The Acquisition of English Onsets: The Case of Amahl[1]

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Abstract

The acquisition of English onsets by one English-learning child is examined in close detail, with particular focus on the acquisition of /s/ and /s/-clusters. The observation that target /s/ in harmony environments is sensitive to the feature [labial] as opposed to [coronal] and [dorsal] provides support for a feature geometry model in which [labial] versus [lingual] is a possible distinction, e.g. Brown (1997). Further, the unique behavior of target /s/ in the developing phonology motivates the proposal that physiological factors, such as articulatory difficulty, can have consequences in the grammatical system. In particular, it is proposed that a constraint against lingual continuants, which require a precise physical coordination that may not have yet developed, can account for the patterns in the child's acquisition of /s/ clusters. A comparison with the acquisition of /f/, a non-lingual continuant, and that of /l/, another lingual continuant, provides further support for this proposal. The conclusions reached here are consistent with notion of a phonological system grounded in independent, functional principles as argued for in, for example, Goad (1997).

[1] **Notational conventions:** IPA symbols are used for transcriptions. However, I follow Smith's (1973) bracketing convention: slanted brackets '/ /' are used for phonemes of the target language (English); straight brackets '| |' represent phonemes of A's developing system; and square brackets '[ ]' represent phonetic realizations. I also use Smith's subscript dot diacritic (superscript on 'g') to indicate a 'voiceless lenis' articulation: i.e. [ḅ, ḍ, ġ].

0. Introduction

This thesis is primarily concerned with the acquisition of onsets, both singleton and cluster, as observed in one child learning English. The particular focus is on fricatives, with an attempt to account for the difference between the treatment of target /f/ and target /s/ in both onset types. The thesis begins with a presentation of the theoretical backdrop for the rest of the paper. Chapter 1 offers an overview of first language acquisition as well as introducing some of the commonly observed processes found in child language. In Chapter 2, I turn to general phonological theory. I outline the relevant aspects of feature geometry theory, present the specific geometry model I adopt, that of Brown (1997), and motivate that choice. This is followed by a return to acquisition, focusing on the feature-geometric approach to phonological development.

Chapter 3 marks the beginning of the case study itself. There I provide a summary of the first seven stages of Amahl's acquisition of singleton onsets according to the data in Appendix C of Smith (1973). Facing some unaccountable patterns in the treatment of /s/, I propose a phonetically-motivated constraint against lingual continuants and suggest that early articulatory difficulties with the pronunciation of /s/ trigger a repair strategy which gradually decreases in linguistic significance. That is, in the stages considered here, the first effect of the constraint is to delete the /s/ altogether; next, only the offending feature, [continuant], delinks; later, the /s/ is finally produced but it is phonetically longer than the target. The hypothesis of an articulatory constraint proves useful in accounting for the behavior of /s/ both in singleton and in cluster onsets.

Amahl's acquisition of onset clusters in the first seven stages is addressed in Chapter 4; here again the proposed constraint helps to account for the unique treatment of target /s/-clusters.

In Chapter 5, I present some data from later stages and demonstrate how they provide support for the constraint against lingual continuants. I show how the effects of this constraint weaken, phonologically speaking, as acquisition proceeds. Some possible implications of this sort of constraint are addressed in Chapter 6.

1. Overview of Acquisition

There has been a steady increase in the interest in acquisition data for phonological theory, especially with the more widespread acceptance of the assumption of continuity between child and adult grammars. The continuity hypothesis claims that although child phonologies are constantly changing, developing toward the target grammar, each change in the developing language conforms to universal principles; at no point in the acquisition process will a child diverge from these principles and use rules or constraints that never occur in adult languages. It must be the case, therefore, that any rule, process, representation, or constraint proposed for a child's grammar is also found in adult language (though not necessarily the target). This corresponds to what Macken (1995) calls the "strong identity hypothesis," which claims that the same fundamental capacity underlies child and adult speech, and language acquisition involves "enhancing" this capacity rather than learning it from scratch.

I likewise assume continuity in this thesis. In addition, I assume that throughout the acquisition process, input from target grammar directs the acquisition path within the confines set by Universal Grammar (UG). Specifically, each elaboration of the child's grammar brings it closer to the target grammar at some level. With respect to the phonology, Ingram (1996) has formalized this latter assumption at the segmental level in his Distinctive Feature Hypothesis (given in (1)), offering a straightforward check for avoiding incompatibility or discontinuity between the developing and developed grammars:

(1) The Distinctive Feature Hypothesis

Any feature assigned to a child's representation must be present in the target phonemes.

For example, Mike (from Pollock, 1983) produces [n] for target /n, w/ and [d] for target /d, s, ð/. There are two ways that the [n] vs. [d] contrast could be represented: i) with the feature [sonorant] – [n] is [+sonorant] and [d] is [–sonorant]; ii) with [nasal] – [n] is [+nasal], [d] is [-nasal]. According to the Distinctive Feature Hypothesis, however, only (i) is compatible with the input; (ii) does not capture the fact that [n] also substitutes for the [-nasal] target, /w/. On the other hand, [sonorant] captures the [n]/[d] contrast and at the same time is consistent with all the target phonemes: [n] is [+sonorant] like /n, w/, and [d] is [-sonorant] like /d, s, ð/ (Ingram, 1996). Only by referring to the Distinctive Feature Hypothesis can continuity be maintained in ambiguous situations like these.

1.1 Phonological processes in acquisition

It is well known in the study of first language acquisition that there is a significant amount of uniformity: that is, certain phonological processes are consistently observed both between languages and within a given language. These can be generally summarized under two categories: syllable-related processes (prosodic level), and segment-related processes (melodic level). The former have been described as driven by a UG-supplied, bimoraic Minimal Word template (Fee, 1995; Salidis & Johnson, 1997). The latter involve feature markedness issues and universal phonological processes. The following sections address each of these levels separately before considering their interaction.

1.2 Syllable-level processes

Fee (1995, 1996) and Demuth & Fee (1995, cited in Demuth, 1996) propose the following stages of prosodic development:

(2) Stage I — Core (CV) Syllables

Stage II — Minimal Words ($\sigma_\mu\sigma_\mu$ or $\sigma_{\mu\mu}$)

a. core syllables – (C)VCV

b. closed syllables – (C)VC

c. vowel length distinctions – (C)VV

Stage III — Stress-Feet

Stage IV — Prosodic Words

In Stage I, children produce what Fee (1996) calls "subminimal" words: monomoraic CV utterances, which tend to show variable length and tension in the vowel. At this stage, commonly-observed processes include Coda Deletion (3a) and Syllable Deletion (usually of the unstressed syllable; see (3b) for an example).

(3) a. coda deletion: 'dog' → [da]

b. syllable deletion: 'away' → [we]

At Stage II, the Minimal Word template requires the presence of two morae in every word. Very often, partial and total reduplication of a single CV syllable will be observed at this point (4a and 4b, respectively). Another common repair strategy, especially in Stage IIa, is epenthesis; for example, in (4c) a schwa is inserted to make the target word into a CVCV form.

(4) a. partial reduplication: 'Peter' → [bibə] (Fee, 1995)
b. total reduplication: 'bottle' → [baba]; 'father' → [fafa]
c. epenthesis: 'pig' → [pigə]; 'blue' → [bəlu]

By Stage IIb, coda segments are no longer deleted; however, consonant clusters are simplified, generally in favor of the least sonorous element (Fikkert, 1994) as in (5) below. The relative sonority of segments, or sonority hierarchy, will be presented in chapter 2 (sections 2.4 and 2.5); for the examples in (5) we can simply note that /s/ is more sonorous than /t/ and /l/ is more sonorous than /k/. Thus, /t/ and /l/ survive their respective cluster reductions.

(5) 'stop' →[tɑp]; 'milk' → [mik]

1.3 Segment-level Processes

On this level, the representation of distinctive features plays the key role. A more detailed discussion of the internal structure of segments can be found in chapter 2.1; here, I will only refer briefly to a few of the main points. First, I assume that segments do have internal organization, and are composed of features drawn from a finite, UG-supplied set. Second, these features are organized in a hierarchy which reflects both markedness (less hierarchical structure = less marked) and phonetic dependency relationships. Finally, as I discuss in chapter 2.3, I assume that UG supplies a minimal structure which is then elaborated in response to cues in the input. For first language acquisition, these assumptions account for the general observations summarized in (6), taken from Macken (1995:676):

(6) In general, the unmarked consonants:

a) are acquired first
b) are most frequent in the child's lexicon
c) have the fewest restrictions on their distribution
d) serve as replacements for the corresponding marked consonants during the stage when the contrast is neutralized.

