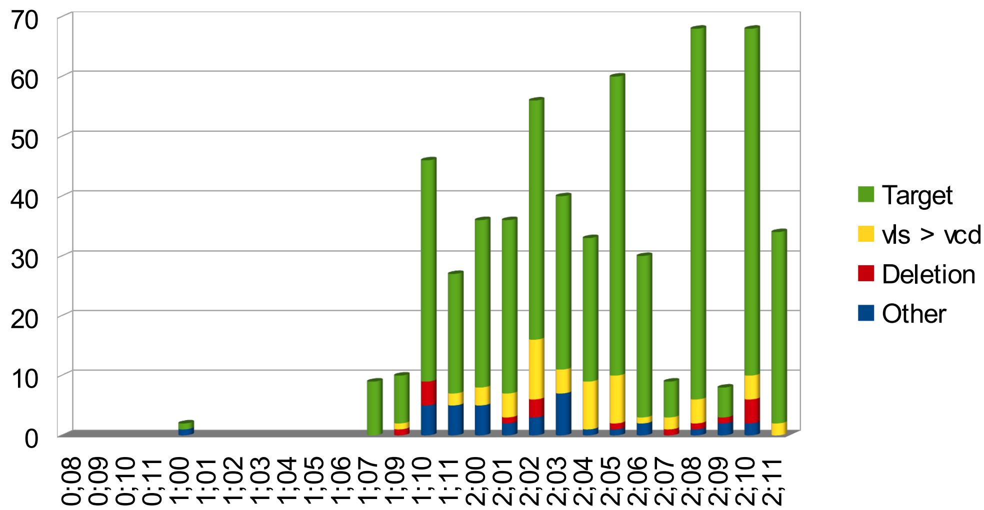
Georgia displays some idiosyncratic patterns within her attempts at voiceless stops. As can be seen in Figure 28, she does not make a single attempt at |p| during the recording sessions between 1;03 and 1;07. However, after 1;09, she has little difficulty producing |p| in singleton onsets, with each session showing an accuracy rate of at least an 89%.

Figure 28: |p| in Singleton Onsets



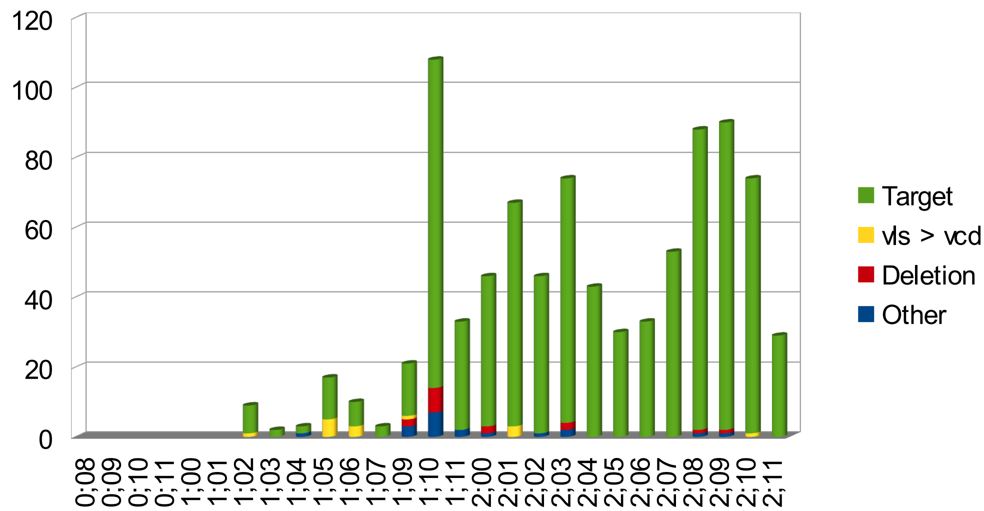
Turning to |t| in singleton onsets, we see a similar pattern of emergence in Figure 29, with no attempts at |t| between 1;01 and 1;06. Overall, Georgia is accurate, producing the majority of attempts at |t| in each session as target-like. However, we observe more variation in her productions of |t| than the other voiceless stops with her accuracy rate dropping below 75% on four occasions, and as low as 62.5% (5/8 attempts) at 2;09. Most of this variation originates from a pattern of voicing |t| to [d]. Although marginal, this pattern is attested in 13 of the 17 sessions which contain attempts at |t|.

Figure 29: |t| in Singleton Onsets



Looking now at |k|, we can see in Figure 30 that Georgia has little trouble with this consonant, and acquires it at 1;10. After this point, she produces at least 87% of the attempts in each session as target-like.

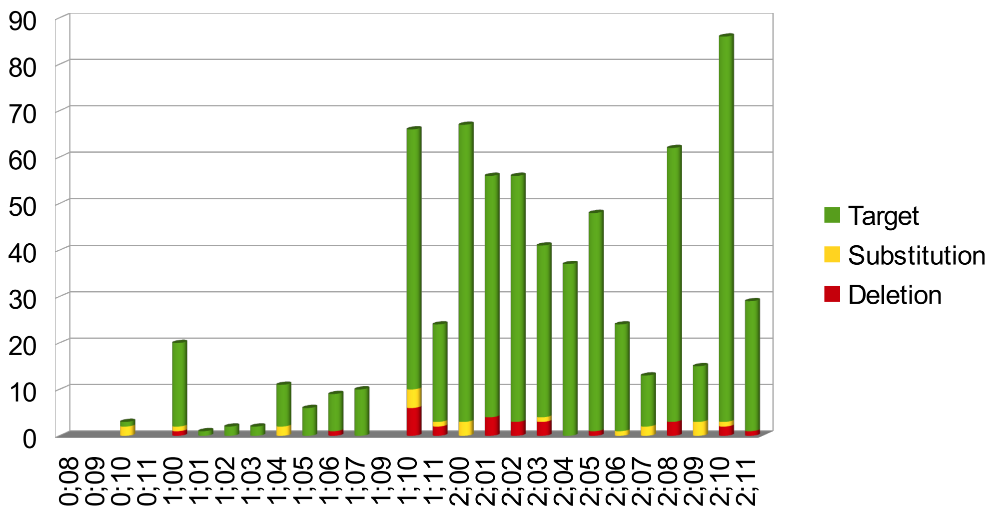
Figure 30: |k| in Singleton Onsets



2.1.2 Voiced Stops

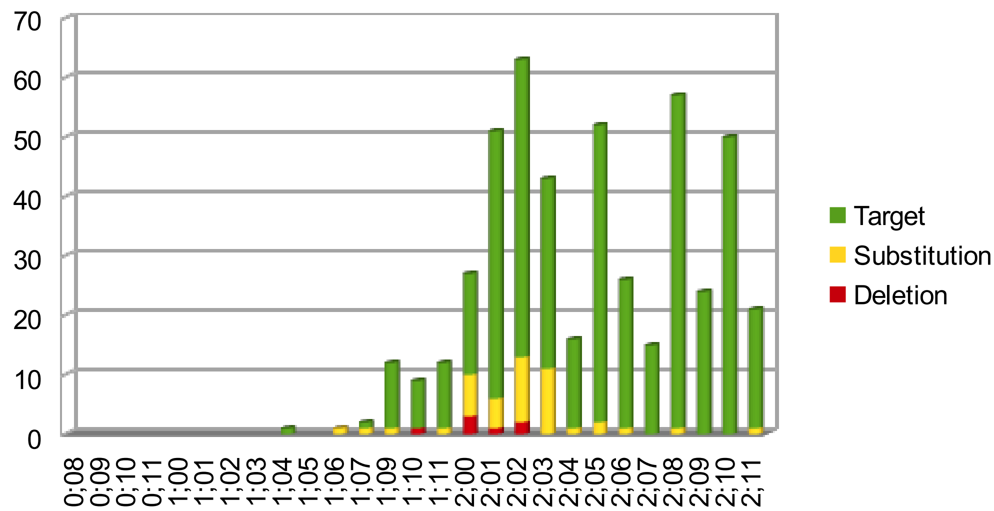
Georgia's development of voiced oral stops mirrors that of her voiceless stops in that |b,g| are acquired with little variation while the coronal |d| is subject to more variability. However, there are also differences between Georgia's development of voiced stops compared to her voiceless stops. As can be seen in Figure 31, Georgia acquires |b| at 1;00 achieving the required minimum of 75% accuracy rate in each session after this point.

Figure 31: |b| in Singleton Onsets



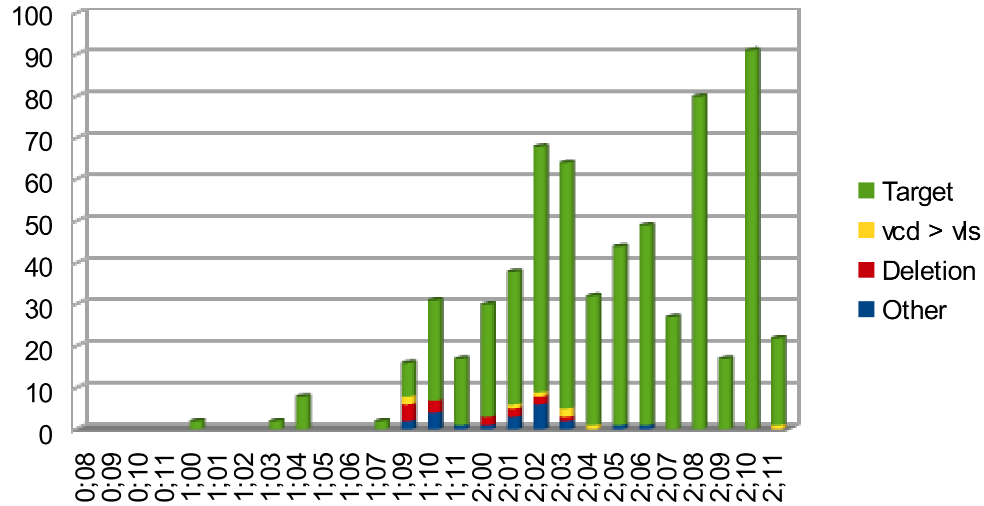
Turning to Figure 32, which illustrates Georgia's development of |d|, we can see that from 1;09 onwards she generally produces this consonant as target-like. Before 1;09, there are only four recorded attempts at |d|, making it difficult to assess Georgia's proficiency with this segment before this point. We also note more variation with |d| than with either |b| (above) or |g| (below). The increase in variation observed between 2;00 and 2;03 is related to three patterns: |d|→[n], |d|→[j] and |d|→[g], with only one other substitution occurring during this period.

Figure 32: |d| in Singleton Onsets



Looking now at Georgia's development of |g|, we can see in Figure 33 that she is accurate from her first attempts at this sound at 1;00. However, she makes only 14 attempts at |g| between 1;00 and 1;07, and this limited number of attempts makes it difficult to judge Georgia's true proficiency with this segment. Regardless of the limited attempts in the early sessions of the corpus, Georgia surpasses the 75% accuracy mark in all but one session (at 1;09) which contain attempts at |g|.

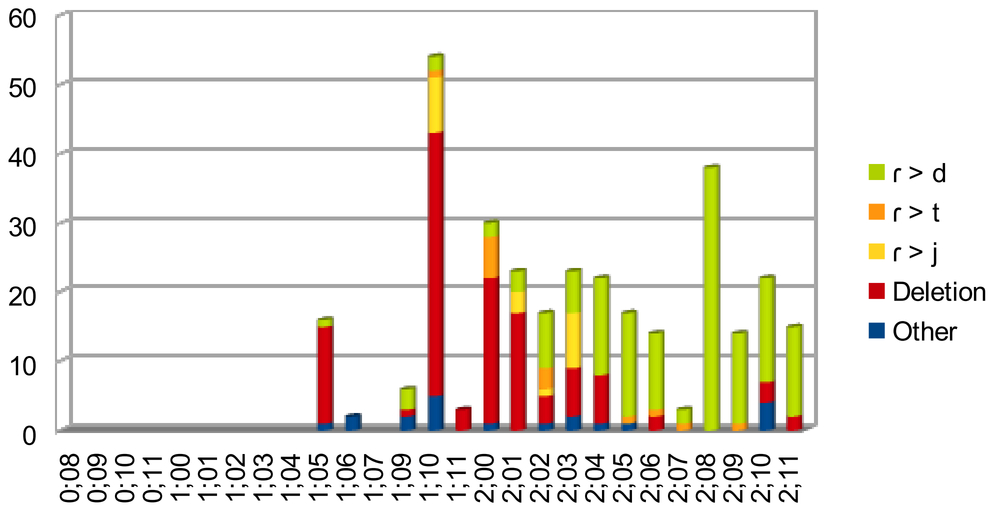
Figure 33: |g| in Singleton Onsets



2.2 Flap

As can be seen in Figure 34, Georgia's early attempts at |ɾ| between 1;05 and 2;01 result in high rates of deletion. This high incidence of deletion, when |d,t| is produced in flapping environments during this stage, suggests that Georgia treats coronal stops differently in flapping versus non-flapping environments. This observation informed my decision to transcribe |ɾ| as a target segment. (Note as well that the corpus provides no evidence concerning the child's actual representation of phonetic flaps at the phonological level.) Beginning at 2;02, a substitution pattern emerges whereby |ɾ| is produced as [d] in Georgia's productions. From 2;04 onwards, this stopping pattern is the dominant pattern, accounting for a majority of the attempts at |ɾ| in each session.

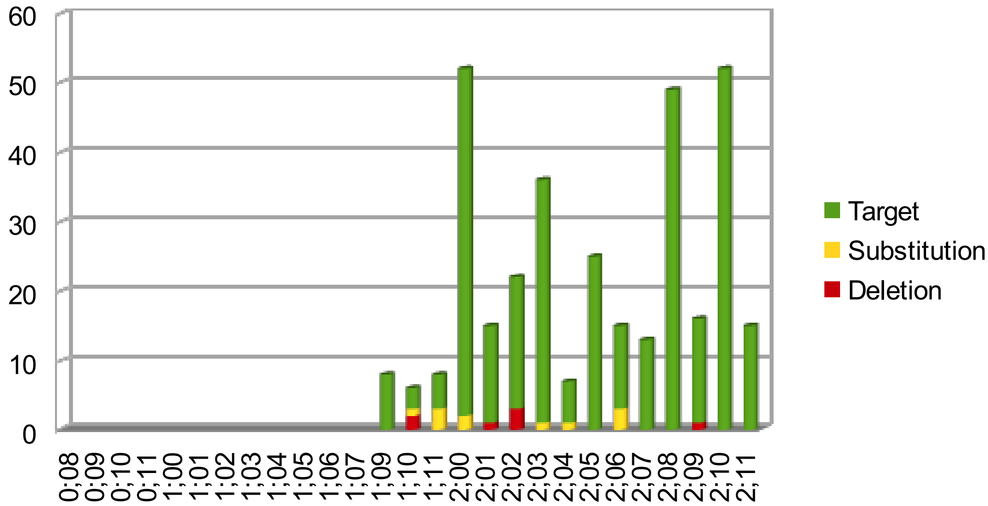
Figure 34: |ɾ|



2.3 Fricatives

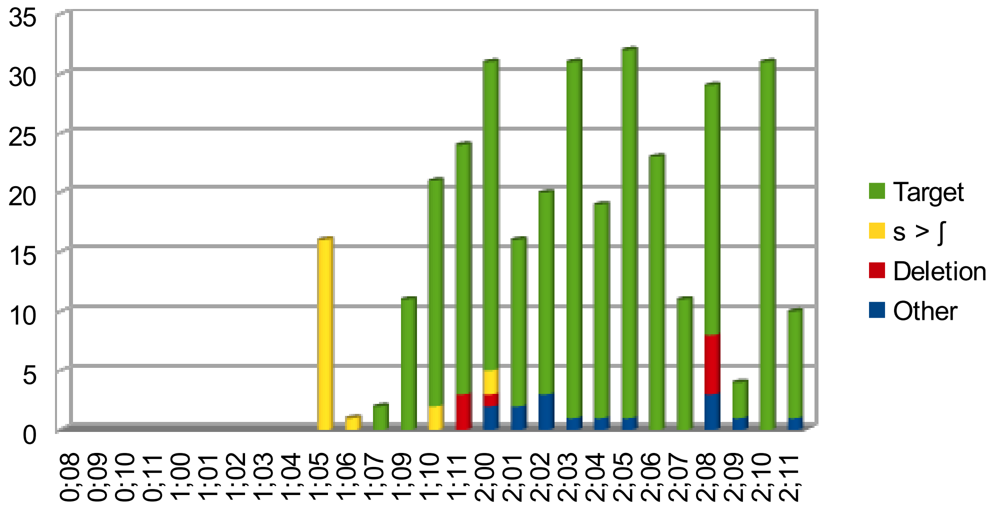
Focusing now on the development of fricatives, Georgia acquires |f| with ease upon her first attempts at 1;09, as illustrated in Figure 35.

Figure 35: |f| in Singleton Onsets



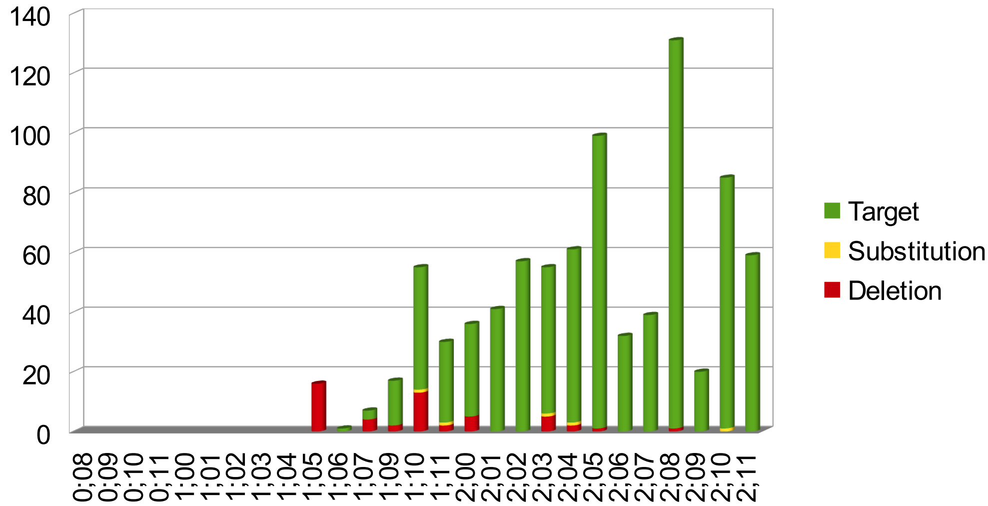
Turning to Georgia's treatment of |s|, Figure 36 illustrates that between 1;05 and 1;06 all 17 attempts at |s| result in [ʃ] production. Note, however, that all of these examples come from the same word: 'Sadie' |sædi|. As of 1;07, Georgia successfully produces the vast majority of her attempts at |s| as target-like, with at least a 75% accuracy rate in each session.

Figure 36: |s| in Singleton Onsets



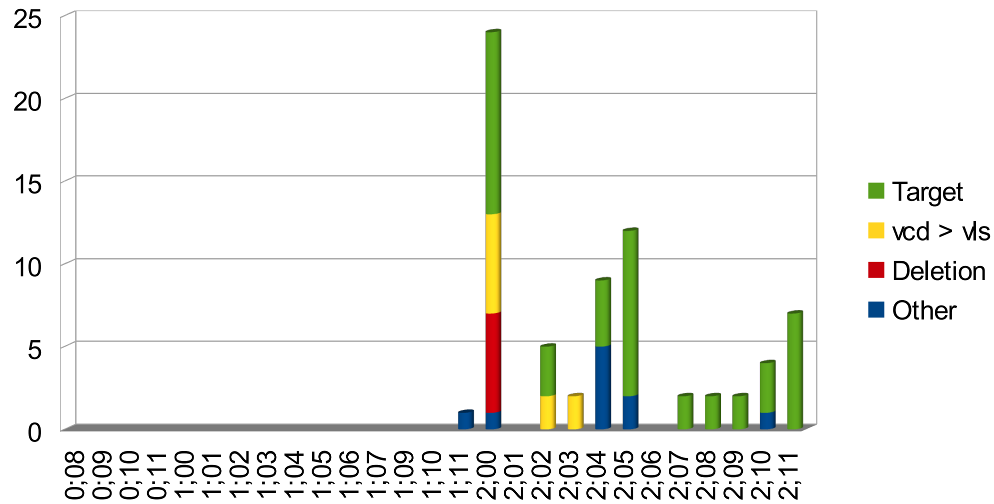
Looking at Georgia's development of |h|, illustrated in Figure 37, we can see that all of the 16 attempts at |h| at 1;05 result in deletion, as do four of the seven attempts at 1;07. This deletion stage is only brief, however. By 1;09, Georgia has acquired |h|, with at least 75% of her attempts in each session resulting in target-like productions.

Figure 37: |h| in Singleton Onsets



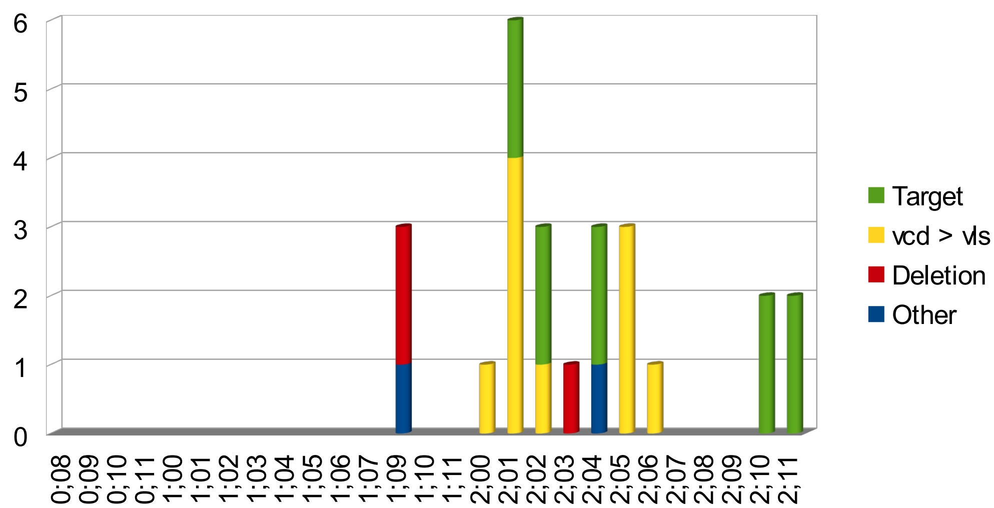
Turning now to the voiced fricatives |v,z|, we see these consonants behaving differently than their voiceless counterparts |f,s|. As can be seen in Figure 38, |v| is not attempted until 1;11, and it is not until 2;05 that Georgia achieves and maintains the required accuracy rate of at least 75% for this segment. It should be noted, however, that between 2;00 and 2;03 the corpus contains 10 occurrences of |v| produced as [f]. If we consider these devoiced productions along with the target-like productions, the majority of the attempts at |v| during these three sessions result in labio-dental fricative outcomes.

Figure 38: |v| in Singleton Onsets



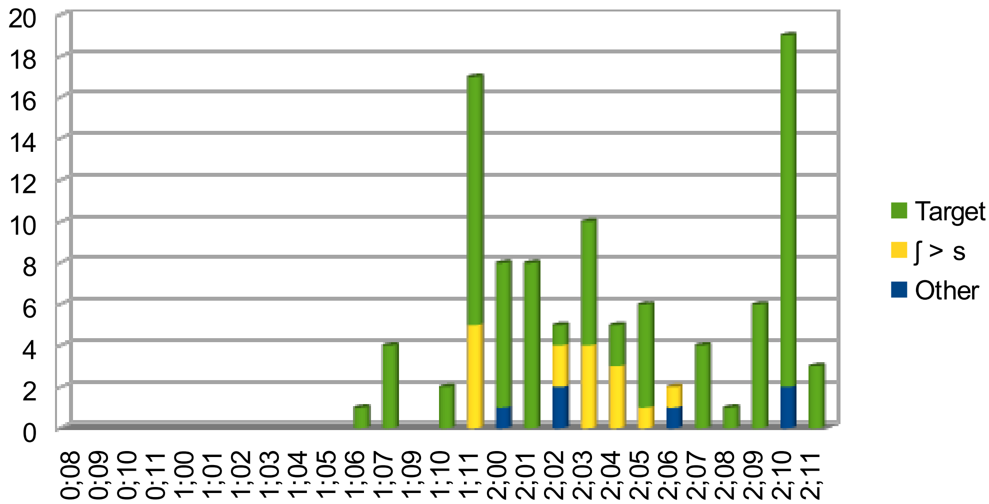
A different pattern is observed with |z|, as can be seen in Figure 39, with consistent target-like productions of |z| not occurring until 2;10. Between 2;00 and 2;06, however, the majority of Georgia's attempts at |z| result in devoicing, as the child keeps with the target place of articulation and manner of articulation.

Figure 39: |z| in Singleton Onsets



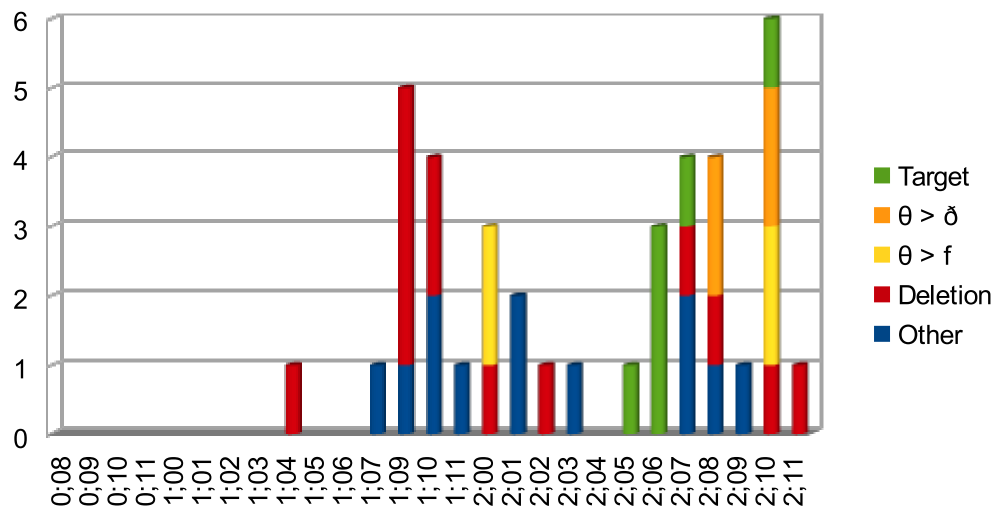
Focusing now on |ʃ|, we can see in Figure 40 that the substitution of |s| with [ʃ] is reciprocated in the data for |ʃ|. Interestingly, Georgia does not begin producing |ʃ| as [s] until 1;11, four months after the point when Georgia corrects the |s|→[ʃ] pattern. This substitution pattern causes Georgia's productions to fluctuate between 1;11 and 2;06. Starting at 2;07, through to the end of the recorded period, she surpasses the required 75% accuracy rate in each session. However, qualitatively we can see that Georgia is proficient at |ʃ| from her first attempt at 1;06.

Figure 40: |ʃ| in Singleton Onsets



If we look at the development of |θ| in Georgia's data, we can see that, similar to Cameron, she has difficulty acquiring this particular sound. However, unlike Cameron, who showed only one case of deletion, deletion is the most common pattern in Georgia's attempts at |θ|. Georgia is unable to maintain a high level of accuracy with |θ| and, therefore, does not acquire this sound during the period covered by the corpus.

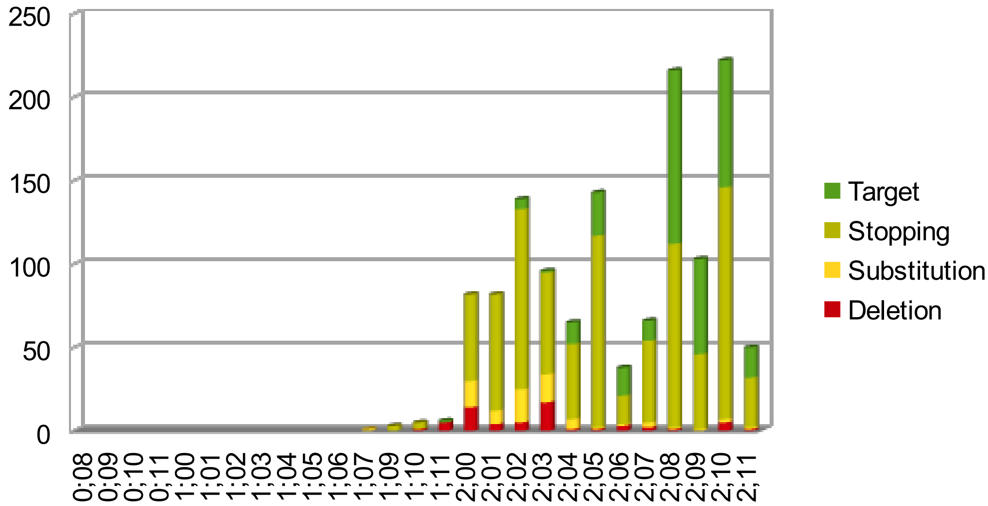
Figure 41: |θ| in Singleton Onsets



Turning to the voiced interdental fricative, we see that Georgia's attempts at |ð| yield a very different pattern. As can be seen in Figure 42, Georgia first attempts |ð| at 1;07, but her attempts at this particular sound skyrocket at 2;00, when function words appear in Georgia's productions. At 1;09, a stopping pattern emerges, with virtually all of the 848 cases of stopping throughout the corpus resulting in |ð| being produced as [d] (|ð|→[d]).[6] Stopping is the most common pattern for |ð| throughout the corpus. In fact, with the exception of 2;09, where 55% of attempts at |ð| are produced as target-like (57/103 attempts), the majority of the attempts made in each session from 1;09 to 2;11 result in the stopping substitution pattern. At 2;08, there is an increase in target-like productions, however these represent a minority of attempts.

6 With the exception of four cases at 2;02 where |ð| is produced as [t].

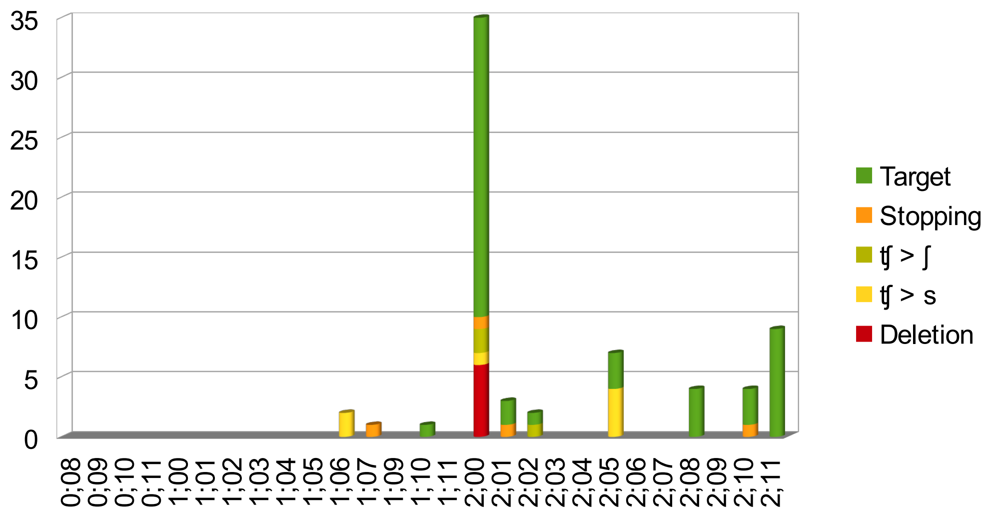
Figure 42: |ð| in Singleton Onsets



2.4 Affricates

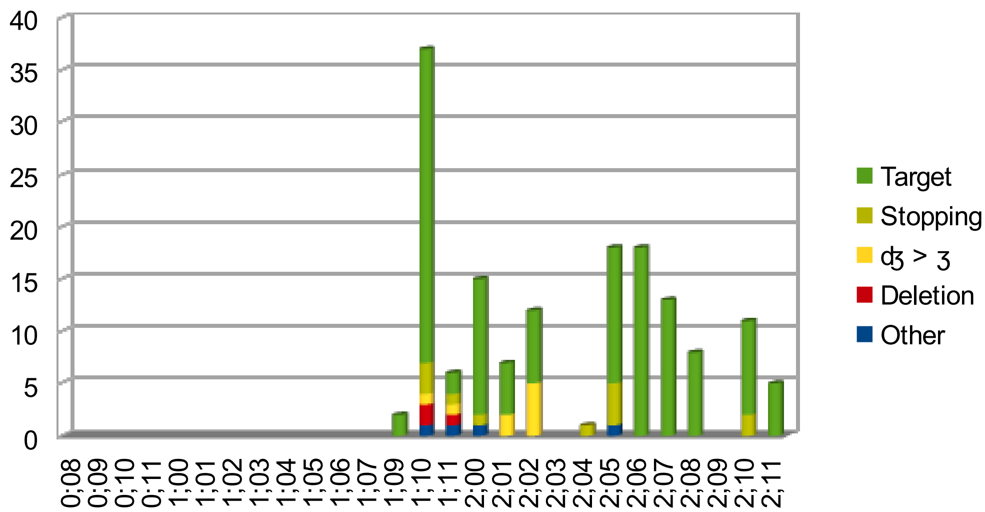
I turn now to affricates, which Georgia, unlike Cameron, acquires with relative ease. Although the data for |ʧ| are sparse, as can be seen in Figure 43, this consonant is arguably acquired at 1;10. Given the limited number of attempts, however, there are some sessions with low accuracy rates due to very few inaccurate productions. Taking this shortcoming of the data into account, it would seem that, qualitatively, Georgia acquires |ʧ| at 1;10.