The unmarked segments have the least hierarchical structure, therefore (6a); typologically, less marked segments are more common in the world's languages, likewise (6b); finally, neutralization of a contrast goes in favor of the less marked, thus (6d). In general, stops are less marked than fricatives and coronals less than non-coronals; acquisition processes associated with these have been called Stopping and Fronting, respectively (Ingram 1976, cited in Fee 1995):

(7) a. Stopping: 'juice' → [dut]; 'this' → [dɪ]
b. Fronting: 'go' → [do]

However, the situation is not as simple as the generalizations in (6) would make it appear. As acquisition progresses, phonological processes such as feature harmony, or assimilation, become more significant. For example, while [d] substituted for [g] in (7b), we find [d] assimilating to [g] in (8). These kinds of examples have often been used to support theories of feature underspecification both in acquisition and in adult languages.

(8) 'desk' → [gɛk] (Smith, 1973)

Assimilation is quite widespread in child language; the examples in (9) show how it can be adjacent or non-adjacent, progressive or regressive:

(9) a. Adjacent assimilation
progressive: 'bump' → [bumb]
regressive: 'sweet' → [fweet]
b. Non-adjacent assimilation
progressive: 'doggie' → [gɑgi]
regressive: 'noisy' → [nojni]

In these cases, there could be more than phonetic assimilation at work. Possibly, at this stage of development there is a restriction at some level against having more than one Place or Manner feature specified. This restriction could trigger assimilation as a repair strategy, but it does not itself select which segment must assimilate; that, presumably, is chosen according to universal rules of feature spreading (see chapter 2.2)

1.4 Interaction between syllabic and segmental levels

Much attention has recently been paid to the ways in which the syllabic and segmental levels interact in acquisition. In a very general sense, it can be said that they do interact, and that prosodic structure does influence segmental elaboration. Slobin (1973) observed that some prosodic positions were more salient to children, and summarized his observation in the phrase, "children pay attention to the edges of words". The interplay between syllable and segment acquisition is illustrated quite clearly in metathesis (the reversal of sounds within a word), another process often observed in child language. Examples of metathesis are supplied in (10).

(10) a. 'spaghetti' → [pəsgɛDi]
b. 'animal' → [amənal]

In (10a), a consonant cluster which violates the Sonority Sequencing Principle (see chapter 2.4) is dealt with through metathesis (thus correcting the violation) as well as epenthesis (reducing the onset members to one). Alternatively, (10a) could be seen as the result of a feature alignment constraint which motivates the movement of [labial] to the left edge of the word. This latter proposal can also account for the metathesis in (10b). Such feature alignment patterns have been noted by several researchers. For example, Fee (1995) notes that segments are first pronounced target-like in syllable-initial position; Macken (1996) in a similar vein discusses how marked features emerge first (and most accurately) word initially. Velleman (1996) deals specifically with metathesis in an OT framework, attributing it to the ranking of feature alignment constraints relative to constraints involving faithfulness to the input. Dinnsen (1996) argues that feature markedness depends on syllable position, and demonstrates compatibility and continuity between child and target language using Kiparsky's (1993) context-sensitive radical underspecification.

Since evidence exists for the context-sensitivity of features, in my analysis of A's inventory I have restricted my attention to a single syllable position: in order to avoid the complications of context effects, only word-initial onsets were considered. This decision is partly motivated by the assumption that a feature can be contrastive in one position but not in another. Evidence that this is in fact the case can be found from pairs like those in (15), which show that at the same stage in Amahl's acquisition (stage 8), [voice] was contrastive in codas (15a) but not in onsets (15b).

(11)	a.	[lɛġ] 'leg'	vs.	[luk] 'look'
	b.	[d̥ɔi:] 'toy'	vs.	[d̥aun] 'down'

To summarize: this chapter has presented some of the commonly-observed ways in which child language deals with difficult aspects of the target language. Given the theoretical importance of the continuity hypothesis, an effort has been made to relate the child and target languages in terms of repair strategies such as deletion, epenthesis and assimilation. In the next chapter, I turn to the relevant areas of linguistic theory which aim at accounting for observations like the ones summarized thus far.

2. Theoretical Background

In this chapter, I summarize the theoretical assumptions which form the backbone of my analysis of the data in the following chapters.

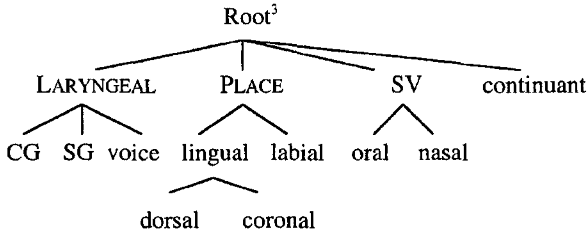
2.1 Internal structure of the segment[2]

Following a common approach in phonological theory, I begin with the assumption that phonological features are not unordered bundles, as in SPE, but are organized in a UG-defined structure known as the feature geometry. While several different models have been proposed, the formal properties of the geometry are generally constant. The particular model I will assume is adapted

[2] Some of the material in this chapter has appeared in an earlier form in Hanson (to appear)

according to Brown's (1997) revisions of the Rice & Avery (1995) geometry. In Section 3 below I will address this model more closely. Note, however, that I do depart from Brown (1997) in placing [voice] as an explicit dependent of the Laryngeal node; this decision is based on acquisition data, and will be motivated in detail in chapter 5.

(12)



As first proposed by Clements (1985), and modified in Rice & Avery (1991), there are two major node types beneath the Root node, which gathers together the segment as a unit. Organizing nodes, indicated by small caps in (12), generally correspond to the anatomy of the vocal tract, and organize features into natural classes or constituents. They dominate the content nodes, which have actual articulatory status such as 'Labial' or 'Spread Glottis', and which in turn may dominate secondary content nodes or terminal features. I adopt the stance that these features are monovalent, with contrasts represented through the presence or absence of a node rather than through binary '+' and '-' values. I further assume that redundant or predictable features, as determined by universal markedness patterns, are absent from underlying representations – that is, they are underspecified – and may be filled in at the level of phonetic implementation by a default fill-in rule.

Within the geometry, nodes are hierarchically related to each other in a dependency relationship. In (12), for example, [spread glottis] is a dependent of the Laryngeal node; this reflects the fact that the activity of the feature [spread glottis] entails the activity of the Laryngeal node. The choice for encoding a particular relationship as one of dependency can be motivated by phonetic

[3] CG = [constricted glottis]; SG = [spread glottis]; SV = Sonorant Voice

considerations (as with the previous example) or by phonological patterns, which are often best captured through underspecification. For example, typologically, the presence of labials and velars in a system implies the presence of coronals; this pattern is reflected in most geometry models by designating [coronal] as the default interpretation of the Place node. In other words, in the unmarked case, coronals are represented with a bare Place node and the feature [coronal] is not specified until phonetic implementation (for further discussion see Paradis & Prunet (eds), 1991).

Finally, the feature geometry is universal, able to capture all existing phonological systems, though no one language will exploit the entire structure.

2.2 Phonological processes

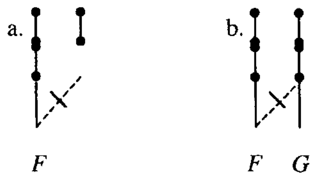
An important advantage of the feature geometry over linear models is the ability it has to capture a wide range of phonological processes with a limit set of well-defined operations. These operations are commonly gathered under three types: Spreading, Delinking, and Fusion (Avery & Rice 1989).

The process of Spreading is schematized in (13) and its general conditions, as summarized by Avery & Rice, are given in (14).