Figure 43: |ʧ| in Singleton Onsets



The data for |ʤ| in Georgia's corpus are more abundant than the data for |ʧ| (153 attempts at |ʤ| versus 68 attempts at |ʧ|). However, contrary to what the astute reader might consider, the increased number of attempts at |ʤ| is not solely the result of Georgia saying her name, |ʤɒɹʤə|, which accounts for just under 20% of attempts. As can be seen in Figure 44 Georgia begins to produce |ʤ| as target-like from her first attempts at 1;09, with accuracy rates above 80% noted at 1;09, 1;10 and 2;00. However, she does not achieve the consistent accuracy required for acquisition until 2;06, with four of the five sessions containing attempts at |ʤ| between 2;06 and 2;11 displaying a 100% accuracy rate.

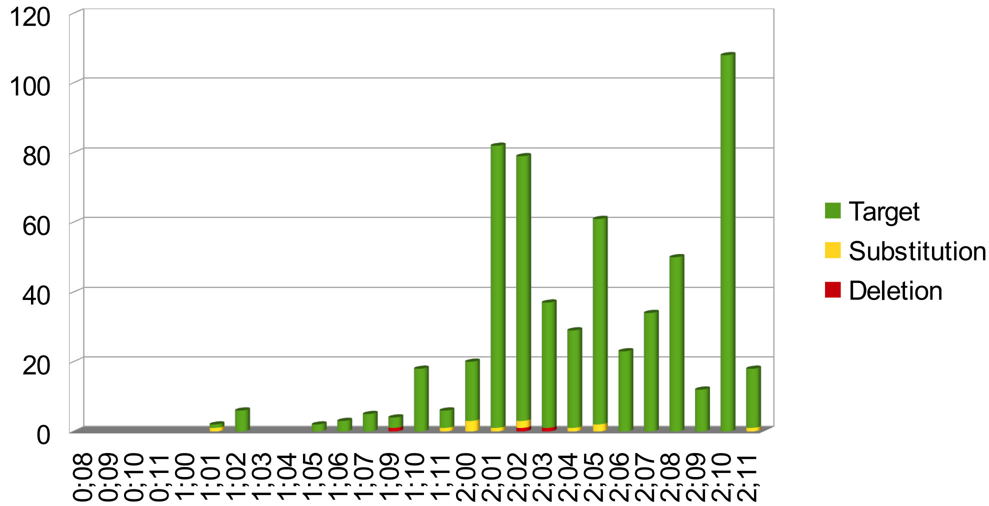
Figure 44: |ʤ| in Singleton Onsets



2.5 Nasal Stops

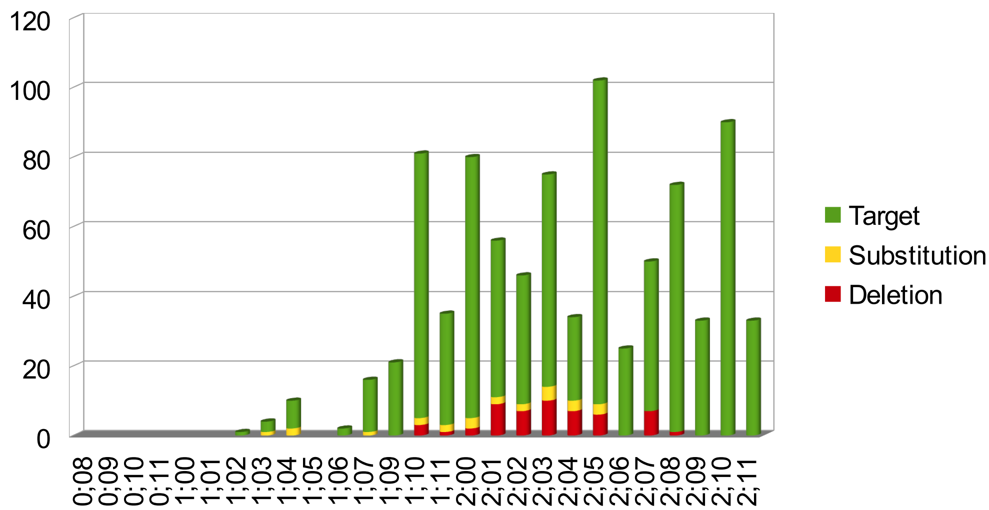
Looking now at nasal stops, Georgia acquires |m,n| without much difficulty, similar to what we saw with oral stops. As can be seen in Figure 45, Georgia acquires |m| with ease at 1;02. She exhibits very few substitutions, with an accuracy rate of at least 75% in all sessions between 1;02 and 2;11, and an accuracy rate of 100% in 15 sessions within this time period.

Figure 45: |m| in Singleton Onsets



Similarly, Georgia has little difficulty with |n|, which she produces accurately upon her first attempts at 1;02. As can be seen in Figure 46, Georgia displays at least a 75% accuracy rate in each session between 1;02 and 2;11 (with the slight exception of 2;04 which has an accuracy rate of 71%). She displays more variation with |n| than with |m|, continuing the trend of coronal stops being slightly more variable than other stops. However, unlike the variation observed in the oral coronal stops, which was generally the result of cases of substitution, the variation observed with the nasal coronal stop is caused mainly by cases of deletion.

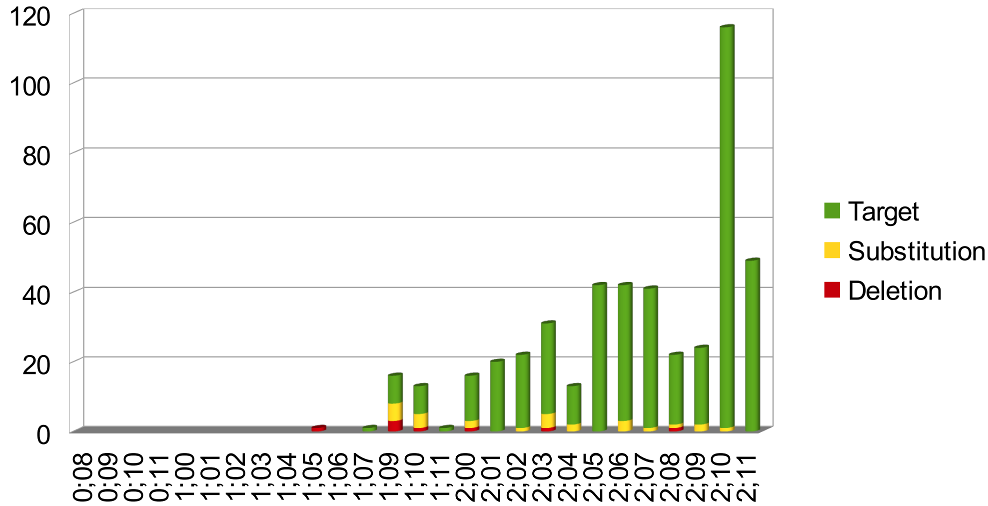
Figure 46: |n| in Singleton Onsets



2.6 Approximants

Shifting our focus to approximants, Georgia makes her first attempts at the glides |j,w| at 1;05, as can be seen in Figure 47 and Figure 48, respectively. Georgia acquires |j| at 1;11, maintaining an accuracy rate of at least 81% through to the end of the corpus.

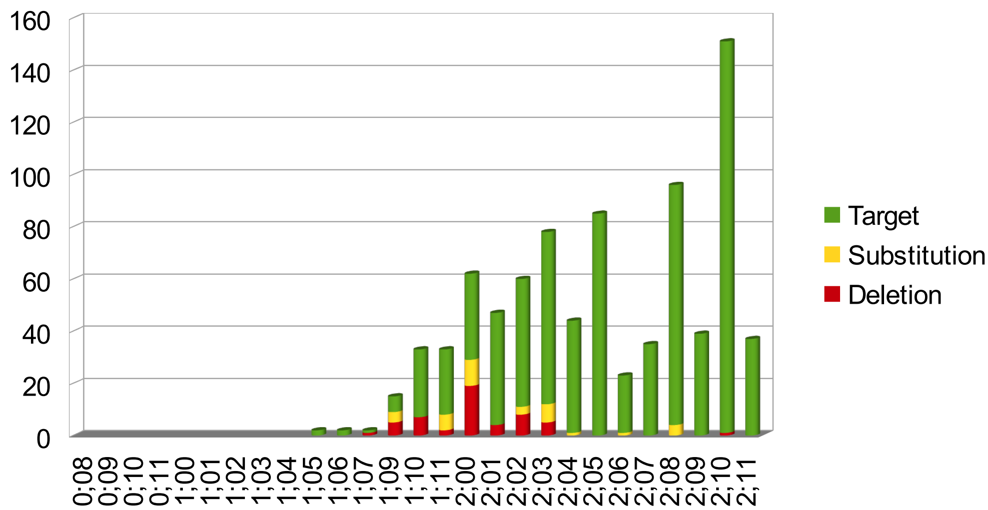
Figure 47: |j| in Singleton Onsets



In contrast to |j|, Georgia acquires |w| upon her first attempt at 1;05 and achieves an accuracy rate of at least 75% in 15 of the 18 sessions which contain attempts at |w|.[7] At 2;00, we see an idiosyncratic increase in deletion. However, 78% of the deletions (15/19 instances) occur in the word 'what('s)', typically in the phrase 'what's that' |wəts ðæt|.

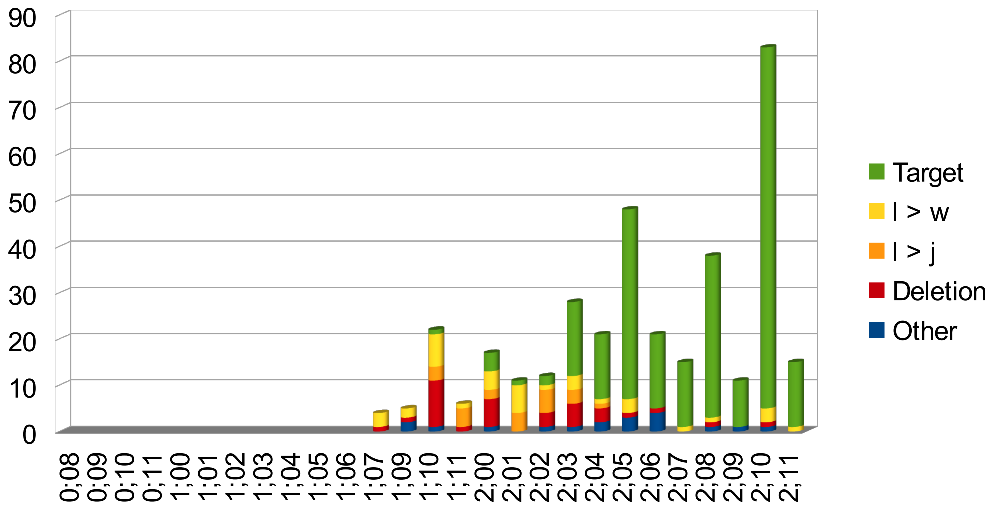
7 At 1;07 we see a 50% accuracy rate, however there are only two attempts; at 1;09 we see a 40% accuracy rate; and at 2;00 we see a 53% accuracy rate due to the deletions mentioned in text.

Figure 48: |w| in Singleton Onsets



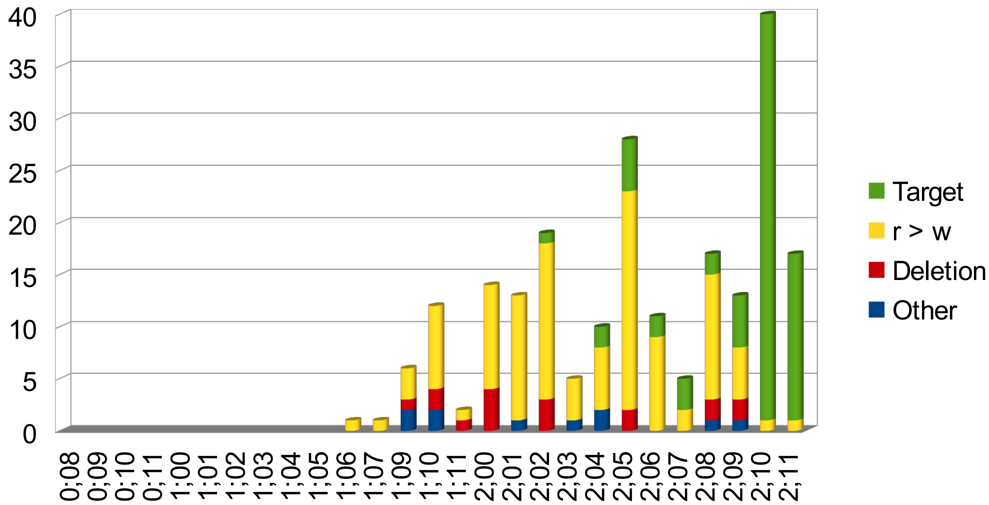
While the two English glides did not pose much difficulty for Georgia, the lateral and rhotic approximants |l,ɹ| proved to be more challenging. As can be seen in Figure 49, Georgia does not acquire |l| until 2;05, after several months of unsuccessful attempts. Between 1;07 and 2;04, two substitution patterns are present. The more common substitution consists of the production of [w] for |l|, but we also see |l| produced as [j] during this time period. Georgia begins to produce more target-like forms at 2;03. At 2;05, she achieves the required mastery level for acquisition with each session displaying an accuracy rate of at least 75%, and accuracy rates of at least 91% between 2;07 and 2;11.

Figure 49: |l| in Singleton Onsets



Turning to |ɹ|, we can see in Figure 50 that Georgia makes her first attempt at |ɹ| at 1;06, which results in substitution by [w]. This is the dominant pattern until 2;08. Between 2;09 and 2;10, there is a sharp decrease in the |ɹ|→[w] pattern, as Georgia begins to produce more target-like attempts at this segment. At 2;10, Georgia acquires |ɹ|, achieving an accuracy rate of over 90% during the last two months of the corpus.