(13)

(14) a. Spreading can occur only if a structural target is present
b. A feature or node can spread only to an empty position

Adopting this view of Spreading (others exist; see for example Steriade 1987) has important implications for my approach to A's data. For example, (14a) rules out any analysis that relies on node generation, such as the spreading of [oral] to a segment that lacks an SV node. (14b) further limits Spreading to a feature filling role rather than a feature changing one ; in other words, it cannot trigger the delinking of a feature that is a dependent of the same node. (15) below illustrates some situations where Spreading fails according to (14): in (15a), the feature (F) fails to spread because the structural target is absent; in (15b) it is because the target position is already filled by another feature, G.

(15) 

"Delinking" refers to the operation that breaks an association line between a feature or node and its superordinate node. It is commonly used to account for instances of neutralization such as word-final devoicing, which involves delinking the Laryngeal dependents in a specific environment (Avery & Rice 1989).

Finally, Fusion is an OCP-driven operation, reducing two identical adjacent elements to one. Avery & Rice define fusion as "an operation which takes identical primary content nodes and fuses them provided that the nodes are non-distinct; i.e. both do not dominate different secondary nodes." Fusion, or coalescence, will not be important in the analysis presented below; however, it has been an important process in other analyses of onset cluster reductions. For example, Hanson (1999) proposes a fusion analysis of A's acquisition of /s/-clusters; Chin & Dinnsen (1992) offer a two-step version of feature coalescence, which they analyze as involving first Spreading and then deletion or degemination; and Gnanadesikan (1995) looks at coalescence in onset clusters from an Optimality Theoretic perspective.

2.3 Acquisition of the feature geometry

If the feature geometry is, as I assume, a reasonable model of phonological representation, any proposed hierarchy must also be able to account for language acquisition. It is particularly important that a model do so without violating the principles of learnability and continuity that are important to all areas of child language theory.

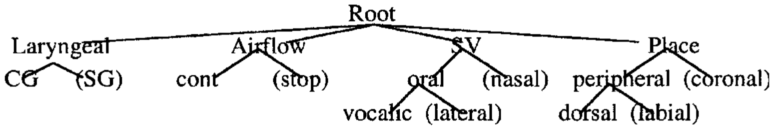
There are two main theoretical approaches to the acquisition of the feature geometry, which Brown (1997) refers to as the "Pruning" and "Building" hypotheses. The Pruning hypothesis assumes that UG supplies a fully differentiated structure like the one in (12) above, capable of representing all possible phonological contrasts. As the child realizes that not all of these possible contrasts are used in the ambient language, the unnecessary structure is "pruned" away. A closely related proposal is what Rice & Avery (1995) call the "full specification" approach to segmental acquisition, which claims that the segments themselves are acquired as units, fully specified for its particular universal features. Underspecification can still be achieved, however, by later pruning away the features that are redundant in that particular system. A disadvantage of the pruning approach is that it relies heavily on negative evidence: adjustments are made to the developing geometry only when it becomes clear that a given contrast is not relevant, or that a given feature is redundant, in the target grammar.

According to the Building Hypothesis, on the other hand, UG supplies only a minimal structure, which is elaborated in response to positive evidence of a relevant contrast in the input. In addition, the geometry is expanded in a step-by-step fashion, or monotonically.

Like Brown and Rice & Avery, I adopt the Structure Building approach; in addition to its reliance on positive evidence, it best captures both the uniformity and the variability so often observed in language acquisition. The uniformity is a result of the deterministic aspect of the geometry when approached with a structure-building view: a higher node (e.g. an organizing node) must be acquired before any of its dependents (e.g. content nodes and/or features). Variability appears due to the individual child's freedom to begin acquisition at any organizing node, and to continue by elaborating either within or outside that node. In other words, the acquisition process is constrained in the general order, but free in the specifics.

Recently, acquisition studies have begun to play an important role in evaluating proposed feature geometry models. As I mentioned in section 2.1 above, the geometry I will adopt here was originally proposed by Rice & Avery (1995) specifically to account for child data, and was revised by Brown (1997) on the basis of further acquisition research. The proposed revisions were to the SV and Place node. For comparison with (12), the Rice and Avery geometry is supplied in (16).

(16) Rice & Avery (1995)



cont = [continuant]; CG = [constricted glottis]; SG = [spread glottis]; SV = Sonorant Voice; brackets indicate default interpretations

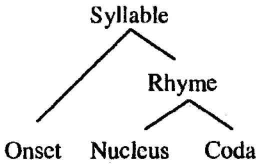
The most obvious difference between (12) and (16) is the lack of the Airflow node in (12). Since the status of this node, proposed by Rice and Avery, is still uncertain and does not figure crucially in this work, I have left it out of the adopted model (12). The revisions of the SV node are not important in this thesis and will not be addressed here except in noting that they were motivated by acquisition data.

The revisions to the Place node, however, will be especially relevant in chapter 3 below. A comparison of (12) and (16) indicates that Brown has dramatically revised Rice & Avery. Like for the SV node, this revision was motivated by acquisition data: many children acquired a labial/velar contrast before acquiring the coronal/non-coronal contrast, an observation which cannot be predicted from the Place node structure in (14). Therefore, Brown departed from Rice & Avery, proposing that the lingual articulations, [coronal] and [dorsal], should be grouped together as opposed to [labial], similar to independently motivated articulation-based geometry models such as Browman & Goldstein's (1986, 1989).

2.4 Internal structure of the syllable

In line with current phonological theory, I assume that the syllable is a phonological constituent, and that it has internal structure. As with the feature geometry, there are several different models of syllable-internal structure (see Blevins, 1995, for a summary); in this paper I will adopt the model presented in (17), though the details of the structure are not crucial.

(17)



Each of the lowest subcomponents – onset, nucleus and coda – can optionally branch, allowing for consonant clusters (branching onset or coda) or for long vowels and diphthongs (branching nucleus).

The syllable has been referred to as a phonological domain containing exactly one sonority peak (Blevins 1995). The importance of sonority in constraining the possible sequences of segments within a syllable has been repeatedly confirmed in phonological research. While it is not altogether clear what the phonetic correlate of sonority is (beyond a general reference to acoustic saliency), in phonological terms it is possible to rank segments according to their sonority. A typical sonority hierarchy for English phonemes is given in (18).

(18) sonority scale (adapted from Carr 1993)
vowels > j, w > r > l > m, n > ð, v, z, ʒ > θ, f, s, ʃ > b, d, g > p, t, k

That is, vowels are the most sonorant segments, and sonority decreases towards the voiceless stops, which have the lowest sonority value. Of particular relevance here is the role of the Sonority Sequencing Principle (SSP, also called the Sonority Sequencing Generalization) in determining what is and is not a possible onset cluster. A version of the SSP is provided in (19), taken from Blevins (1995).

(19) Sonority Sequencing Principle
Between any member of a syllable and the syllable peak, a sonority rise or plateau must occur.

In other words, sonority rises towards the nucleus of the syllable, with the preference being that the edges of the syllable will have the lowest sonority possible. However, as we will see in Chapter 4, sonority isn't always respected. In particular, /s/ is notorious for violating the SSP; for example, /s/-stop clusters (e.g. /sp, st, sk/), the more sonorant /s/ is further from the nucleus than the stop and yet these clusters are very common in the world's languages. The problem of /s/ in clusters has been extremely persistent; it continues to be a theoretical puzzle and has been dealt with in various ways. Clements & Keyser (1983) propose that /s/ is extrasyllabic and thus is not part of the onset at all; a similar view is taken by Kaye et al. (1990), who claim that /s/ is in the coda of a null syllable preceding the other 'cluster' members. Phonetically, /s/ could be granted "quasi-syllabic" status because it compares to typical syllable nuclei in its acoustic salience and intrinsic length (Dobrovolsky, p.c.). This quasi-syllabic behavior shows up, for example, in English paralinguistic utterances like 'psst'. In this thesis, I propose that the precision necessary for its articulation can also contribute to the unusual behavior of /s/.

2.5 Acquisition of syllable structure

In an extensive study of the acquisition of syllable structure in Dutch, Fikkert (1994) found that the SSP played a central role in onset cluster reduction, and that acquisition seemed to follow a sonority-directed path. The various acquisition paths she recorded can be resolved into two main strategies, given in (20).

(20) a. Maximize sonority distance between onset and rhyme
b. Maximize sonority distance between members of the onset cluster

(20a) captures the tendency for the least sonorant member of the target onset to survive cluster reduction (cf. (5) in chapter 1.2); (20b) captures the observation that when onset clusters are produced by the child, there is a tendency for the elements of the cluster to be as far apart in sonority value as possible even if that causes a divergence from the target.

Up to this point, we have looked at observational patterns of L1 acquisition (chapter 1) and presented relevant aspects of linguistic theory (this chapter). Beginning with the next chapter, the remainder of this thesis will be devoted to a single case study, looking in detail at one child's early stages of onset acquisition.

3. The Acquisition of Singleton Onsets

This chapter looks in detail at the early steps taken by one child in the acquisition of singleton onsets. The data is taken from Smith's (1973) diary study of Amahl (henceforth 'A'), with a focus on the first seven stages as delineated by Smith.

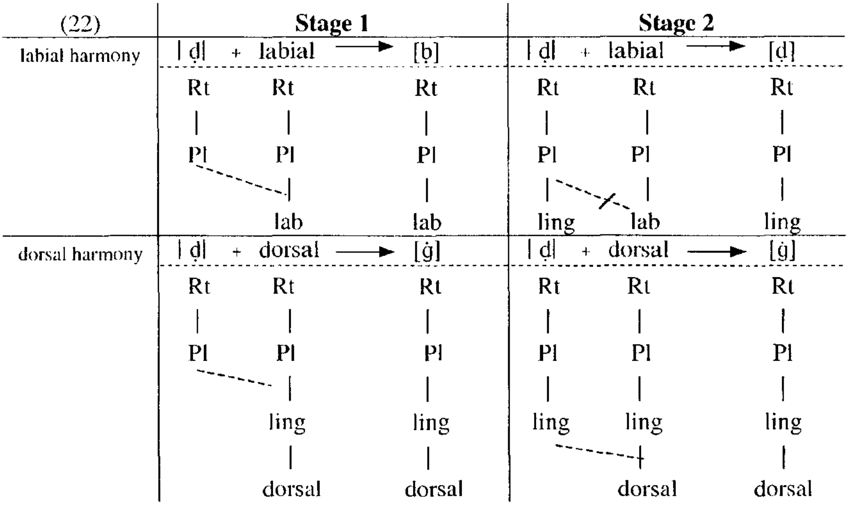
3.1 Summary of the data

When Smith's study begins, A has already made some progress towards the target geometry. A survey of his productive inventory through stages 1-7 is provided in (21) along with the target phonemes that each segment replaces; on the far right is the feature which, according to the Distinctive Feature Hypothesis (see (1) in Chapter 1 above), is assumed to be specified on the given segment.

(21)	**Amahl**	**Target(s)**	**Feature**
a.	| b̥|	/p, b/ - also /t/, stage 1 only	[labial]
b.	| d̥|	/t, d, s, z, l/	([lingual])
c.	| g̊|	/k, g/ - also /s/ and /l/ under harmony	[velar]
d.	| w|	/f, w/ - also /s/ and /l/ under harmony	[cont]; [labial]
e.	| m|	/m/	[nasal]; [labial]
f.	| n|	/n/	[nasal]

To explain the parentheses in (21b): in Stage 1, there is one instance of target /t/ being realized as [b̥] (e.g. [b̥ebu] 'table'), though by Stage 2 /t/ resists labial harmony while still being subject to velar harmony (e.g. [g̊e:k] 'take'). I assume, then, that at Stage 1 the coronal stop was represented with a bare Place node, thus being vulnerable to the spreading of any Place features. At Stage 2, however, [lingual] is specified; from that point on spreading is blocked in the case of [labial] but not [velar], which is also a dependent of [lingual]. This development of the Place node is illustrated in (22).

(22)

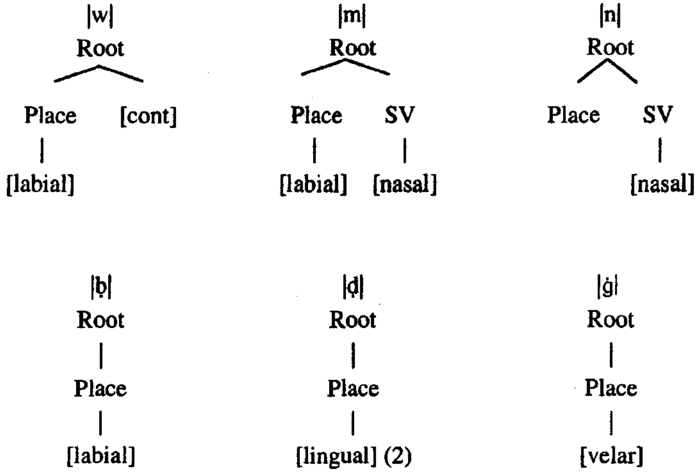


Using the Rice and Avery model (see chapter 2.3.2), it is not clear how to capture harmony in which [velar] but not [labial] can spread to an underspecified coronal.

From the information in (21), we can see that A has elaborated the Place node to distinguish the three major places of articulation. The SV node, with its [nasal] dependent, is also contrastive. Note, however, that A's |w| cannot be specified [SV], since target /f/, which it substitutes for, is not [SV]. I assume, therefore, that |w| has been analyzed as a labial continuant which is phonetically realized by A as an approximant. Obstruent voicing is not yet contrastive.

The underlying representations of each of (21a) – (21f) are provided in (23) below to illustrate the parts of the geometry A is working with at this point. In (23b), the feature [lingual] is absent at Stage 1 but present from Stage 2 onward. This same feature is deliberately absent from the coronal nasal (23f) out of preference for underspecification: even without an elaborated Place node, |n| is distinct from the rest of A's inventory.

(23)



With this information about the correspondence between A's phonemes and the target ones, we can now look more closely at his phonological system. Substitution patterns in particular can provide valuable insights into this system; the next few sections therefore will focus on A's substitutions for target /s/ and /l/.

3.2 The split realization of /s/

Target /s/ shows an interesting pattern of replacement by A. We saw in the previous section (in (21) above) that /s/ can be realized predictably as [ḍ], [ġ] or [w]. The examples in (24) illustrate.

(24)	a.	'see' [ḍiː]		'side' [ḍaiḍ]	
	b.	'sock' [ġɔk]			
	c.	'soft' [wɔpt]		'same' [weːm]	

In (24a) and (24b), we see /s/ realized as a stop, coronal in isolation or in a coronal environment, and velar in a velar environment. So far, it seems like this is straightforward consonant harmony, with /s/ underlyingly no different from the coronal stop in terms of both manner and place features. This hypothesis is strengthened when we look at the realizations of /t/ (25) in coronal and velar environments: they are identical with the realizations of /s/.

(25) a. 'tie' [ḍai] 'tight' [ḍait]
b. 'talk' [ġɔk]

However, when we look at the labial environment, there is an unexpected divergence. In (24c) above, we saw that target /s/ is realized as [w] if [labial] is specified in the same word. With the target /t/, on the other hand, we find the expected labial stop [ḅ] as the output (26).

(26) 'table' [ḅe:bu]

Furthermore, recall from section 3.1 above that the coronal stop assimilates to the labial only in this one instance in all of Smith's database – and only for the first stage. By Stage 2, labial harmony no longer applies to the stops. For /s/, however, labial harmony continues until Stage 10. Clearly, then, /s/ and /t/ are different for A, as illustrated in the following summary of their respective substitution patterns (note that these are not intended as formal rules; the format is used for convenience only):

(27)	/s/ → [w]/ __ (...) [labial]	/t/ → [ḅ] / __ (...) [labial] (Stage 1 only)
	→ [ġ] / __ (...) [velar]	→ [ġ] / __ (...) [velar]
	→ [ḍ] elsewhere	→ [ḍ] elsewhere

Although they are only distinct in one environment, the fact that /s/ and /t/ are subject to different substitutions indicates that they must have different underlying representations. However, it is surprisingly hard to pinpoint exactly what the underlying difference is: since /s/ is realized as [ḍ] in non-harmony conditions, it seems that it must have a UR identical with that of [ḍ]. Likewise, the fact that both emerge as the velar stop [ġ] under velar harmony confirms this hypothesis. Unfortunately, /d/ becomes [ḅ] under labial harmony, while /s/ becomes [w] – so perhaps /s/ is underlyingly [continuant], distinguished from [w] only by place features. Why, then, should it be realized as [ḍ] in isolation?