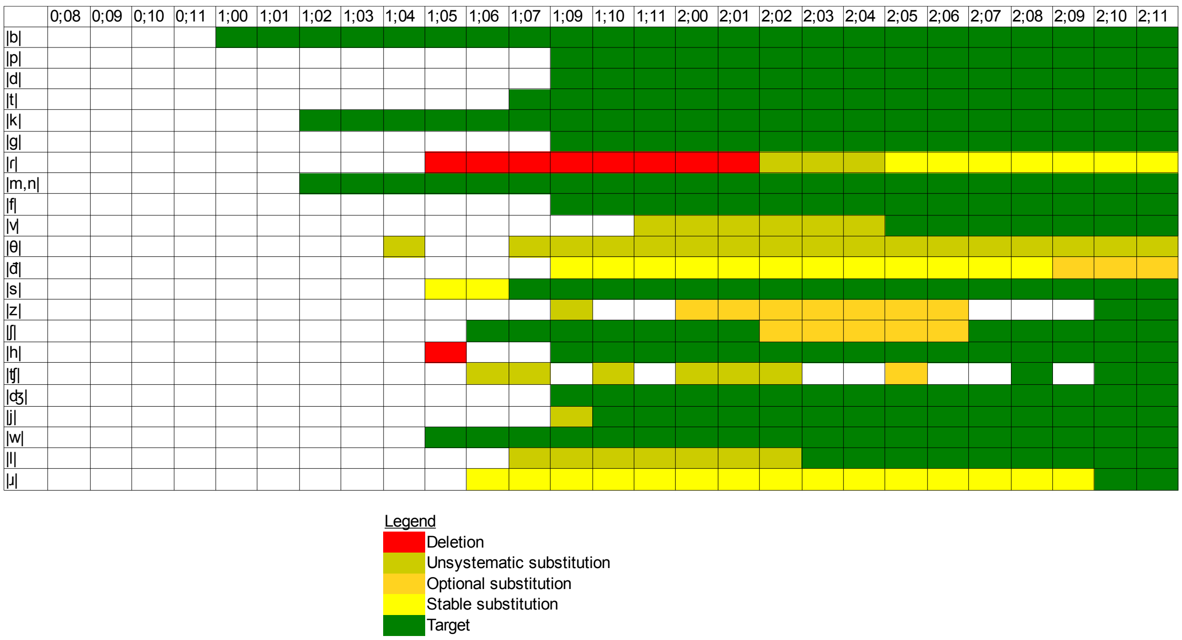
Figure 50: |ɹ| in Singleton Onsets



2.7 Summary of Observations for Singleton Onsets

While Georgia's data display similarities with Cameron's data, there are also some striking differences between these two toddlers. Similar to Cameron, Georgia easily acquires her nasal and oral stops, as well as her glides and the voiceless labio-dental fricative |f|, as can be seen in Table 8. Georgia also displays some difficulty with the lateral and rhotic approximants |l,ɹ|, as well as with |θ|. However, unlike Cameron, Georgia acquires the two English affricates with ease. Across the data, Georgia seems to display a tendency to either delete or simply not attempt segments which are not yet acquired. This is discussed further in Chapter 7. Georgia's development does not appear to display any natural class effects, for example the class of stops is acquired over the course of several months between 1;00 (|b|) and 1;09 (|p,d,g|). Further considering age of acquisition, there are some interesting trends in Georgia's data. While she was somewhat slow in her acquisition of certain stops, which appeared to give her no articulatory difficulty (given her high degree of accuracy when she finally does attempt these stops), other segments, such as |l|, were acquired relatively quickly. Comparing the two children, Georgia acquires |l| at 2;05 whereas Cameron does not acquire this segment until 2;10.

Table 8: Timeline of Georgia's Singleton Onset Development



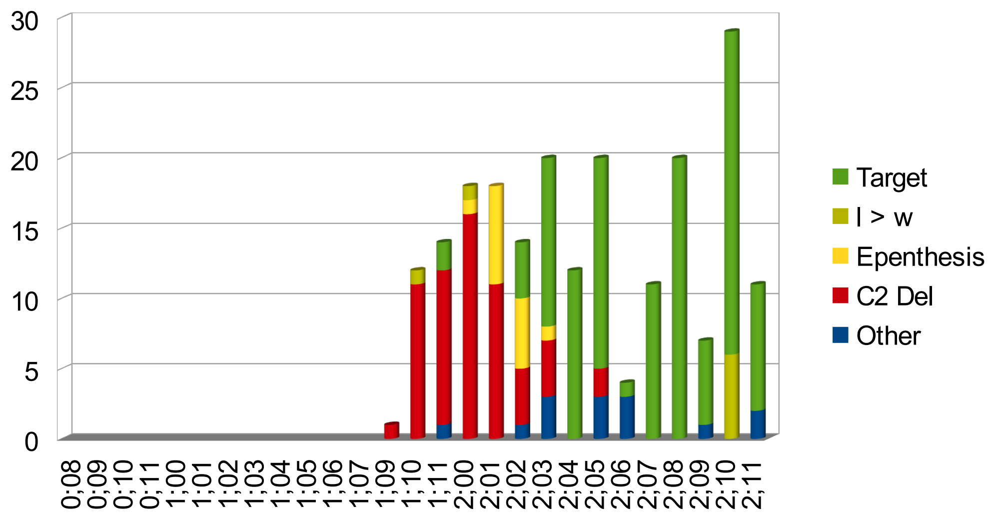
3. Branching Onsets

In this section I focus on Georgia's phonological development of branching onsets. As was the case with Cameron, the data available for branching onsets in Georgia's corpus is more sparse than the data for singleton onsets. However, it is still possible to draw meaningful conclusions based on the available data. I begin with the |Cl| clusters, followed by |Cɹ| clusters and, finally, |Cw| clusters.

3.1 |Cl|

Figure 51 summarizes all the |Cl| branching onsets attempted by Georgia throughout the corpus. While there is some variation observed (i.e. |l|→[w], and epenthesis), Georgia essentially goes through two phases in the acquisition of these clusters. Between 1;09 and 2;01 Georgia produces at least 78% of attempted |Cl| clusters in each session with C2 deletion. At 2;02, we see some variation and, at 2;03, we see that Georgia begins to consistently produce a majority of target-like productions. With the exception of 2;06, Georgia produces at least 75% of the attempts in each session as target-like between 2;04 and 2;11.

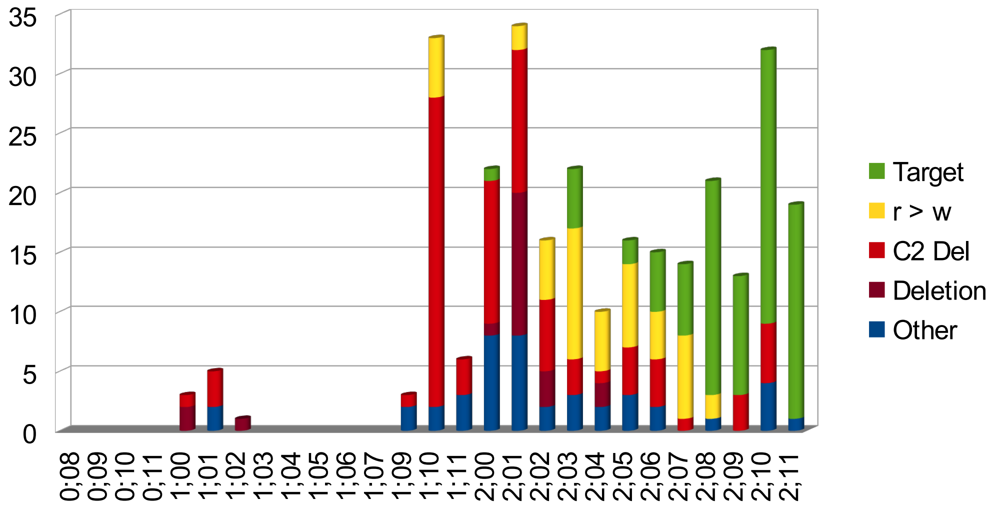
Figure 51: All |Cl| Branching Onsets Attempted by Georgia



3.2 |Cɹ|

The data for Georgia's |Cɹ| branching onsets contain a little more variation than was present in the |Cl| cluster data, as can be seen in Figure 52.

Figure 52: All |Cɹ| Branching Onsets Attempted by Georgia



The early nine attempts at |Cɹ| branching onsets between 1;00 and 1;02 all come from |vɹ| in 'vroom' |vɹu:m|, an onomatopoeic form. At 1;09, we find more attempts at |Cɹ| clusters, the majority of which result in C2 deletion, which is the most common pattern between 1;09 and 2;00. At 2;01, all cases of the idiosyncratic pattern of full cluster deletion involve the word 'hungry' |hʌŋgɹi:| being produced as [hʌŋi:]. Between 2;02 and 2;07, we see a new pattern emerge where Georgia substitutes the |Cɹ| with [Cw] (e.g. 'pretzel' |pɹɛtzəl|→[pwɛsəl] at 2;05.21). At 2;08, target-like productions begin to dominate Georgia's attempts at |Cɹ| branching onsets, with three of the last four sessions having accuracy rates of at least 77%.[8]

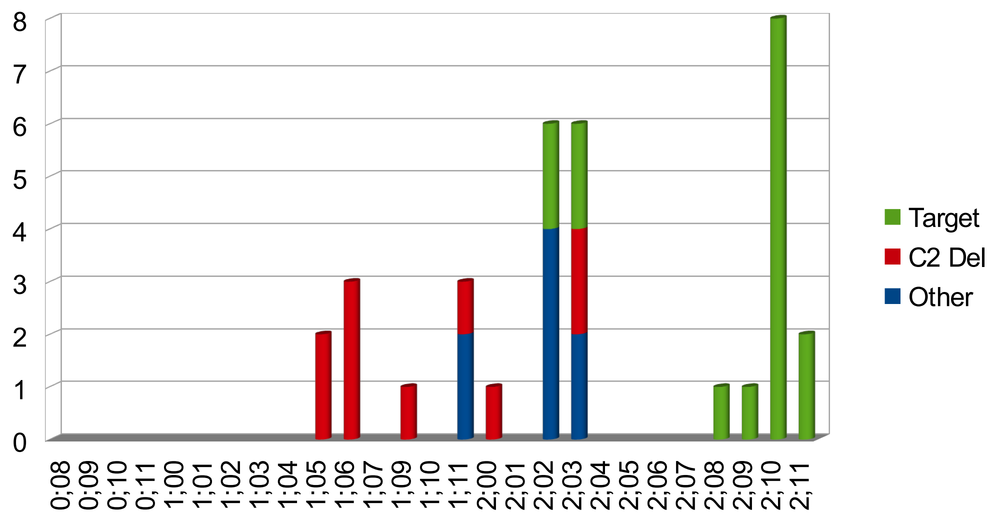
3.3 |Cw|

The number of attempts made at |Cw| branching onsets in Georgia's corpus are very limited, as can be seen in Figure 53. Georgia essentially goes through two phases during the corpus.

8 2;06 has an accuracy rate of 72%.

Between 1;05 and 2;00, the majority of attempts result in the deletion of |w|, with a transition towards mastery between 2;02 and 2;03. By 2;08, |Cw| clusters are acquired with all attempts resulting in target-like productions.

Figure 53: All |Cw| Branching Onsets Attempted by Georgia



3.4 Summary of Observations for Branching Onsets

Georgia's data regarding branching onsets presents a different pattern than we saw in Cameron's data. Table 9 illustrates one important similarity between Georgia's treatment of |Cl| and |Cɹ| branching onsets: the C2 deletion stage begins at 1;09 and ends at 2;01 in both cases. We did not see this type of symmetry in Cameron's treatment of branching onsets. There are also important relationships between Georgia's acquisition of |Cl| branching onsets and her acquisition of |l| in singleton onsets. The |Cl| onsets begin to be produced as target-like at 2;03, at the same time as |l| singleton onsets. |Cw| branching onsets also display relationships with |Cɹ| branching onsets. Target-like productions of |Cw| clusters beginning one month before the

|Cɹ|→[Cw] pattern emerges. Also, the acquisition of both |Cɹ| and |Cw| branching onsets occurring at 2;08.

Table 9: Timeline of Georgia's Branching Onset Development

	0;08	0;09	0;10	0;11	1;00	1;01	1;02	1;03	1;04	1;05	1;06	1;07	1;09	1;10	1;11	2;00	2;01	2;02	2;03	2;04	2;05	2;06	2;07	2;08	2;09	2;10	2;11
|Cl|																											
|Cɹ|																											
|Cw|																											

Legend
C2 deletion
Transition between patterns
Unsystematic subs
Stable substitution
Target

I will return to the children's segmental development in the early word productions in Chapter 7. However, in the next chapter, I focus on the segmental inventory found in the babbled utterances of both children.

Chapter 6: Consonantal Inventory in Babbled Utterances

1. Introduction

In this chapter, I describe the segmental inventory present in the onsets of the babbled utterances of both children. As mentioned in Chapter 3, babbled utterances were syllabified in Phon following rules of English syllabification. I first summarize Cameron's segmental inventory, which is followed by a summary of Georgia's segmental inventory. As we will see, these children share many similarities with respect to the phonetic content of their babbled utterances.

2. Cameron

Table 10 illustrates the consonantal inventory present in the onsets of Cameron's babbled utterances. We can see that the majority of onset consonants in Cameron's babbles consist of voiced stops (both oral and nasal), glides, [h], and [l]. However, she produces very few fricatives (other than [h]), voiceless stops, affricates, or [ɹ]. There is also a significant drop in the number of babbled utterances at 1;05, when Cameron begins to produce more attempts at meaningful words.

The most striking observation is that all English consonants, except for |θ|, appear in Cameron's babbled utterances before they are attempted in meaningful words. Interestingly, Cameron never produces [θ] in a babbled utterance, and it also proves to be quite difficult for her in word productions. We can also see similarities between the stages of emergence of sounds in babbles and the time of their acquisition in meaningful words. For example, many of the sounds present in babbles at the beginning of the corpus are the same sounds that Cameron acquires easily once word production begins at 0;09, namely voiced stops, nasals, glides, and the fricative |h|. However, the appearance of a sound in early babbled utterances does not necessarily mean it will be acquired early in words. Both [l] and [z] appear in the recorded babbles at 0;08, with [l] being quite common between 0;08 and 1;01 and [z] appearing more than [s] during this period. Despite this, neither [l] nor [z] are acquired until after Cameron is two years of age, as was shown in Chapter 4, Section 2. The asymmetrical treatment of [l] in babbles and early word productions will be further discussed in Chapter 7.

Table 10: Cameron's Consonant Inventory in Babbled Onsets

	0;07	0;08	0;09	0;10	0;11	1;00	1;01	1;02	1;03	1;05	1;06	1;08	1;09	1;10	1;11	2;00	2;01	2;03	2;04	2;05	2;06	2;07	2;09	2;10	2;11
b	2	182	290	144	487	264	331	201	173	19	6	4	0	6	1	3	2	3	1	3	1	1	4	1	26
d	60	110	385	304	208	170	106	100	98	19	9	9	4	10	5	4	7	1	1	8	0	9	2	7	31
g	20	54	113	56	134	102	120	66	56	15	4	4	0	2	1	11	0	0	0	2	0	0	1	1	1
p	0	0	0	6	8	9	5	0	14	14	4	2	2	3	1	0	0	0	1	6	0	2	10	0	0
t	0	0	6	2	1	6	5	2	7	5	3	4	4	3	2	3	3	0	0	0	6	0	9	0	1
k	2	7	20	6	6	11	2	6	6	9	4	6	4	2	0	1	0	1	0	4	0	3	0	3	0
ʔ	1	0	3	2	2	14	24	14	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
m	1	37	40	27	133	40	49	68	50	3	3	3	1	3	0	6	1	0	0	4	0	0	1	1	4
n	75	76	36	77	109	72	58	40	81	12	2	9	4	2	2	9	0	0	2	11	0	3	5	7	3
ŋ	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
β	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
v	0	7	4	1	9	1	2	1	2	0	0	0	0	1	0	0	0	0	0	1	0	0	0	3	0
f	0	0	0	0	0	0	1	1	5	0	0	0	2	1	0	0	0	0	0	1	0	2	0	1	2
ð	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
θ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
z	0	1	3	0	0	1	1	5	1	4	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2
s	0	0	0	0	0	1	0	1	4	6	0	8	1	4	1	1	0	0	2	1	0	3	1	0	0
ʒ	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ʃ	0	0	0	0	0	1	0	1	0	4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
h	8	10	28	18	12	7	6	58	39	8	14	5	0	5	1	0	0	0	1	0	0	1	1	3	6
ʣ	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ʤ	0	0	1	0	1	11	0	5	1	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0
ʧ	0	0	0	0	0	2	0	5	0	2	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0
j	4	15	154	70	165	57	35	36	79	9	1	3	2	3	0	0	0	1	0	0	0	0	0	1	10
w	2	57	92	82	116	96	158	143	199	16	6	8	5	8	3	0	2	2	1	6	2	10	4	2	6
l	0	31	30	51	5	27	16	0	2	1	0	1	0	0	0	0	0	0	0	1	0	0	1	3	0
ɹ	0	0	1	0	0	1	0	2	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
r	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

We can also see from Table 10 that Cameron produced three sounds not found in the English phonological system: [β, r, ʣ]. These are the only non-English sounds recorded in Cameron's babbles, but they share commonalities with English sounds. For example, [β] and [v] are both recorded in babbles starting at 0;08. Both sounds are voiced fricatives and both involve a labial articulation; the only difference is that [β] is bilabial, while [v] is labio-dental. The alveolar trill [r], observed in the babbled utterance of both Cameron and Georgia, is the only sound produced using a novel manner of articulation. However, it is produced at a place of articulation common in English. Even though trills do not occur in English, they can be common in extra-linguistic productions. For example, caregivers may produce labial trills during language play with their infants and toddlers. It is therefore plausible that Cameron would have been exposed to trill-like sounds.