There are two features to which we could reasonably attribute the divergence between /s/ and /t/ under conditions of labial harmony. First, the feature [labial] itself is obviously important. The other relevant feature is [continuant], since it distinguishes the two output forms, [w] and [ḅ]. In order to better understand how these two features contribute to A's treatment of /s/, it would be helpful to try to account for his choice of substitutions; in the next section, one possible account is brought forward and evaluated.

3.3 A Constraint against lingual continuants

The following proposed account for the realization of /s/ makes crucial use of Brown's (1997) revision of the Place node. Recall from chapter 2.3.2 that in this model, [coronal] and [velar] are subsumed under the node [lingual], which along with [labial] is a direct dependent of the Place node. Both |ḍ| and |ġ| are specified for [lingual], while |ḅ| is not (rather, [labial]).

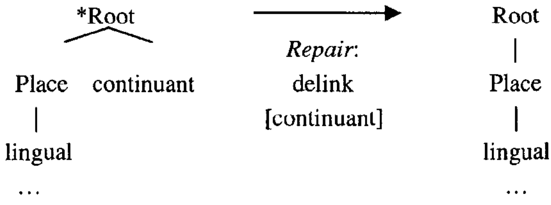
I propose that the split substitution of /s/ can be accounted for by positing a low-level, articulatory constraint against lingual continuants; under this proposal, lingual continuants are targeted for repair for articulatory reasons. Thus, the proposed constraint has a phonetic motivation: it is easier to articulate a labial approximant continuant than a coronal (or dorsal) fricative continuant, since fricatives require greater precision in their articulation (Ladefoged & Maddieson, 1996:329). The consequent repair could come in the form of delinking [continuant], as discussed immediately below, or by deleting the /s/ altogether – as, for example, in the stage 1 productions of 'soap' and 'soup':

(28) 'soap' [u:p] 'soup' [u:p]

The strategy of deleting /s/ will appear again in A's reduction of /s/-clusters (chapter 4); for now, let's look more closely at the implications of the proposed constraint.

Under this hypothesis, |s| is in fact specified as [continuant] underlyingly. However, it can only surface as a continuant if it is non-lingual (i.e. [labial]) – that is, under conditions of labial harmony – since at the level of phonetic implementation, any representation specified for both [continuant] and [lingual] will be repaired by delinking [continuant]. This is illustrated in (29), where the asterisk on the left indicates that the structure is (temporarily) disallowed in A's system.

(29)

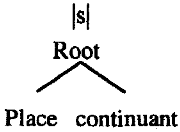


It is reasonable to assume that [continuant] should delink rather than, say, the Place node, for two reasons. First, A's system already includes lingual non-continuants, so the repaired structure is consistent with his phonology; this would not be true if Place delinked since /h/ (the Placeless continuant) has not been acquired and /l/ has its own difficulties (see 3.4 below). Second, it is [continuant] that is causing the phonetic difficulty: A has no difficulty producing stops at all places of articulation. Thus, delinking [continuant] is the simplest way to repair the offending representation. It is important, however, to note that delinking is not triggered for labial continuants, which do not require such fine motor control to articulate.

With this foundation laid, the split replacement of /s/ can be accounted for in the following way. Recall that /s/ becomes [w] only if [labial] is present within the same word. This substitution, at first glance, appears to be easy enough to account for under the current hypothesis: it is simply due to feature spreading. Since the result of spreading yields a geometry containing [labial] and [continuant], (29) does not apply and the target /s/ is realized as a labial continuant: [w]. However, this solution raises another problem: how can [labial] spread to the position already occupied by [lingual]? Only a feature-changing operation could accomplish this, but in a theory of monovalent features as we are assuming here it is preferable to limit Spreading only to a feature-filling role (Brown, 1997). Thus, an account which avoids feature changing is to be preferred over one that depends on it.

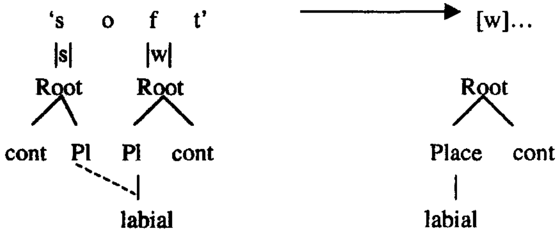
In this case, it is relatively simple to avoid the feature-changing operation, if we assume that in A's system |s| is represented as in (30), with a bare Place node (compare the proposal for |n| in (23) above):

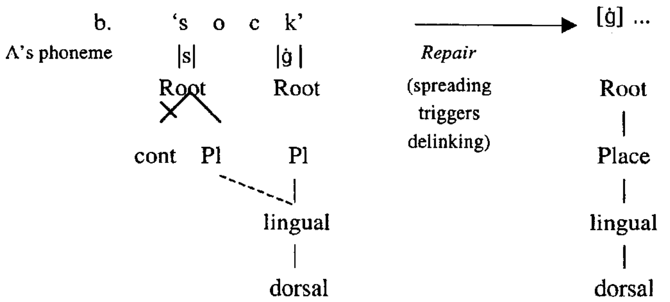
(30)

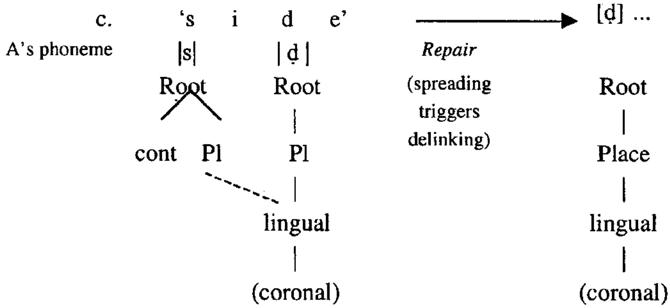


Further Place specifications are received either through Spreading (of [lingual] plus dependents, or of [labial]) or through a default fill-in rule providing [lingual] and implemented as [coronal]. If Spreading provides [labial], |s| is realized as [w], as in (31a). If Spreading provides [lingual]-[dorsal], the structure qualifies for repair and [continuant] delinks, yielding the dorsal stop [ġ] as in (31b). Finally, if Spreading (or the default rule) provides [lingual]-[coronal], again the repair strategy applies, yielding the coronal stop [ḍ] as in (31c). Note that in this hypothesis we are committed to order the default rule before the repair strategy.

(31) a.
A's phoneme







We will find some further support for the proposed constraint against lingual continuants in chapter 4, from the behavior of /s/ in cluster reduction strategies. Now, let's look briefly at A's treatment of /l/, which is quite similar to that of /s/.

3.4 The realization of /l/

The situation of target /l/ is even more difficult to pinpoint than that of /s/, especially because of the widespread disagreement in the literature regarding the representation of laterals. Levin (1988), Rice & Avery (1991), Piggott (1992, 1993), Yip (1990) and Brown (1997) all propose different models to account for various patterns in the crosslinguistic behavior of lateral segments. Brown (1997) provides a survey of the existing versions, and proposes that the feature [lateral] is not a phonological primitive; instead, laterals emerge phonetically from a certain combination of features (i.e. a bare Place node plus either the SV node (for sonorant [l]) or the Airflow node (non-sonorant [ɬ])). Because these feature combinations can easily be produced by spreading operations, in acquisition data it is difficult to discern whether a surface lateral is contrastive or simply the result of consonant harmony. As we will see in a moment, A's acquisition data do not make the problem of laterals any easier to solve. Let's begin, then, by simply noting the different realizations of target /l/ in these early stages; these patterns will prove important in chapter 4.

Table 1 organizes some representative examples of A's substitutions for target /l/ in different feature environments. Unfortunately, there are no words available to illustrate /l/ in isolation; 'lady' and 'lazy' come the closest with only coronals in the word. 'Lamp' and 'left' illustrate the realization of /l/ in the presence of [labial], while 'lick' and 'leg' illustrate the [velar] environment. Blank cells in the table indicate stages where no data is available and '>' indicates that the onset has reached consistent target production.