In sum, while Cameron at times produced non-native sounds, she did not produce these sounds at random. Instead, she produced segments which share articulatory similarities (either place features, manner features or both) with her native phonology. Similar patterns regarding non-native segments are observed in Georgia's data, to which we turn now.

3. Georgia

Georgia's babbled utterances share some similarities with Cameron's, such as the presence of voiced stops, nasals, glides and [h] in babbles when the recordings begin at 0;08. As we can see in Table 11, fricatives (excluding [h]) and approximants are considerably less frequent than stops, nasals and glides in Georgia's recorded babbles, although affricates are relatively common (especially between 1;04 and 1;05). Similar to what we saw with Cameron, the vast majority of consonants appear in Georgia's babbled utterances before they are attempted in words, with the exception of [v,ð,ɹ], with [ð] never recorded in babbles. We see [v] appear in recorded babbles at 1;01, one month after it is attempted in branching onsets. It is possible that its absence prior to this point may be the result of a gap in the recorded data. In contrast, [ɹ] does not appear in babbles until 2;09. While this is over one year after |ɹ| is first attempted in words, it is only one month before Georgia achieves mastery of |ɹ| in singleton onsets. While

|ð,ɹ| do not appear in babbles before being attempted in words, they behave fairly systematically in Georgia's word productions. Recall that both of these consonants display stable substitution patterns beginning with very early attempts (from 1;09 for |ð| and from 1;06 for |ɹ|). Georgia's treatment of |v| is less systematic with the majority of attempts resulting in variable substitutions between 1;11 and 2;04.

Table 11: Georgia's Consonant Inventory in Babbled Onsets

	0;08	0;09	0;10	0;11	1;00	1;01	1;02	1;03	1;04	1;05	1;06	1;07	1;09	1;10	1;11	2;00	2;01	2;02	2;03	2;04	2;05	2;06	2;07	2;08	2;09	2;10	2;11
b	23	6	44	52	89	39	47	16	55	60	78	32	7	26	3	2	7	1	7	0	1	1	0	6	0	1	0
d	9	1	15	25	56	53	200	83	95	223	136	28	39	35	7	19	22	9	37	5	12	142	1	2	2	0	0
g	22	9	11	5	36	35	36	24	96	103	57	17	11	37	8	4	2	1	6	1	4	3	0	0	0	0	0
p	1	0	2	7	6	0	4	0	1	14	13	5	7	4	4	27	2	0	2	1	0	0	0	1	0	0	0
t	1	0	2	2	3	1	5	2	24	45	26	21	4	10	1	3	3	3	7	0	5	0	0	0	0	2	0
k	11	3	11	0	12	7	7	2	23	22	37	18	11	27	3	9	1	2	4	0	0	0	0	0	0	0	0
ʔ	6	2	2	9	9	12	1	0	39	46	18	2	0	3	1	0	0	1	0	2	0	0	0	0	0	0	0
m	10	4	8	9	18	10	16	9	20	38	20	3	5	14	4	3	2	3	8	1	0	0	1	0	0	0	0
n	5	2	2	3	1	3	36	17	21	44	22	10	7	17	10	9	4	22	10	2	2	3	0	0	0	1	0
ŋ	0	0	0	0	0	0	0	0	0	5	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
ɸ	1	2	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
v	0	0	0	0	0	3	0	0	7	7	10	1	0	3	0	10	0	0	1	0	1	0	0	0	0	0	0
f	0	0	1	0	0	0	1	0	3	12	6	6	7	6	2	7	1	1	5	0	1	1	0	0	1	0	0
ð	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
θ	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
z	0	0	0	0	4	0	0	2	5	14	16	16	0	4	3	2	0	5	0	2	1	0	0	0	0	0	0
s	2	0	0	0	1	0	2	0	20	56	56	18	4	26	1	3	0	3	5	0	0	0	0	0	0	4	0
ʒ	0	0	0	0	0	0	0	0	7	19	3	8	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
ʃ	1	0	0	0	1	0	0	0	54	83	49	5	3	11	4	3	0	0	1	0	0	0	0	0	0	0	0
h	43	25	8	50	66	9	17	0	69	68	76	35	3	49	11	6	15	11	9	5	1	1	0	4	0	3	0
x	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ʤ	2	0	2	0	0	0	1	1	7	10	4	2	0	4	1	0	0	0	0	0	0	0	0	0	0	0	0
ʧ	2	0	0	0	0	0	0	0	25	16	5	0	4	3	4	3	1	0	1	0	0	0	1	0	0	0	0
j	9	1	2	8	14	1	8	4	21	25	34	14	3	21	3	3	2	3	4	0	0	0	4	1	0	0	0
w	9	13	18	16	19	9	12	10	24	37	47	25	16	16	13	11	6	5	13	1	5	2	1	0	1	2	0
l	0	0	0	0	0	0	1	0	0	5	12	1	1	0	0	1	2	1	1	1	1	0	2	1	0	0	0
ɹ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
ɾ	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
r	1	0	0	0	1	0	0	0	1	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Note, as well, that Georgia's babbles are fairly limited before 1;04. At this point, fricatives begin to appear and the frequency of most other segments increases. For example, there is a noticeable increase in the number of fricatives produced in babbled utterances after 1;04, particularly the voiceless coronal fricatives [s,ʃ]. There is also an increase in the number of voiceless stops, glides, and affricates produced after 1;04. We can also see a significant drop in the number of babbled utterances recorded at 1;09, the same month that the number of word attempts per session skyrockets in Georgia's data. If we look at the voiceless stops leading up to

1;04, we can see that most months contain more productions of [k] than either [p] or [t]. As discussed in Chapter 5, |k| is the only voiceless stop that does not display a gap when examining attempts in singleton onsets. The consistent presence of [k] in babbles thus seems to influence Georgia’s willingness to attempt |k| in meaningful words.

Georgia also displays three non-English sounds in her babbled utterances: [ɸ,r], similar to what we saw in Cameron, and also the voiceless velar fricative [x]. Both [ɸ,r] are present in babbles at the beginning of the corpus, with a single production of [x] appearing at 1;00. Both [ɸ,x] share common attributes with English phonemes, such as fricative manner of articulation. Regarding the presence of the alveolar trill [r], as was discussed in Section 2 above, Georgia may have been exposed to this manner of articulation in extra-linguistic productions. In this case, the production of [r] would then involve the combination of a phonologically novel manner of articulation with a common English place of articulation.

In the next chapter, I build on the segmental inventory of Cameron's babbles, and her segmental development in words, through a comparison of the treatment of [l] across her babbles and early productions. The asymmetry mentioned in Section 2 above poses an interesting challenge for many of the theoretical approaches considered here, and will therefore be considered in more detail. The chapter then moves on to a formal analysis of both children's segmental development.

Chapter 7: Analysis

1. Introduction

In this chapter, I propose a series of analyses on the development of Cameron and Georgia's phonological systems. I begin with an excursus into the differing segmental treatment observed in Cameron's babbled utterances and early words. In order to account for this aspect of Cameron's phonological development, I systematically compare her consonantal productions against their corresponding targets, and also consider babbled utterances. An examination of all three allows us to see Cameron's full repertoire of phonological abilities, and note key differences among them. As is often the case, these differences turn out to be more informative than the similarities observed. I then move to the study of phonological productions proper, performing a formal analysis of the segmental development of both Cameron and Georgia, as well as examining the substitution patterns found in the productions of both children.

The chapter is organized as follows. I begin with an examination of the treatment of [l] in Cameron's babbled utterances and early word productions. As mentioned in Chapter 6, Section 2, this segment receives quite different treatments across Cameron's productions. Following this, I highlight some similarities and differences in the patterns of phonological development found in the productions of both Cameron and Georgia. I then present an analysis of these data using Feature Co-occurrence Constraints (FCCs; Levelt & van Oostendorp 2007). This is followed by a discussion of the benefits and drawbacks of using this approach to explain the phonological development of these two children. Nevertheless, in spite of the differences observed between the children's patterns of development, both their systems can be described using this approach to featural acquisition. However, this analysis leaves no way to consider the status of segments which are not yet acquired by the learner. I address this issue through a consideration of the likely influences involved in the main substitution patterns displayed in the children's productions.

2. Segmental Differences in Cameron's Early Productions

One interesting aspect of Cameron's babbled utterances concerns the relationship between their phonetic content, discussed in Chapter 6, Section 2, and the phonetic content of early word attempts. While the development of certain segments is similar across both babbled utterances and early word productions (for example, voiced stops appear early in both, and are produced with great accuracy in early words), other segments display asymmetries across Cameron's babbled utterances and early word productions. Table 12 is a repeat of the data on the consonantal inventory derived from Cameron's babbled utterances. Recall Cameron's treatment of [l]: she produces this sound early and consistently in her babbles (starting at 0;08). Yet she is unable to consistently produce it as target-like in her word productions until 2;10, as illustrated in Figure 54 and (8) below.

Table 12: Cameron's consonantal inventory in babbled utterances (Table 3, repeated)

	0;07	0;08	0;09	0;10	0;11	1;00	1;01	1;02	1;03	1;05	1;06	1;08	1;09	1;10	1;11	2;00	2;01	2;03	2;04	2;05	2;06	2;07	2;09	2;10	2;11
b	2	182	290	144	487	264	331	201	173	19	6	4	0	6	1	3	2	3	1	3	1	1	4	1	26
d	60	110	385	304	208	170	106	100	98	19	9	9	4	10	5	4	7	1	1	8	0	9	2	7	31
g	20	54	113	56	134	102	120	66	56	15	4	4	0	2	1	11	0	0	0	2	0	0	1	1	1
p	0	0	0	6	8	9	5	0	14	14	4	2	2	3	1	0	0	0	1	6	0	2	10	0	0
t	0	0	6	2	1	6	5	2	7	5	3	4	4	3	2	3	3	0	0	0	6	0	9	0	1
k	2	7	20	6	6	11	2	6	6	9	4	6	4	2	0	1	0	1	0	4	0	3	0	3	0
ʔ	1	0	3	2	2	14	24	14	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
m	1	37	40	27	133	40	49	68	50	3	3	3	1	3	0	6	1	0	0	4	0	0	1	1	4
n	75	76	36	77	109	72	58	40	81	12	2	9	4	2	2	9	0	0	2	11	0	3	5	7	3
ŋ	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
β	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
v	0	7	4	1	9	1	2	1	2	0	0	0	0	1	0	0	0	0	0	1	0	0	0	3	0
f	0	0	0	0	0	0	1	1	5	0	0	0	2	1	0	0	0	0	0	1	0	2	0	1	2
ð	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
θ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
z	0	1	3	0	0	1	1	5	1	4	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2
s	0	0	0	0	0	1	0	1	4	6	0	8	1	4	1	1	0	0	2	1	0	3	1	0	0
ʒ	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ʃ	0	0	0	0	0	1	0	1	0	4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
h	8	10	28	18	12	7	6	58	39	8	14	5	0	5	1	0	0	0	1	0	0	1	1	3	6
ʣ	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ʤ	0	0	1	0	1	11	0	5	1	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0
ʧ	0	0	0	0	0	2	0	5	0	2	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0
j	4	15	154	70	165	57	35	36	79	9	1	3	2	3	0	0	0	1	0	0	0	0	0	1	10
w	2	57	92	82	116	96	158	143	199	16	6	8	5	8	3	0	2	2	1	6	2	10	4	2	6
l	0	31	30	51	5	27	16	0	2	1	0	1	0	0	0	0	0	0	0	1	0	0	1	3	0
ɹ	0	0	1	0	0	1	0	2	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
r	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

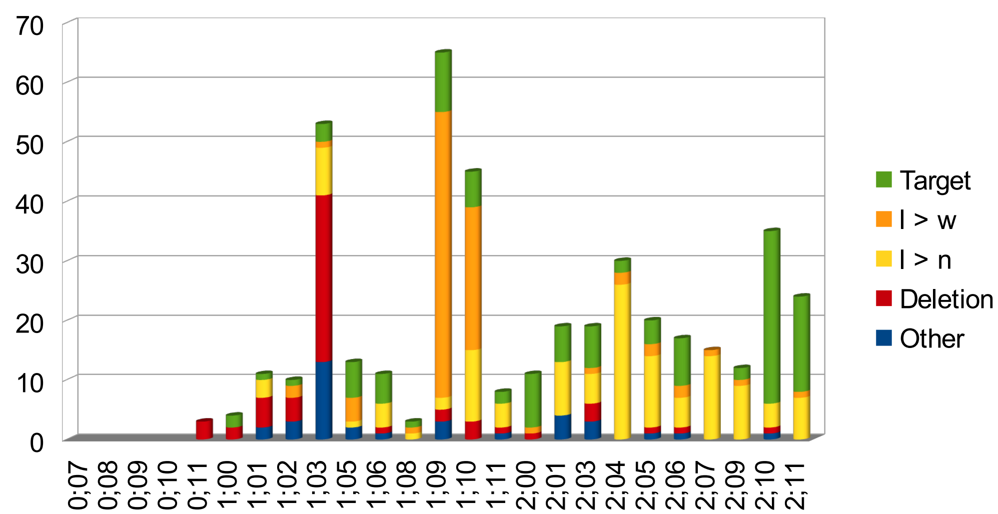
Between the ages of 0;08 and 1;01 (highlighted in the table above) Cameron frequently produced babbled utterances containing [l]. As the examples in (7) illustrate, some of these babbled utterances are quite complex, and [l] appears in various positions across different productions (e.g. in singleton onsets and in clusters, both babble-initially and medially).

(7) Cameron's [l] in Babbled Utterances

a) [agəl̲ə] 00;08.08
b) [l̲ʌhaidʌ] 00;08.15
c) [hæl̲ɛgɛ] 00;09.12
d) [dædædædl̲ʌ] 00;10.03
e) [l̲ababl̲a] 00;10.03
f) [l̲ʌl̲ː] 00;10.03
g) [bʌdəwibl̲ɛdə] 01;00.18
h) [dol̲o] 01;00.25

However, as Figure 54 illustrates, Cameron was not producing |l| as target-like in her word productions during this same period; she was instead mostly deleting it altogether from her productions.

Figure 54: Cameron's |l| Singleton Onsets (Figure 23, repeated)



The most surprising aspect of the different behaviours of [l] in babbled utterances versus word productions is that even when a target word is similar in structure to a produced babble, the two segments are treated differently. For example, consider (7h) [dolo] and (8c) 'pillow' |ˈpɪloʊ|→[bio], produced at 1;00.25 and 1;01.15, respectively. The target |l| in 'pillow' appears in the same position as the produced [l] in [dolo]; both are in a singleton onset in the second syllable of a disyllabic utterance. Despite the structural similarity between these two forms, [l] is produced in the babble while it is deleted in the word production. Also, while the initial [d] may influence the appearance of [l] within this particular babbled utterance, if we compare (7f) [lʌlː] with (8d) 'leg' |ˈlɛg|→[nɛ], we reach the same conclusion. Both these forms are monosyllabic utterances with an initial singleton onset, yet [l] is produced in the babble while the target |l| is substituted by [n] in the word production. This behaviour is even more surprising given that the babbled form is produced three months before the attempted word form.

(8) Cameron's early attempts at |l| onsets

a)	'balloon'	|bəˈluːn|	→	[bau]	0;11.06
b)	'balloon'	|bəˈluːn|	→	[bo]	1;00.25
c)	'pillow'	|ˈpɪloʊ|	→	[bio]	1;01.15
d)	'leg'	|ˈlɛg|	→	[nɛ]	1;01.15

This asymmetry is particularly difficult to explain using the bio-mechanical and perceptual approaches outlined in Chapter 2, Sections 1.1 and 1.2, respectively. If either articulatory or perceptual influences strongly guide language learning, then perceiving and producing a sound in babbles should predict an ability to produce that sound in word forms. Clearly Cameron is physically able to produce [l], which begs the question as to why she does not produce it in the words she attempts. Concerning the templatic approach, the same fundamental issue arises, since template learning emphasizes a combination of perceptual and articulatory factors, along with properties of the ambient language. This suggests that a child's productive abilities in word attempts should mirror his/her productive abilities in babbles, which is clearly not the case here.