Table 1: A's production for target /l/ in various environments

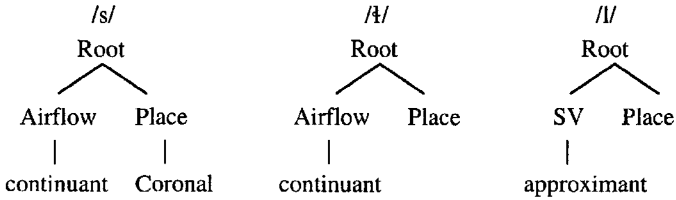
	Stages						
Example	1	2	3	4	5	6	7
'/l/ady'	d̥	d̥/l		l >			
'/l/azy'	d̥			l >			
'/l/amp'					w		
'/l/eft'			w				
'/l/ick'				ġ			ġ/l
'/l/eg'	ġ						

From this table we can see that there is a striking similarity between A's treatment of /l/ and that of /s/. Both harmonize to place of articulation, with the same output: [w] under labial harmony, [ġ] under velar, and [d̥] in the presence of coronals.

Using the Optimality Theory framework, Goad (1997) addresses in detail A's treatment of /l/ in these harmony environments. To account for the patterns, Goad offers the following proposal: while [labial] and [approximant] can be licensed on a single segment [coronal] (or [dorsal]) and [approximant] cannot. Taking into account the functional equivalence between the features [continuant] and [approximant] (Brown 1997), this proposal is practically identical to the constraint proposed here, which permits labial but not coronal and dorsal continuants.

The similarities between /s/ and /l/ in A's system are intriguing; unfortunately, a more detailed look at them would go beyond the scope of this thesis. However, further research might find an advantage in using Brown's model, in which the representations of /s/ and the laterals are very similar:

(32)



Because of his nearly identical treatment of target /s/ and /l/, the patterns in A's data support the approach in (32) more than one in which [lateral] is a feature dependent on the SV node and /l/ has little or nothing in common with /s/.

4. The Acquisition of Onset Clusters

Given the proposals in Chapter 3 for A's geometry elaboration in these early stages, I now turn my attention to his acquisition of onset clusters. Again, the data is taken from stages 1 to 7 in Smith (1973). Since target complex onsets are not acquired until stage 9, we can expect to find A employing consistent repair strategies to deal with this deficit. We can also expect to gain more information regarding the underlying representations of segments in A's inventory by looking at how different segments interact with each other and with the available syllable structure.

4.1 A's onset simplification

Before looking in detail at these early stages in A's acquisition of onset clusters, I want to draw attention to the fact that stop- and fricative-initial clusters are not treated the same way. The division between the two types of obstruent-initial cluster is illustrated in (33) comparing 'play' versus 'fly' and 'slide'.

(33) a. 'play' [b̥ei]
b. 'fly' [wai] 'slide' [lait]

The stop-initial cluster /pl/ is reduced to a plosive, while the fricative-initial /fl, sl/ is apparently reduced in favor of the sonorant. This latter reduction is especially interesting, since it goes against the preferred sonority sequencing. As discussed in chapter 1.2 above, acquisition is expected to follow a sonority-directed path; that is, onset cluster reductions should be in favor of the least sonorous element in order to maximize the sonority rise between onset and nucleus. From (33) we see that the stop-initial clusters conform to this generalization, but the fricative-initial clusters do not. Thus, in the following sections I will address each of these separately.

4.2 Stop-initial clusters

A's stop-initial clusters follow straightforwardly along the predictions of sonority, and so do not require much discussion. Representative data for all the target stop-initial clusters are provided in Table 2. Note that in each case it is the plosive that survives the reduction while the more sonorant liquid is deleted. From (33b) above we know that this pattern is not due to an inability to produce onset liquids and can best be attributed to the SSP.

Table 2. Reduction of target stop-initial clusters

Example	Target cluster	A's production
'play', 'black'	/pl/ or /bl/	[b̥]
'precious', 'bread'	/pr/ or /br/	[b̥]
'tray', 'drive'	/tr/ or /dr/	[d̥]
'clean', 'glue'	/kl/ or /gl/	[g̊]
'cloth', 'green'	/kr/ or /gr/	[g̊]

The lack of voicing contrast that we saw above (chapter 3.1) in the singleton onset stops appears here in the clusters as well. It is reasonable to assume, then, that A repairs the target clusters simply by deleting the sonorant; the remaining stop is, as expected, specified only for place of articulation.

4.3 Fricative-initial clusters

The fricative-initial clusters are not so simple to deal with: not only do they seem to reduce contrary to sonority expectations, in this section we will see that not even all fricative clusters behave the same way.

It turns out that the /f/-clusters are the easiest to address, so we will start with them. Although their substitute, the highly sonorant [w], is unexpected, at least it is always the same. As Table 3 illustrates, regardless of the second member of the cluster, and regardless of the featural environment, /f/-clusters are always reduced to [w].

Table 3. Reduction of target /f/-initial clusters (Stages 1-7)

Example	A's production
'/fl/ag'	[w]
'/fl/ower'	[w]
'/fr/uit'	[w]
'/fr/og'	[w]

Recall that singleton /f/ was also realized as [w]; it looks, then, like /f/ clusters are treated just like the stop-clusters we saw in 2.1 above. That is, they are reduced in favor of the less sonorant element (/f/), which is then treated exactly as if it were a singleton onset. The [w] cannot be the realization of the liquid, since /l/ is realized as [w] only in the presence of a labial (/r/ behaves the same way in this matter). From examples like 'flag' and 'fruit', then, we can conclude that it is the /f/, not the liquid, which survives the reduction: the liquid would have been realized as [g̊] in 'flag' and as [d̥] in 'fruit'.

There is an alternative analysis, which allows that it is the liquid that survives. Since /f/ is labial, it is possible that the feature [labial] spread from /f/ to the liquid, yielding [w] as with singleton /l/. Subsequent deletion of the /f/ would leave just [w] in the onset as observed. However, this analysis is less favored for two reasons. First, it is more complicated than the previous analysis, involving a rule ordering of consonant harmony before deletion rather than simply deletion;

and second, it contradicts the SSP while the previous analysis followed the predictions of sonority. It is more reasonable to assume that the liquid was deleted due to a preference for a sharper sonority rise from onset to nucleus; the fact that the actual output, [w], does not conform to sonority preferences is simply a consequence of A's phonological system at this point.

Now, let's turn to /s/-clusters. Singleton /s/ onsets, we saw, acted differently from both stops and /f/ - or rather, acted like both, depending on the environment. In terms of cluster reduction, however, stop- and /f/-initial clusters behaved the same way; does /s/ conform to the pattern, or does it diverge again?

As we will soon see, /s/ is once again treated differently than we might expect. Since /s/, like /f/ and the stops, is assumed to be lower in sonority than liquids, nasals and glides, we would expect to find that /s/ is consistently the survivor of reduction for /s/-sonorant clusters. For /s/-stop clusters, on the other hand, we would expect the stop to survive. Unfortunately for sonority considerations, this is not the actual pattern.

Table 4 below summarizes A's output for each target /s/-clusters (only two-member clusters are addressed).

Table 4. Reduction of target /s/-initial clusters (Stages 1-7)

Target cluster	Example	A's production
/sp/	'spit'	[ḅ]
/st/	'stay'	[ḍ]
	'stuck'	[ġ]
	'stop'	[ḍ] / [ḅ] (stage 1 only)
/sk/	'sky'	[ġ]
/sl/	'sleep'	[w]
	'slide'	[l]
	'slug'	[l]
/sm/	'small'	[m]
/sn/	'snail'	[n]
	'snake'	[ŋ]

Before discussing the information in Table 4, it would be useful to recall the substitution patterns of each relevant segment when it is alone in the onset. These patterns are summarized in (34).

(34) a. /s/ → [w]/ ___ (...) [labial]
→ [ġ] / ___ (...) [velar]
→ [ḍ] elsewhere

b. /p/ → [ḅ]

c. /t/ → [ḅ] / ___ (...) [labial] (Stage 1 only)
→ [ġ] / ___ (...) [velar]
→ [ḍ] elsewhere

d. /k/ → [ġ]

e. /l/ → [w]/ ___ (...) [labial] (simplified)
→ [ġ] / ___ (...) [velar]
→ [ḍ] elsewhere

f. /m/ → [m]

g. /n/ → [n]

Now we are in a better position to evaluate A's reduction strategy. First, consider the /s/-stop clusters in Table 2. These are realized as unvoiced stops, which is not surprising since both /s/ and stops are usually produced that way; but we do have evidence that it is in fact the stop which survives cluster reduction. The crucial example is 'stop', where /st/ is realized as [ḍ] (alternating with [ḅ] at stage 1) in the environment of [labial]; this is how /t/, but not /s/, acts in a singleton onset. Assuming that A employs the same strategy for all /s/-stop clusters, we can thus conclude that these clusters are reduced in favor of the stop. So far, sonority predictions are borne out just as with stop- and /f/-initial clusters.