As for representational approaches, the production of, and attempt at, a sound could indicate that the child has developed a representation for that sound, even if it is only partially represented in the phonological system. However, given that babbled utterances are not necessarily governed by the child's phonological system, the appearance of a sound in babbles does not predict that the child is able to represent this sound in his/her phonological system. If phonological representations are instead related to a connection established between an identifiable acoustic dimension and a related articulatory plan (e.g. Stevens 1972; Halle & Stevens 1979; Stevens 1989; Mielke 2005; Lin & Mielke 2008; Mielke 2008; Rose 2009; Stevens & Keyser 2010; Mielke 2011; Rose to appear), then the ability to simply produce a segment is not sufficient to inform a representation for that segment.

Based on the fact that Cameron so frequently and fluently produces [l] in her babbles and struggles so much with |l| in her attempted words, I hypothesize that these two 'segments' are, in fact, not formally the same in her system. The strong recurring presence of [l], along with the limited variability in the non-English sounds displayed in Cameron's babbles[9] (as discussed in Chapter 6, Section 2), suggests that the child has relatively systematic control over her vocal apparatus. If this were not the case, we would expect to see more variety and frequency in the non-English segments present throughout Cameron's babbles, since she would just be producing segments through random, unguided vocal gestures. This level of control may also be indicative of the child attempting to create an articulatory (motor) plan for a particular segment (in this case |l|). This seems to suggest that a segmental representation entails both a category in perception and a corresponding articulatory plan, as argued in the literature cited in the previous paragraph.

3. A Comparison of Cameron and Georgia

In this section, I engage in a systematic comparison of the phonological development of Cameron and Georgia. As we will see, these two children at times display stark differences in the development of their respective phonological systems, for example concerning timing of

9 This limited variability seems to suggest an understanding of the physical relationships between the natural groupings of sounds involved in English phonology, something that would be interesting to explore in future research.

acquisition, and patterns of variability present in their productions. We also observe many similarities, especially regarding the development and treatment of branching onsets. I begin with these similarities in development, in the next subsection.

3.1 Similarities

If we examine the segmental relationships between sounds commonly produced in babbles and those produced in early words, we find many similarities between these two children's production patterns. These similarities are not related to timing or specific order of segmental acquisition, but to the general trends observed between babbles and early words. Both children display a preference for stops, nasals, glides and [h] in their babbled utterances; these segments also appear early in their word productions. There is also a preference for voiced stops over voiceless stops in the babbles of both children, with, however, no voicing preference noted for fricatives. Also interesting are the non-native sounds which appear in babbled utterances. As mentioned previously (see Chapter 6, Sections 2 and 3) both children display limited instances of non-native sounds, and those that do appear are generally similar to English segments in manner and place. These segments generally contain featural combinations not found in English, as opposed to containing features not found in English. For example, both children produce bilabial fricatives in babbles, and English contains both bilabial segments and fricative segments. Conversely, neither child produces sounds like clicks or uvular implosives, for example, whose place and manner features are not found in English.

Another key similarity between Cameron and Georgia is that both children begin producing branching onsets as two-segment clusters (as opposed to reducing the cluster to one segment) after they have attempted both of the target segments in singleton onsets. For example, Georgia begins to attempt |l| in singleton onsets at 2;01, with |Cl| branching onsets produced as clusters at 2;02. Also, consistent target-like productions for this cluster are attained at 2;03, the same age where |l| is mastered in singleton onsets. Cameron's productions display a similar pattern, with attempts at |l| in singleton onsets beginning in earnest at 1;05, and |Cl| branching onsets beginning to be produced as clusters at 1;08. Both children's productions also display a similar pattern with |ɹ| singleton onsets and |Cɹ| branching onsets. This pattern suggests an awareness to both the segments and their combinations within complex onsets.[10]

In sum, we observe similarities both in terms of segmental patterns and, also, developmentally, at least concerning the sounds that are acquired early in word productions. That is not to say that Cameron and Georgia followed fully identical learning paths. In the next subsection, I highlight some of the key differences found between their respective developmental patterns.

3.2 Differences

One of the most drastic differences between these two children concerns the way in which they develop their segmental system. While much of Georgia's development seems to occur on a segment-by-segment basis, Cameron appears to develop her system on a feature-by-feature basis, as evidenced by her development of natural classes as well as her substitution patterns. In Section 4, I formalize this distinction using Feature Co-occurrence Constraints (FCCs). As we will see, because of her apparent segment-by-segment developmental path, the account of Georgia's system requires twice as many FCCs as Cameron's. Recall from Chapter 5, Section 2, that Georgia displayed relatively few substitution patterns, and was instead more likely to either

10 It should be noted that it is attempts at the segments in singleton onsets that precede attempts at these segments in branching onsets, not necessarily acquisition of the individual segments involved in the cluster.

not attempt or delete a segment that she had not yet acquired. This behaviour caused members of natural classes to appear at different points throughout the corpus. Often, large gaps were observed between the acquisition of the first and last member of a natural class. The class of oral stops provide great examples of this behaviour; looking at labial stops, for example, we see |b| appearing at 1;00 and |p| not appearing until 1;09. In comparison, Cameron displays very systematic acquisition of her oral stops. In Chapter 4, Section 2.1, I showed that Cameron acquired all three voiced stops within a one-month window, at 0;11, and began producing all voiceless stops as target-like at 1;05.

Cameron's substitution patterns are also suggestive of further generalizations across different speech sounds. For example, as stated in Chapter 4, Section 2.3, Cameron displays 36 instances of substitution in her attempts at |θ|, 34 of those substitutions share common features with |θ|. In fact, 32 of those substitutions (89%) differ in only one feature: either place (|θ|→[f]), voicing (|θ|→[ð]), or manner (|θ|→[t,d]).[11] This suggests that Cameron had a good understanding of the phonetic properties of this segment, even though she had not yet mastered its precise articulation. Such robust feature-based patterns were not observed in Georgia's productions.

In sum, the two children show systematic differences in the development of their phonology. I highlight key properties of these differences through a formal analysis of their actual word productions, to which I turn next.

11 Cameron only produces the substitution of |θ|→[d] during the time period when all stops are produced as voiced (i.e. before the age of 1;05), therefore this pattern still arguably constitutes the changing of a manner feature ([+continuant]→[-continuant]).

4. Phonological Analysis

In this section, I formalize the phonological development of both Cameron and Georgia using the Feature Co-occurrence Constraint (FCC) framework proposed by Levelt & van Oostendorp (2007), introduced in Chapter 2, Section 1.4. As mentioned above, these analyses reveal further differences between Cameron and Georgia, in terms of the number of features needed to describe their respective systems, the order of acquisition of these features, as well as how the features interact within each child's system.

4.1 Assumptions

4.1.1 The Phonetic Basis for Features

The analyses below are based on a number of additional assumptions. In line with previous research (Stevens 1972; Halle & Stevens 1979; Stevens 1989; Mielke 2005; Lin & Mielke 2008; Mielke 2008; Rose 2009; Stevens & Keyser 2010; Mielke 2011; Rose to appear), I assume that features represent formal links between stable areas in the acoustic space and their corresponding motor articulations and phasing in the production domain. In line with this assumption, the set of unary features required for this analysis includes: [labial], [coronal], [dorsal], [spread glottis], [nasal], [approximant], [continuant], [sibilant], [distributed], [aspirated], [voiced], [rhotic], [lateral], and [delayed release]. The feature set used in these analyses is, therefore, slightly different than the feature set used by Levelt & van Oostendorp (2007).

The features [labial], [coronal], and [dorsal] encode the three major supralaryngeal places of articulation. While labial refers to all sounds which involve one or both lips (e.g. bi-labial; labio-dental), [coronal] and [dorsal] both involve the tongue. Sounds which are [coronal] involve the tongue tip and either the hard palate or alveolar ridge, while sounds which are [dorsal] involve the tongue dorsum and the soft palate.

All other features used in these analyses are manner features. The feature [spread glottis] denotes a slight constriction of the glottis, producing the aperiodic noise typical of all fricatives. The feature [nasal] denotes a lowered velum, allowing airflow through the nasal cavity to produce nasal stops. The features [continuant] and [approximant] both denote that a sound has continuous airflow. The distinction between these different types of continuancy is that continuant obstruents (fricatives) are characterized by aperiodic noise (turbulent airflow) (Ladefoged 2006:169), while approximants display periodic resonances devoid of significant amounts of air turbulence (Ladefoged 2006; Borden, Harris & Raphael 2006). Based on this salient perceptual difference, [approximant] is sufficient to classify oral sonorants as continuant, while the feature [continuant] encodes fricative continuancy. The feature [sibilant] provides further distinction between fricatives. Sounds marked as [sibilant] possess greater acoustic energy at a higher pitch than non-sibilant sounds (Ladefoged 2006:170). The feature [distributed] distinguishes between coronal fricatives, such as [s] and [ʃ]. Sounds marked as [distributed] are articulated with the tongue blade, as opposed to the tongue tip (Ladefoged 2006:275). The features [rhotic] and [lateral] distinguish between the two alveolar approximants [ɹ,l], respectively. The feature [delayed release] is a manner feature which describes the manner of articulation of affricates.

The feature [aspirated], in this analysis, represents the distinction between what are traditionally described as voiced and voiceless stops. The articulatory basis for this feature is the presence of aspiration in the voiceless stops [p,t,k], which is not found in the voiced stops [b,d,g]. Therefore, the presence/absence of aspiration can be used to distinguish these two groups of sounds (Lisker & Abramson 1964). Using [aspirated] instead of [voiced] to distinguish between the two groups of stops is a decision based on the different perceptual cues from voiced stops versus other voiced obstruents. Stops are considered voiced based on the length of their Voice Onset Time (VOT), which is a measure of when voicing begins relative to the release of the stop closure (Ladefoged 2006:146), and is difficult (if not impossible) to perceive in isolation. However, all other obstruents are considered to be voiced based on a perceivable acoustic quality caused by regular vibrations of the vocal folds when they are in close proximity to one another (Ladefoged 2006:143). These regular vibrations are what the abstract feature [voiced] relates to in the physical world, hence [voiced] is used only for sounds with a continuant voicing quality (i.e. fricatives). As we will see, this distinction between two types of voicing accounts for asymmetries in the treatment of 'voiced' and 'voiceless' stops versus other voiced and voiceless obstruents in the productions of both Cameron and Georgia.

4.1.2 Featural Development

From a developmental perspective, this analysis also assumes that children, starting with a featureless system, gradually acquire the required feature set for the target language (following Levelt & van Oostendorp 2007:166-167). A feature is assumed to be acquired when there is a contrast present that makes the feature necessary in order to distinguish between two sounds. For example, the feature [voiced] is assumed not to be present in the child's phonological system until a voicing contrast is present. This provision proves especially necessary in Georgia's analysis, in order to rule out unattested classes of sounds, such as the set of voiced fricatives, at relevant stages.

Further, this analysis assumes default states for inherent segmental properties. For example, sounds which are specified for [nasal] in English are also inherently voiced and non-continuant (stop). Since there are no other types of phonemically nasal sounds in English, there is no need to specify these inherent properties within the analysis (following Levelt & van Oostendorp 2007:169). Similarly, sounds specified as [approximant] are also inherently voiced and continuant. They will therefore be irrelevant to features or FCCs stating these properties. Also of importance is the assumption that sounds which do not have a specified manner feature will be produced as oral stops. This assumption is based on the ease of articulating a stop compared to articulating a continuant, since stops require significantly less control of the articulators involved (Ladefoged & Maddieson 1986; Levelt & van Oostendorp 2007).

4.2 Cameron

I begin with an analysis of Cameron's phonological development, summarized in Table 13. As we can see, this analysis provides a straightforward account of Cameron's various developmental stages. When she began speaking in earnest, at 0;11, she already had the three major place features necessary for English consonants ([labial], [coronal], and [dorsal]), as well as two manner features ([nasal] and [approximant]). However, no voicing contrast was produced at this stage. This resulted in a phonological inventory containing the full set of (voiced) stops (oral and nasal) and both glides. As mentioned above, the feature [approximant] implies continuancy, but without the fricative noise associated to the feature [continuant], which was not yet acquired at this early stage.

Table 13: FCC Analysis of Cameron

Age	Features	FCCs	Predicted Inventory
0;11	[labial], [coronal], [dorsal], [nasal], [approximant]	---	[b,d,g,m,n,j,w]
1;02	[spread glottis], [sibilant], [continuant]	---	[b,d,g,m,n,j,w,<u>f,s,h</u>]
1;05	[aspirated]	---	[b,d,g,<u>p,t,k</u>,m,n,j,w,f,s,h]
1;09	[voiced]	i. *[voi, sib]	[b,d,g,p,t,k,m,n,j,w,f,<u>v</u>,s,h]
2;05	[delayed release]	ii. [del.rel]⊃[voi]	[b,d,g,p,t,k,m,n,j,w,f,v,s,h,<u>ʤ</u>]
2;10	[lateral]	---	[b,d,g,p,t,k,m,n,j,w,f,v,s,h,ʤ,<u>l</u>]
2;11	[distributed]	iii. [dis]⊃[voi]	[b,d,g,p,t,k,m,n,j,w,f,v,s,h,ʤ,l,<u>ð</u>]

At 1;02, Cameron added the features [spread glottis], [sibilant], and [continuant], which resulted in the addition of [f,s,h] to her productive inventory of phones. While the feature [sibilant] is not necessary to distinguish [s] from [f] or [h], all of which have distinct places of articulation, [sibilant] plays a crucial role in ruling out the unattested [z] at a later stage in Cameron's development. At 1;05, she acquired the feature [aspirated], which gave rise to a voicing distinction among oral stops. At 1;09, Cameron added [voiced] to her set of features, and [v] appeared in her inventory. This was also the point when her first FCC manifested itself, prohibiting voiced sibilants (i.e. [z]). At 2;05, the feature [delayed release] appeared, along with an FCC mandating that affricates be voiced, resulting in the addition of [ʤ] to Cameron's segmental inventory. At 2;10, Cameron acquired [lateral], and [l] appeared in her inventory. Finally, at 2;11, Cameron acquired the feature [distributed], which allowed [ð] to emerge in her segmental inventory. The constraint that distributed sounds be voiced rules out the yet unacquired [θ] at this stage. This was the last stage observable in Cameron's corpus. Under the current analysis, her later acquisition of |ʃ,ʒ| would have involved the feature [posterior], in order to distinguish the these stridents from the anterior fricatives [s,z].

4.3 Georgia

Turning now to Georgia, Table 14, below, illustrates her systematic phonological development. As can be seen, Georgia began her word production with a much smaller phonological inventory than Cameron. Only [labial] and [dorsal] were present in Georgia's system at 1;00, limiting her sound inventory to [b,g].