The surprises show up in the /s/-sonorant clusters. Turning now to target /sl/, once again it appears that we will not be able to tell which of the two cluster members remains, since /s/ and /l/ are so much alike in their behavior at this point. With 'sleep', for example, it is unclear how to determine which one of the members is ultimately being realized as [w]; both are equally likely candidates. Again, however, there is more explicit information available from other examples.

'Slide', which is produced with an [l] onset, doesn't prove very helpful. At the point when this production of 'slide' was recorded, both /s/ and /l/ are known to surface as [l]:

(35)	'slide' → [lait/d̥ait]	'sit' → [lit]
	'light' → [lait]	'little' → [d̥idi:/lidi:]

However, since it was more usual for /l/ to become [l] than for /s/, we can tentatively propose that it is /l/ which survives the reduction – though more support is certainly necessary.

That support comes from considering A's production for target 'slug'. This word was first recorded at stage 10, unfortunately outside the current range of stages, but still useful – particularly when we take into account the realizations of target /s/ and /l/ by that point. At stage 10, /s/ is no longer ever realized as [l], but /l/ always is. Thus, since /sl/ug surfaces as [l]ug, we can assume that the /s/ is deleted and the more sonorant /l/ is retained. Again, assuming that A's phonological system is consistent, we can hypothesize that all /sl/ onsets have been repaired in this way.

This hypothesis gains strength when we look at /s/-nasal clusters. From Table 4 we know that these clusters surface as a nasal; thus, there is sufficient evidence to propose that all /s/-sonorant clusters are reduced in favor of the sonorant. This is, according to sonority, a dramatic difference from the treatment of all other onset clusters and deserves a closer look.

4.4 /s/-clusters and the constraint against lingual continuants

From the /s/-clusters it is apparent that sonority sequencing is not the only factor in determining which member of the onset will survive reduction: regardless of whether the output maximizes the sonority curve, /s/ is deleted. However, we saw with the other onset clusters that the SSP was the deciding factor. The fact that /f/-clusters obeyed the SSP while /s/-clusters did not is further support for the hypothesis that /s/ itself is problematic for A (rather than, say, fricatives in general). Thus, if we assume that there is a phonetically-motivated constraint against lingual continuants, the unique treatment of /s/-clusters falls out naturally. It is no surprise that these clusters should be reduced by deleting the problematic /s/, even if the result is less favored according to sonority. And since the constraint does not apply to labial continuants, /f/-clusters, like stop-clusters, are free to reduce according to sonority preferences.

In summary, then, a consideration of A's treatment of target onset clusters has revealed that in all but one case, clusters are reduced in favor of the less sonorant element. The one exception is in the target /s/-clusters, which are always reduced by deleting the /s/ regardless of the relative sonority of the surviving element. This 'deletion' repair strategy is consistent with the constraint against lingual continuants which was motivated by the treatment of target /s/ in singleton onsets.

5. A Glance at Later Stages

The previous two chapters focussed on the first seven stages of A's acquisition of onsets. We saw that the realization of /s/ as either a stop or as [w], depending on the environment, posed some problems if we wished to maintain continuity assumptions along the lines of the Distinctive Feature Hypothesis. In response to these difficulties, I proposed am articulatory constraint that targets lingual continuants for repair. In this chapter, I will present some developments beyond stage 7 which provide further support for this proposal.

5.1 Development of the obstruent voicing contrast

The elaboration of the Laryngeal node occurs in the following way. First, at Stage 11, obstruent voicing begins to appear on target voiced stops (looking at word-initial onsets only):

(36) 'bath' [ba:t] 'bottle' [bɔg̊əl] (cf. [b̥ɔkəl] at stage 10)

Target voiceless stops, however, generally remain as they were before – voiceless lenis, or perhaps better, 'unvoiced' in contrast with the voiced stops.

(37) 'pink' [b̥ig̊] 'pig' [b̥ig]

Throughout the next stage, the non-voiced stops gradually become phonetically voiceless, often alternating between non-voiced and voiceless for a while according to Smith's transcription; but it is not until stage 13 that they become aspirated in the appropriate context. The appearance of aspiration indicates that the feature [spread glottis] ([SG]) has been acquired.

The development of the voiceless half of the target voicing contrast is illustrated in (38) with 'pink'.

(38) 'pink' [b̥ig̊] (Stage 11)
[b̥iŋk/piŋk] (12)
[pʰiŋk] (13)

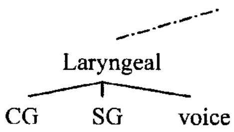
These observations have implications for the structure of the Laryngeal node. First, modal voicing emerged at a stage where target voiceless stops were still produced as they were before voicing became contrastive. This indicates that the voiced segments receive the new feature specification, and that it is therefore necessary for [voice] to be in the geometry as a dependent of the Laryngeal node. The voicing contrast at stage 11, then, would be represented as in (39).

```
(39)        /p, t, k/             /b, d, g/
            |b̥, d̥, g̊|             |b, d, g|
              Root                  Root
               |                     |
           Laryngeal             Laryngeal
                                     |
                                   voice
```

This kind of representation neatly captures the continuity between the previous stages (when [voice] was not specified) and the target voiceless stops in stage 11 – both of which have the same phonetic manifestation. Based on this argument, then, I would propose a revision to the Laryngeal node in the Rice & Avery and Brown geometries, placing [voice] explicitly as a dependent to represent modal voicing. This revision, illustrated in (40) for Rice & Avery, differs from most long-standing models of the geometry (for example: McCarthy

1988, Clements & Hume 1995) only in that I assume all features to be unary rather than binary.

(40)



At stage 11, then, only the feature [voice] is specified; the unstable realization of the voiceless stops at stage 12 (see (38)) I attribute to an attempt to make the distinction between the voiced and unvoiced versions more acoustically distinct. At stage 13, the addition of the feature [spread glottis] allows aspiration to appear – and also has a significant effect on the voiceless fricatives, which I will address in the next section.

5.2 Development of fricatives

Stage 13 marks an important point in A's development of voiceless fricatives; now, /f/ begins to appear as target in onset position:

(41) 'full' [wul/vul/ful] 'first' [fəːt] (stage 14)

Something very different happens with target /s/, however, as the examples in (42) illustrate. The previous replacement pattern for /s/, discussed in chapter 3.1, suddenly changes, and /s/ is now realized as either an aspirated stop or an affricate.

(42) 'say' [t^{s}ei] 'same' [t^{h}eim] 'sock' [k^{h}ɔk/t^{h}ɔk]

Comparing (41) and (42), it becomes apparent that once again the labial and coronal continuants are being treated differently: /s/ always is realized as either an aspirate or an affricate, and /f/ never is – it never surfaces as [p^{h}] or [p^{f}], for example. I will return to this issue shortly, but first I want to address the fact that aspiration and voiceless fricatives (at least, /f/) are acquired at the same time.

It is very common in feature grids to see voiceless fricatives specified [-voice], or lacking [voice], except for [h] which is universally specified [SG] like the aspirated stops . This kind of model, however, cannot capture the simultaneous acquisition of voiceless fricatives and aspiration at stage 13. A's acquisition data strongly suggest that voiceless fricatives are also specified [SG]. Independent support for this specification can also be found in both phonological and phonetic research.

The phonological support comes from a variety of sources. For example, Clements (1985) explicitly places [SG] in his representation of /s/. Lévesque (1992) argues that the specification of [SG] on fricatives greatly simplifies the autosegmental account of the behavior of coda-/s/ in Seville Spanish. Hanson (2000) proposes that this same specification helps to unify aspiration and sonorant devoicing patterns in English onset clusters. Finally, the common process of debuccalization, where /s/ becomes [h], can be easily accounted for under this hypothesis through the delinking of Place features (McCarthy 1988).