Table 14: FCC Analysis of Georgia

Age	Features	FCCs	Predicted Inventory
1;00	[labial], [dorsal]	---	[b,g]
1;02	[coronal], [nasal], [aspirated]	i. [cor]⊃[nas] ii. [asp]⊃[dors]	[b,g,k,m,n]
1;05	[approximant]	iii. [app]⊃[lab]	[b,g,k,m,n,w]
1;06	[distributed], [sibilant], [continuant]	Revoke i. iv. [sib]⊃[dist] v. [cont]⊃[cor]	[b,d,g,k,m,n,w,ʃ] *[d] predicted, but not attempted*
1;07	---	Revoke ii.	[b,d,g,p,t,k,m,n,w,ʃ]
1;09	[delayed release], [spread glottis], [voiced]	Revoke iii. Revoke iv. vi. [del.rel]⊃[voi] vii. *[cont, voi]	[b,d,g,p,t,k,m,n,f,s,ʃ,h,w,j,ʤ]
1;10	---	Revoke vi.	[b,d,g,p,t,k,m,n,f,s,ʃ,h,w,j,ʤ,ʧ]
2;04	[lateral]	---	[b,d,g,p,t,k,m,n,f,s,ʃ,h,w,j,ʤ,ʧ,l]
2;05	---	Revoke vii. viii. *[sib, voi]	[b,d,g,p,t,k,m,n,f,v,s,ʃ,h,w,j,ʤ,ʧ,l]
2;10	[rhotic]	Revoke viii.	[b,d,g,p,t,k,m,n,f,v,s,z,ʃ,ʒ,h,w,j,ʤ,ʧ,l,ɹ] *[ʒ] predicted, but not attempted*

At 1;02, Georgia added [coronal], [nasal], and [aspirated] to her feature set, resulting in the addition of [k,m,n] to her segmental inventory. Her system at this stage was also constrained by two FCCs: one mandating that coronal segments be nasal, the other mandating that aspirated stops be specified for [dorsal]. At 1;05, the feature [approximant] was added to the system, along with one FCC mandating that approximants have a labial place of articulation. This new feature and FCC correctly predict the addition of [w] to Georgia's inventory. At 1;06, Georgia added the features [continuant], [distributed], and [sibilant] along with two FCCs, one stating that sibilant sounds be distributed, the other that continuants be coronal. At this stage, the FCC stating that coronals must be nasal is revoked in order to account for the acquisition of [ʃ]. This leads to a prediction that [d] should appear in Georgia's productive inventory, but, as illustrated in Figure 32, she made no attempts at [d] until the age of 1;09. (Note that this empirical gap may be due to sampling, and so does not contradict the prediction that Georgia's phonological system is now able to represent |d|.) At 1;07, Georgia added [p,t] to her inventory by revoking the FCC mandating that aspirated sounds be specified for [dorsal]. At 1;09, the features [delayed release], [spread glottis], and [voiced] were added to Georgia's system, along with two FCCs stating that continuants not be voiced and that affricates (delayed release) be voiced. Also, the FCCs mandating that approximants be specified for [dorsal] and that sibilant sounds be distributed were both revoked. This stage thus yields the addition of [f,s,h,j,ʤ], along with the appearance of [d], which was already predicted at 1;06. At 1;10, the FCC stating that affricates be voiced was revoked, which in turn yielded the emergence of [ʧ] in Georgia's productive inventory. At 2;04, the feature [lateral] was added to the system, yielding [l]. At 2;05, the FCC prohibiting continuants to be voiced was revoked, allowing for the addition of [v] to Georgia's sound system. In fact, this constraint appears to have become more narrowly focused, only targeting the combination of features involved in the production of [z], which was not successfully acquired until 2;10. Finally, at 2;10, the feature [rhotic] was added, which accounts for the mastery of [ɹ].

4.4 Interim Discussion

As we can see from these analyses, Georgia thus required more developmental stages as well as roughly twice as many FCCs as Cameron. While Cameron acquired her phonology through broad generalizations corresponding to natural classes of sounds, Georgia instead appears to have developed her consonantal system on a sound-by-sound basis. This difference between the two children is captured through the use of different features and FCCs. As discussed in Chapter 2, Section 1.4.2, features encode natural classes while FCCs encode gaps in natural classes. Since Georgia had more gaps in her segmental inventory, the analysis of her system required more FCCs.

I was thus able to capture the children's behaviours through analyses based on featural development and associated FCCs. However, this framework does not enable us to capture some potentially crucial pieces of the puzzle, for example avoidance behaviours, such as those displayed by Georgia. As we saw in Chapter 4, Cameron substituted many sounds for several months before mastering their production. For example she stopped |ʤ| to [d] from 1;02 until 2;05, when it was finally acquired, and the voiceless stops |p,t,k| were produced as voiced from 0;11 until 1;05, when the full set was acquired (Chapter 4, Sections 2.4 and 2.1.2, respectively). In contrast, we saw in Chapter 5 that Georgia generally deleted and, at times, appeared to also avoid segments she was unable to produce. This apparent avoidance behaviour even affected common English phonemes such as |p| and |t|, with no attempts at |p| found between 1;03 and 1;07, nor attempts at |t|, between 1;01 and 1;06 (see Chapter 5, Section 2.1).

In sum, when we compare both children using a strictly production based approach, many of the differences between Cameron and Georgia are lost by not considering attempted productions, in addition to production patterns. This analysis thus gives little insight concerning how the children treated sounds at stages when they had yet to be acquired. Given the lack of attention paid to unacquired sounds in the FCC analyses, and the potentially illuminating nature of the substitution patterns observed in both children's productions, I consider these substitution patterns in more detail in the next section.

5. Influences on Substitution Patterns

In this section, I examine the substitution patterns exhibited in the productions of both children, and investigate some of the factors which likely influenced the patterns observed. Recall the approaches to phonological development highlighted in Chapter 2, Section 1: the bio-mechanical/articulatory approach, the perceptual approach, the templatic approach, and the representational approach. Each of these approaches is driven by a key factor, with bio-mechanics driven by articulatory difficulty (Section 1.1), perception driven by acoustic salience and frequency (Section 1.2), templates by both perceptual and articulatory factors (Section 1.3), and representations by formal properties of the target structures (Section 1.4). Building on earlier works on the relations between the acoustic and articulatory aspects of segmental representations, I take as a starting point that the child's phonological representations are formed by connecting identifiable dimensions within the speech signal with the articulatory/motor plans involved in the reproduction of these dimensions in spoken forms (Stevens 1972; Halle &

Stevens 1979; Stevens 1989; Mielke 2005; Lin & Mielke 2008; Mielke 2008; Rose 2009; Stevens & Keyser 2010; Mielke 2011; Rose to appear). Given this view of the composition of a phonological representation, a substitution pattern is evidence of an erroneous or incomplete representation which can generally be attributed to either articulatory influences, perceptual influences, or both.

Not all the substitutions observed have a clear, singular motivation, however, as will be seen below. In cases with multiple possible motivations, I will restrict the extent of my claims through simply highlighting the most likely possibilities. For sake of convenience, I begin with a summary of each of the children's patterns noted in preceding chapters.

5.1 Cameron

I begin with Cameron, whose substitution patterns are summarized in Table 15. As mentioned previously, Cameron's productions display numerous substitutions throughout the corpus.

Table 15: Cameron's Substitution Patterns

Age	Target Segment	Produced Segment
1;01-1;09	ʧ	t
1;02-2;11	ɹ	w
1;02-2;10	ð	d
1;03-2;06	θ	t
1;03-2;09	l	w, n
1;06-2;10	ʃ	s
2;01-2;04	ʧ	s
2;07-2;09	ʧ	ʃ
2;09	θ	f
2;11	θ	ð

The first pattern noted is that of affricate stopping (|ʧ|→[t]), which later gives way to affricate substitution by a fricative (|ʧ|→[s,ʃ]). Articulatorily, affricates are difficult to produce, given the tight sequencing of the two manners of articulation they involve (stop closure followed by fricative release), an articulatory profile that the child must acquire on the basis of distributional evidence. Cameron's developmental pattern for this consonant suggests that she did indeed analyze it as a single consonant, as she apparently never attempted to produce it as a sequence of two consonants. Initially, the child produces the articulatorily simple portion of the affricate, resulting in stopping, which itself entails the loss of the perceptually salient fricative portion of the affricate. The subsequent substitution parallels the development of the fricative counterpart to the affricate |ʃ|, characterized by a fronting of the target posterior coronal, to be discussed further below.

A substitution pattern that persisted throughout much of Cameron's recorded development is the optional rhotic gliding of |ɹ| into [w]. This substitution is particularly interesting because of the back-and-forth pattern Cameron displayed between substitution and target-like production of the rhotic consonant (see Figure 24 on page 44). Given the fluctuating nature of this pattern, articulatory factors were the most likely cause. Essentially, Cameron was unable to consistently produce the correct articulation, but at times managed to be accurate. Alternatively, it is possible that the fluctuation observed was an instance of a partially covert contrast (discussed in Chapter 4, Section 2.6), in which case it was not Cameron's productions that were fluctuating but the listener's perception of her productions (e.g. Scobbie et al. 1996; Gibbon 1999). The fact that this was a unidirectional substitution pattern (i.e. Cameron never displays the reverse |w|→[ɹ] pattern in her productions) also argues against perceptual influences, as it suggests that Cameron was treating these two segments as separate categories in perception.

Cameron also displayed a stopping pattern of the interdental fricatives |θ,ð|, producing them as [t,d], in spite of her early acquisition of other fricatives such as |f,s,h|. This stopping behaviour was most likely the result of articulatory factors. When attempting to produce the narrow opening required for turbulent airflow within the (inter)dental place of articulation, it is plausible that Cameron was overshooting the articulation to the extent that it resulted in full closure (e.g. Marshall & Chiat 2003; Inkelas & Rose 2007; Rose & Inkelas 2011). Interdental fricatives continued to be a source of difficulty for Cameron, as she developed additional substitution patterns for |θ|. At 2;09, we saw [f] produced for target |θ| (Figure 17). Given the shift in major places of articulation (from [coronal] to [labial]), I suggest that this substitution was likely not the result of articulatory factors but rather was likely related to a misperception on the child's part. These sounds are extremely similar acoustically and can be very difficult for the untrained ear to distinguish and, therefore, represent (e.g. Borden, Harris & Raphael 2006). In this context, if Cameron was not able to perceptually distinguish between these two sounds, then she did not have the required basis to acquire the features needed to fully, and correctly, specify |θ|. Further, even though she was potentially able to perceptually distinguish the two sounds, it is also possible that she had not yet acquired a way to represent them contrastively. The fact that neither interdental fricative was acquired at this point in Cameron's development supports the possibility that she lacked the required representations. In addition, since many other fricatives had already been successfully acquired, we cannot relate the problem to a general articulatory difficulty with fricatives. Cameron's shift from producing |θ| as [f] to producing it as [ð], which coincided with her acquisition of |ð|, further supports the hypothesis that these substitutions were driven by representational influences. The development of this new phone, |ð|, thus offered the child a closer substitute for target |θ|.

Cameron also displayed difficulty with |l|, a pattern which I attribute to the lateral articulation involved in the production of this consonant. In the face of this difficulty, Cameron developed two suitable substitution patterns: |l|→[w] and |l|→[n]. Both of these substitutions approximated articulatory characteristics of the target segment: [w] is an oral approximant, like |l|, while [n] maintains the same place of articulation as |l|.

Finally, as alluded to above, Cameron exhibited a pattern of optional fronting of the alveopalatal fricative |ʃ| to [s]. In this case, it is likely that Cameron had not fully mastered the [anterior]/[posterior] distinction which separates these two segments. Her mastery of |s| suggests that she had fully acquired the [anterior] articulation, but the contrasting articulation represented by [posterior] was still being learned. Based on the lack of representational instruction (as a lack of place feature should entail a lack of articulatory plan), Cameron's productions varied from attempt to attempt, resulting in the instability observed in the recorded data. The asymmetry in directionality observed here, as with the rhotic gliding, argues against perceptual influences for this substitution pattern.

5.2 Georgia

I turn now to the substitution patterns observed in Georgia's productions. As illustrated in Table 16, below, she displays many of the same substitution patterns discussed above for Cameron, but also some patterns which are unique to her.

Table 16: Georgia's Substitution Patterns

Age	Target Segment	Produced Segment
1;05-1;06	s	ʃ
1;06-2;09	ɹ	w
1;06-2;05	ʧ	s/ʃ; t/d
1;07-2;01	l	w
1;10-2;03	l	j
2;00-2;11	ð	d
2;00, 2;10	θ	f

The first substitution pattern observed in the recorded data is that of |s| produced as [ʃ]. I argue that the main influence for this pattern was articulatory. Georgia was placing her tongue too far back along the coronal region. I do not adopt the analysis of a possible missing place feature for |s|, as was posited for Cameron's behaviour of |ʃ| becoming [s] above, for Georgia's substitution pattern of |s|→[ʃ]. Recall that Cameron displayed a back and forth behaviour between the two segments, whereas Georgia consistently produced the wrong segment during this period. Georgia's substitution pattern, therefore, seems indicative of an incorrect motor plan being associated with her perceptual representation for |s|, as opposed to an incompletely-specified motor plan.

Georgia also displayed the substitution of |ɹ| by [w] in a stable fashion, as opposed to Cameron's fluctuating pattern. Given the difficulty children generally have with the intricate articulations required for |ɹ|, articulatory factors remain the most likely cause for this substitution. These segments ([ɹ,w]) involve similar articulations in many respects, so children often make small mistakes with articulator position that lead to this pattern. Just as with Cameron, the possibility that this substitution was actually an example of a covert contrast also needs to be entertained. However, the absence of optionality in Georgia's productions makes the covert contrast analysis less likely. Interestingly, both the |ʃ|→[s] and |ɹ|→[w] patterns display a degree of tongue backing, the first from alveolar to alveopalatal and the second from coronal to labiovelar. This observation suggests the possibility that some larger articulatory pressures were causing Georgia to back her coronal productions.

The voiceless affricate |ʧ| also causes problems for Georgia, and she displayed multiple concurrent substitutions for this target phone. Georgia produced |ʧ| by approximating either the closure or the release of the segment, resulting in a stopping substitution (|ʧ|→[t,d]) or in |ʧ| being produced as [s,ʃ], similar to what was observed with Cameron. Both of these patterns appear to have articulatory underpinnings, given the complicated nature of affricate production, as discussed above. However, the production of the fricative portion of the affricate was likely related to the perceptual salience of the fricative portion, compared to the stop portion, of the affricate. Therefore, these substitution patterns may have arisen from an interplay between articulatory and perceptual influences.

Georgia displayed a pattern of substituting the liquid |l| with the glide [w], a pattern commonly observed in the phonological development of English speaking children, including both Cameron and Georgia (e.g. Smit 1993; Bernhardt & Stemberger 1998). These data suggest that Georgia had not yet discovered how to produce lateral articulations, and settled on an approximation which shares many of the articulatory and acoustic features of the target segment |l|. Georgia also displayed an additional substitution pattern for |l|, producing it as [j]. Again, this pattern was likely articulatorily driven. The production of the target lateral |l| as a glide offers the closest alternative place of articulation, as well as the presence of the approximant nature of the target phone. Importantly, this second pattern emerged at the stage when Georgia acquired |j|. The two patterns (|l|→[w], |l|→[j]) co-existed for approximately three months, at which point Georgia favoured [j] as a substitute for |l|. This also reveals aspects of the child's alternative motor plans for the target lateral.

Moving on to Georgia's treatment of the interdental fricatives |ð,θ|, her substitution of [d] for the voiced interdental fricative |ð| was likely caused by articulatory factors. As was the case with Cameron, it is plausible that Georgia likely overshot the articulation while attempting to create the narrow (inter)dental opening required for fricative production, resulting in a stop production. Note that this behaviour was specific to this segment, Georgia produced other fricatives as target-like (with the exception of |θ| which underwent various treatments but crucially did not exhibit a stopping pattern).

As we saw with Cameron, Georgia also displayed the perceptually influenced pattern of substituting [f] for |θ|, a commonly attested substitution related to the acoustic similarity of the two segments. This behaviour again carried the representational implication that if Georgia could not distinguish between these two segments acoustically, then she had no basis to posit the phonological features which separate |f| from |θ|.

5.3 Discussion

In sum, a few striking similarities emerge from the comparison of Cameron and Georgia's patterns of phonological development. In spite of their very different developmental paths, these children display similar substitution patterns for many of the same sounds (i.e. |l,ɹ,θ,ð,ʧ|). Further, the vast majority of the substitutions observed are arguably driven by articulatory factors, with relatively few substitutions having clear perceptual influences. In all cases, we can see an attempt on the child's part to match the target segment (as she perceives it) with an appropriate motor plan. This observation is in line with the view of features entertained throughout this thesis, whereby the child needs to establish connections between identifiable dimensions of the acoustic signal and related articulatory targets. This view of phonological development is in fact compatible with any theory that focuses on the child's building of phonological representations. Regarding the nature of these phonological representations, one central question is the level of granularity involved. For example, do children build their phonological representations at the word or segmental level. The presence of natural class effects in child language data (as seen in this thesis in Cameron's data) supports traditional representations based on sub-segmental features, since larger representational units (e.g. word templates) would have no way to explain these observed natural class effects.

Throughout this chapter, and, indeed, this thesis, I have argued for a multi-faceted approach to phonological development. I revisit the most central evidence considered throughout this discussion in the following chapter.

Chapter 8: Conclusion

1. Introduction

The main goal of this thesis was to attain an in-depth understanding of the phonological development of two English-learning children, Cameron and Georgia. In order to achieve this goal, I first tracked the segmental development of each phoneme appearing in onset position throughout babbles and early word productions. I then compared the treatment of one segment, [l], across Cameron's babbles and early word attempts. Following this, I performed a formal analysis of both children's word productions, and then explored possible influences on the substitution patterns displayed in their productions. The results obtained demonstrate the need for a multi-faceted approach when studying phonological acquisition. Each aspect of this research (based on examination of developmental milestones and segmental treatment) captures critical elements of the children's phonological development. I summarize the most central observations in the next section.

2. Summary of Results

2.1 Segmental Development in Word Productions

I began by detailing each child's segmental acquisition in the onsets of early word productions (Cameron in Chapter 4 and Georgia in Chapter 5) and their consonantal segment inventory in babbled utterances (Chapter 6). This investigation of segmental acquisition detailed the different learning path of each child. Cameron started speaking fairly early, with her first words at 0;09 and consistent word production beginning at 0;11. She often attempted segments whose production lay beyond her articulatory abilities, resulting in numerous substitutions patterns, as summarized in Chapter 7, Section 5.1.

In contrast, Georgia began speaking slightly later, with her first words at 0;10. However, few segments are attempted before 1;04. She displayed a tendency to either delete or simply not attempt segments which she had yet to acquire. Georgia produced relatively few word attempts in recording sessions before 1;09, at which point she mastered multiple segments: |p,d,g,f,s,h,ʤ| (see Table 8). The limited number of attempts before this age makes it difficult to form generalizations about Georgia's development.

I also examined the development of branching onsets in both children, for which they also showed different developmental trends. Cameron displayed earlier attempts at branching onsets, as well as consistent substitution patterns for both |Cl| and |Cɹ| branching onsets. The substitution patterns in branching onsets were consistent with the substitution patterns she displayed for the approximants |l,ɹ| in singleton onsets. This behaviour suggests a level of awareness of the segmental makeup of branching onsets. In contrast, Georgia only established a substitution pattern for |Cɹ|, which was also consistent with the substitution pattern she displayed for |ɹ| in singleton onsets. Georgia acquired |Cl| clusters considerably earlier than Cameron (compare Table 9 and Table 7, respectively), but Georgia also acquires singleton |l| six months earlier than Cameron (compare Table 8 and Table 6, respectively).

Some commonalities also existed between Cameron and Georgia's developmental paths. Both children only began producing branching onsets as clusters after they had begun consistently producing attempts at the approximant involved, either |l| or |ɹ|, in singleton onsets. Also, both children displayed difficulty with |Cw| branching onsets despite both of them using [Cw] as a substitution for other branching onsets.

2.2 Segmental Inventory in Babbled Utterances

In Chapter 6, I explored the segmental inventory of the babbled utterances of Cameron and Georgia. Perhaps the most interesting patterns displayed in Cameron and Georgia's babbled utterances are the strong tendency of segments to appear in babbles before being attempted in word productions, and the limited number of non-native segments. Of all the segments Cameron attempts in word productions, only |θ| fails to appear in babbles before being attempted in words (interestingly, Cameron also has notable difficulties with |θ| in word productions). Georgia's productions contain only three segments which are attempted in words before they are recorded in babbles, |v,ɹ,ð|. Turning to the non-native segments that the children produce in babbles, they generally contain novel combinations of phonological features present in English as opposed to entirely novel features. For example, both children display a bilabial fricative [β,ɸ] in their babbled utterances. English contains both bilabial segments and fricative segments, it simply does not contain this combination of features. This, again, suggests an awareness of the segmental units that compose their native language.

2.3 Segmental Treatment in Babbles and Early Words

Following the description of segmental development, I investigated the treatment of [l] across the babbled utterances and early word productions of Cameron. Despite having much difficulty with target |l| in early word productions, [l] is quite common in Cameron's early babbles. The data even contain comparable babble and target word form pairs, which illustrate that in similar structural positions, [l] was produced in babbles but either deleted or substituted in word attempts. The observations presented in this investigation contradict any approach which does not separate the physiological ability to produce a speech sound from the grammatical ability to represent that sound.

2.4 Phonological Analysis

I then formulated a formal analysis of both children's segmental development. This analysis reveals some of the differences between the segmental acquisition of Cameron and Georgia. Cameron tended to acquire sounds in natural classes (she acquired all three voiced stops together, then all three voiceless stops together, and three voiceless fricatives, |f,s,h|, were acquired together as well) and required half as many FCCs in her development. The limited FCCs required relates to the fact that FCCs encode gaps in natural classes. Georgia acquired segments on a sound-by-sound basis, with no clear natural class effects, and, therefore, required many more FCCs in order to rule out unacquired segments.

While this analysis allows for a concise description of patterns of segmental acquisition, FCCs are not construed to capture major differences that exist between these two children. For example, the tendency to delete unacquired segments instead of substituting them, or the apparent avoidance behaviour exhibited by Georgia compared to the precocious speech of Cameron. Addressing this shortcoming, I performed a separate analysis on the substitution patterns of each child. This examination suggests that the majority of the substitution patterns for both children are influenced by articulatory factors, with a handful of perceptual effects also playing a role. Further, similar segments underwent substitution, with both children developing the same patterns for |l,ɹ,θ,ð,ʧ| in their productions.

3. Outstanding Issues

While this research illustrates the benefit of multi-faceted approaches to phonological development, it also leaves much work remaining for future research. The ultimate goal of a genuinely comprehensive approach to child phonological acquisition is extremely challenging to reach and, as such, this work only offers one more step in that direction. The current work focused mainly on empirical questions with the hope that answering these questions would then set the stage for the development of a comprehensive framework capable of offering a unified interpretation of all aspects of segmental acquisition examined here.

The differences observed between these children also relate to the larger question of variation between learners. It would be interesting to identify more learners similar to either Cameron or Georgia concerning their respective developmental paths, in order to see if they can predict whether a child will err on the side of substitution or deletion in the context of unacquired segments.

There is also the larger question of the generalizability of the current work. This research was conducted on a small scale, through an in-depth analysis of phonological acquisition data recorded in only two children. These two children displayed important differences in their respective learning paths, conceivably representing two relatively different points on the continuum of phonological development paths. While the differences observed between these children may seem to call into question how representative these data can be of the general population of learners, it may also suggest that the similarities between these children are fundamental to acquiring English phonology. Any answer to this question lies far beyond the scope of this thesis. It is, however, my hope that the current work will provide one further step in this direction.

References

Bernhardt, Barbara H. & Joseph P. Stemberger. 1998. *Handbook of Phonological Development from the Perspective of Constraint-Based Nonlinear Phonology*. San Diego: Academic Press.

Borden, Gloria J., Katherine S. Harris & Lawrence J. Raphael. 2006. *Speech Science Primer: Physiology, Acoustics, and Perception of Speech, 5th Edition*. Philadelphia: Lippincott Williams & Wilkins.

Chomsky, Noam & Morris Halle. 1968. *The Sound Pattern of English*. New York: Harper & Row.

Davis, Barbara L. & Peter F. MacNeilage. 1990. Acquisition of Correct Vowel Production: A Quantitative Case Study. *Journal of Speech and Hearing Research* 33. 16–27.

Dinnsen, Daniel A. 2008. A Typology of Opacity Effects in Acquisition. In Daniel A. Dinnsen & Judith A. Gierut (eds.), *Optimality Theory, Phonological Acquisition and Disorders*, 121–176. London: Equinox.

Fikkert, Paula. 1994. *On the Acquisition of Prosodic Structure*. The Hague: Holland Academic Graphics.

Fikkert, Paula & Clara Levelt. 2008. How does Place Fall into Place? The Lexicon and Emergent Constraints in Children's Developing Grammars. In Peter Avery, B. Elan Dresher & Keren Rice (eds.), *Contrast in Phonology: Theory, Perception, Acquisition*, 231–268. Berlin: Mouton de Gruyter.

Gibbon, Fiona E. 1999. Undifferentiated Lingual Gestures and their Implications for Speech Disorders in Children. *Proceedings of the XIVth International Congress of Phonetic Sciences* 3. 1913–1916.

Giegerich, Heinz J. 1992. *English Phonology: An Introduction*. Cambridge: Cambridge University Press.

Goad, Heather & Yvan Rose. 2004. Input Elaboration, Head Faithfulness and Evidence for Representation in the Acquisition of Left-edge Clusters in West Germanic. In René Kager, Joe Pater & Wim Zonneveld (eds.), *Constraints in Phonological Acquisition*, 109–157. Cambridge: Cambridge University Press.

Hale, Mark & Charles Reiss. 1998. Formal and Empirical Arguments Concerning Phonological Acquisition. *Linguistic Inquiry* 29(4). 656–683.

Halle, Morris & Kenneth N. Stevens. 1979. Some Reflexions on the Theoretical Bases of Phonetics. In Björn Lindblom & Sven E. G. Öhman (eds.), *Frontiers of Speech Communication Research*, 335–349. New York: Academic Press.

Inkelas, Sharon & Yvan Rose. 2007. Positional Neutralization: A Case Study from Child Language. *Language* 83(4). 707–736.

Jakobson, Roman. 1941. *Kindersprache, Aphasie, und allgemeine Lautgesetze*. Uppsala: Almqvist & Wiksell.

Kern, Sophie & Barbara L Davis. 2009. Emergent Complexity in Early Vocal Acquisition: Cross Linguistic Comparisons of Canonical Babbling. In Ioana Chirotan, Christophe Coupé, Egidio Marisco & François Pellegrino (eds.), *Approaches to Phonological Complexity*, 353–375. Berlin: Mouton de Gruyter.

Ladefoged, Peter. 2006. *A Course in Phonetics*. 5th Edition. Boston: Wadsworth Cengage Learning.

Ladefoged, Peter & Ian Maddieson. 1986. Some of the Sounds of the World's Languages. *UCLA Working Papers in Phonetics*, vol. 64, 1–137. UCLA: Department of Linguistics.

Leopold, Werner F. 1947. *Speech Development of a Bilingual Child: A Linguist's Record, Vol. II: Sound-learning in the First Two Years*. Evantson, IL: Northwest University Press.

Levelt, Clara. 1994. *On the Acquisition of Place*. The Hague: Holland Academic Graphics.

Levelt, Clara C., Niels O. Schiller & Willem J. Levelt. 1999. The Acquisition of Syllable Types. *Language Acquisition* 8(3). 237–264.

Levelt, Clara & Marc van Oostendorp. 2007. Feature Co-occurrence Constraints in L1 Acquisition. In Bettelou Los & Marjo van Koppen (eds.), *Linguistics in the Netherlands 2007*, 162–172. Amsterdam: John Benjamins.

Levitt, Andrea, Peter W. Jusczyk, Janice Murray & Guy Carden. 1987. Context Effects in Two-Month-Old Infants' Perception of Labiodental/Interdental Fricative Contrasts. *Haskins Laboratories Status Report on Speech Research* 91. 31–43.

Lin, Ying & Jeff Mielke. 2008. Discovering Place and Manner Features: What can be Learned from Acoustic and Articulatory Data. *University of Pennsylvania Working Papers in Linguistics* 14(1). 241–254.

Lintfert, Britta. 2009. Phonetic and Phonological Development of Stress in German. Universität Stuttgart Ph.D. Dissertation.

Lisker, Leigh & Arthur S. Abramson. 1964. A Cross-Linguistic Study of Voicing in Initial Stops: Acoustical Measurements. *Word* 20(3). 384–422.

Macken, Marlys A. 1980. The Child's Lexical Representation: The "Puzzle-Puddle-Pickle" Evidence. *Journal of Linguistics* 16. 1–17.

MacNeilage, Peter F. & Barbara L. Davis. 1990. Acquisition of Speech Production: Achievement of Segmental Independence. *Speech Production and Speech Modeling*, 55–68. Kluwer: Dordrecht.

Marshall, Chloe & Shulamuth Chiat. 2003. A Foot Domain Account of Prosodically-conditioned Substitutions. *Clinical Linguistics and Phonetics* 17. 645–657.

Menn, Lise & Marilyn Vihman. 2011. Features in Child Phonology. In G. Nick Clements & Rachid Ridouane (eds.), *Where do Phonological Features Come From?*, 261–301. Amsterdam: John Benjamins.

Mielke, Jeff. 2005. Ambivalence and Ambiguity in Laterals and Nasals. *Phonology* 22(02). 169–203.

Mielke, Jeff. 2008. *The Emergence of Distinctive Features*. Oxford: Oxford University Press.

Mielke, Jeff. 2011. Distinctive Features. In Colin J. Ewen, Elizabeth Hume, Marc van Oostendorp & Keren Rice (eds.), *The Blackwell Companion to Phonology*, 391–415. Malden, MA: Wiley-Blackwell.

Oller, D. Kimbrough. 1980. The Emergence of the Sounds of Speech in Infancy. In Grace H. Yeni-Komshian, James Francis Kavanagh & Charles Albert Ferguson (eds.), *Child Phonology 1: Production*. New York: Academic Press.

Rose, Yvan. to appear. The Emergence of First Language Phonology: Perception, Articulation and Representation. In Ana Lúcia Santos (ed.), *Selected Proceedings of Romance Turn V*.

Rose, Yvan. 2009. Internal and External Influences on Child Language Productions. In François Pellegrino, Egidio Marsico, Ioana Chitoran & Christophe Coupé (eds.), *Approaches to Phonological Complexity*, 329–351. Berlin: Mouton de Gruyter.

Rose, Yvan & Sharon Inkelas. 2011. The Interpretation of Phonological Patterns in First Language Acquisition. In Colin J. Ewen, Elizabeth Hume, Marc van Oostendorp & Keren Rice (eds.), *The Blackwell Companion to Phonology*, 2414–2438. Malden, MA: Wiley-Blackwell.

Rose, Yvan & Brian MacWhinney. in press. The PhonBank Initiative. In Jacques Durand, Ulrike Gut & Gjert Kristoffersen (eds.), *Handbook of Corpus Phonology*. Oxford: Oxford University Press.

Rose, Yvan, Brian MacWhinney, Rodrigue Byrne, Gregory Hedlund, Keith Maddocks, Philip O'Brien & Todd Wareham. 2006. Introducing Phon: A Software Solution for the Study of Phonological Acquisition. In David Bamman, Tatiana Magnitskaia & Colleen Zaller (eds.), *Proceedings of the 30th Annual Boston University Conference on Language Development*, 489–500. Somerville, MA: Cascadilla Press.

Scobbie, James M., Fiona Gibbon, William J. Hardcastle & Paul Fletcher. 1996. Covert Contrast as a Stage in the Acquisition of Phonetics and Phonology. In Michael B. Broe

& Janet B. Pierrehumbert (eds.), *Papers in Laboratory Phonology V: Acquisition and the Lexicon*, 43–62. Cambridge: Cambridge University Press.

Smit, Ann Bosma. 1993. Phonologic Error Distribution in the Iowa-Nebraska Articulation Norms Project: Consonant Singletons. *Journal of Speech and Hearing Research* 36. 533–547.

Smith, Neilson V. 1973. *The Acquisition of Phonology: A Case Study*. Cambridge: Cambridge University Press.

Smolensky, Paul. 1996. On the Comprehension/Production Dilemma in Child Language. *Linguistic Inquiry* 27. 720–731.

Spencer, Andrew. 1986. Towards a Theory of Phonological Development. *Lingua* 68. 3–38.

Stark, Rachel E. 1980. Stages of Speech Development in the First Year of Life. In Grace H. Yeni-Komshian, James Francis Kavanagh & Charles Albert Ferguson (eds.), *Child Phonology 1: Production*, 73–90. New York: Academic Press.

Stevens, Kenneth N. 1972. The Quantal Nature of Speech: Evidence from Articulatory-acoustic Data. In Edward E. David & Peter B. Denes (eds.), *Human Communication: A Unified View*, 51–66. New York: McGraw-Hill.

Stevens, Kenneth N. 1989. On the Quantal Nature of Speech. *Journal of Phonetics* 17(1-2). 3–45.

Stevens, Kenneth N. & Samuel J. Keyser. 2010. Quantal Theory, Enhancement and Overlap. *Journal of Phonetics* 38(1). 10–19.

Stoel-Gammon, Carol & Judith A. Cooper. 1984. Patterns of Early Lexical and Phonological Development. *Journal of Child Language* 11. 247–271.

Vihman, Marilyn & William Croft. 2007. Phonological Development: Toward a “Radical” Templatic Phonology. *Linguistics* 45(4). 683–725.

Vihman, Marilyn May. 2014. *Phonological Development: The First Two Years*. 2nd ed. Malden, MA: Wiley-Blackwell.

Vihman, Marilyn May, Charles A. Ferguson & M. Elbert. 1986. Phonological Development from Babbling to Speech: Common Tendencies and Individual Differences. *Applied Psycholinguistics* 7. 3–40.