The phonetic evidence for [SG] on voiceless fricatives is even more striking. Laryngeoscopic studies show that the glottis is in fact open wide during the production of [s] (Dobrovolsky, p.c.). Hirose (1999) likewise notes that there is a tendency for the glottis to open further for [s] than for stops.

Furthermore, there are articulatory advantages to having a spread glottis during the production of fricatives, which involve a precise – tight but not closed – stricture in the vocal tract. Opening wide the glottis allows more air through, making it easier to maintain a supraglottal air pressure high enough to keep air moving through the resistant, narrow opening.

Therefore, based on A's acquisition and supported by these phonetic and phonological observations, I will assume that voiceless fricatives are specified for the feature [SG] .

But even if this is the case, how does it help us account for the latest developments in the problematic /s/? In particular, it does not explain why there is such a long delay between when /f/ reaches target and when /s/ does. I propose that this particular divergence is, like the others we have seen, attributable to the articulatory constraint against lingual continuants, and that the addition of [SG] to the distinctive feature inventory has an important impact on how the constraint is implemented. In the next section, the arguments for this proposal are presented.

5.3 Spread Glottis and the constraint against lingual continuants

We noted above that increasing the volume of high-pressure air through the oral cavity greatly helps in the production of frication. It is feasible that this kind of assistance could weaken the effect of the articulatory constraint proposed here. One phonetic obstacle would have been removed, namely the difficulty in producing a turbulent airstream with the limited amount of air that a 'voiceless lenis' vocal fold setting allows into the oral cavity. Thus, once [SG] is specified underlyingly the constraint against lingual continuants can relax to the point that it is no longer obligatory to delink [continuant].

One advantage of this approach is that it provides a phonetic motivation for the sudden change in a phonetically-motivated constraint. Another is that it allows that the constraint itself is only weakened, not removed. This point is important in order to account for the fact that it is another ten stages before /s/ is produced as target. If the constraint was done away with at this stage, why the delay? On the other hand, if the constraint is not affected by the acquisition of [SG], why the sudden change in the realization of /s/ so soon afterwards? It is important to recall that /f/ has begun to reach target production, indicating that the difficulty is, once again, with the lingual continuant alone.

But again, if this is the case, then why is /s/ realized as a stop – aspirated or affricated, true, but a stop nonetheless? Since [continuant] is no longer delinked, why isn't it at least a continuant of some sort? This question is especially relevant when we see that the voiced coronal fricative is also affricated at stage 13:

(43) 'zoo' [d^zu:]

In order to get a better understanding of what is happening with /s/, and so to answer these questions, it is particularly relevant to note that target affricates are not realized as affricates at this point. The examples in (44) show how they are realized as stops well past stage 13 (the numbers in parentheses indicate stages).

(44)	'chair' [tɛ:]	(13)	'giant'	[dæ:nt]	(19)
	[t^sɛə]	(21)		[dzaint]	(28)

Arguably, then, the "affricates" produced by A in place of /s/ are not true affricates; there is no reason to believe that they are phonologically complex segments. This observation, I believe, suggests that A's [t^h] and [t^s] can reasonably be considered continuants. That is, I propose that the affrication and aspiration portions actually represent A's primary attempt at the lingual continuant, with the [t] portion being an excrescent stop inserted to make the articulation easier – similar to glottal stop epenthesis in vowel-initial words but with a purely phonetic purpose.

Under this hypothesis, there is no need to claim that the stop portion of the articulation has any phonological status. Rather, we can keep the representation for /s/ that we have used so far, and assume that it continues to be underlyingly specified for [continuant]. In this way continuity can be maintained.

To summarize, in this section I have argued that the acquisition of [spread glottis] allows a relaxation of the constraint against lingual continuants. With this constraint weakened, the feature [continuant] is able to influence the articulation of target /s/ to a greater extent than it could before. As a result, instead of a bare stop replacing /s/, at this stage the replacement is a stop-initiated continuant: either [t^h] and [t^s], in free variation.

Before we move on past this stage, recall that the target voiced fricative /z/ also appeared as an 'affricate' at stage 13 (see (43) above). This does not cause any difficulty for the current account: if the constraint is weakened, then all lingual continuants should show the effects, not just the [SG] ones.

5.4 Gradually relaxing the constraint

The analysis so far implies that the removal of the proposed articulatory constraint is a gradual process. If that is the case, then there should ideally be more evidence of its relaxation before /s/ finally reaches target production. In fact, there are two pieces of data from later stages that provide such evidence.

First, and perhaps most striking, are the following stages in the development of 'see':

(45) 'see' [t^{h}i:/t^{s}i:] (13)
[^{t}si:/si:] (21)
[si:] (22)

Note especially stage 21, where Smith transcribes the stop portion with a superscript, indicating that it is now less robust than it was earlier. This kind of phonetic weakening of the stop is just what we would predict if the [t^{s}] of previous stages was a "stop-initiated continuant" as I claimed in the preceding section. The fact that the next step after [^{t}s] is the target production is also expected.

Another support for the gradual relaxation of the constraint against lingual continuants comes from the two observed instances of lengthening the fricative in target /s/-clusters at stage 23:

(46) 'Smith' [m̥əuk/məuk/s:m̥əuk]
'snail' [n̥eil/s:n̥eil]

Since the lengthening in these cases alternates with the absence of the /s/, it is reasonable to assume that it is simply a consequence of the difficulty in pronouncing that segment. In other words, the proposed constraint has by this stage been weakened to the point that it could hardly be called a constraint – more like a cautionary notice, a flag to indicate that this segment requires more attention than others.

The examples in (46) draw attention to another puzzling aspect of A's onset clusters: the production of voiceless sonorants in the place of target /s/ clusters. This is a consistent strategy between stages 15 and 24. In addition to the /s/-nasal clusters in (46), /sl/ and /sw/ are also affected:

(47) slide [ɬaid] (Stage 15)
sweet [w̥i:t/fi:t] (Stage 16)

When we look closer at A's data, we find that this phenomenon is not limited to /s/ clusters, but also occurs (though much less often) with target /f/-clusters:

(48)	flapjack	[læpdæk/ɬæpdæk]	(Stage 15)
	flower	[læwə/ɬæwə]	(Stage 15)

While space and scope limitations force me to leave this as an observational note, it does appear that the articulatory constraint proposed here is not directly involved. More likely, the feature [spread glottis] is important in these cases: the substitution begins soon after that feature is acquired at stage 13; and both fricatives are involved, not just /s/. It is possible that the asymmetry between the fricatives, with /s/-clusters more likely to show up as voiceless sonorants than /f/-clusters, is due in part to the articulatory constraint which targets /s/. However, it is difficult to tell if there is a true asymmetry here, or if it simply appears that way because there are fewer /f/-clusters in English to begin with.

6. Conclusion

The data presented in this thesis have posed some challenges to feature geometry theory if adopted to the exclusion of extralinguistic factors in phonological acquisition. The first challenge appeared in Chapter 3, when we saw that coronal stops were subject to velar but not labial harmony. Under Rice & Avery's (1995) geometry model, this asymmetry cannot be predicted. Instead, a model such as Brown's (1997) or Browman & Goldstein's (1986) proved necessary, in which [coronal] and [dorsal] are dependents of a single node opposing [labial] under the Place node. Such a model also allows for lingual articulations to form a natural class, proving useful in accounting for the problematic treatment of target /s/.

In Chapters 3 and 4, the substitution patterns of /s/ were looked at in detail. According to these patterns, /s/ behaved simultaneously like an underlying stop and an underlying continuant, depending on the featural environment. The decisive feature in the environment, it turned out, was [labial] as opposed to [coronal] and [dorsal]. Using Brown's model made it possible to capture this important conditioning factor since the two halves of the opposition ([labial] and [lingual], respectively) are directly represented in the tree. However, to fully capture the behavior of /s/ it was necessary to postulate an articulatory constraint against lingual continuants. Motivated by non-linguistic factors (the need for fine control of the tongue muscles), this constraint was shown to have linguistic consequences which gradually decreased as acquisition progressed. In the early stages, it effected the delinking of [continuant] from segments also specified [lingual], neutralizing the stop-fricative contrast for lingual segments only. Later, however – specifically, when fricatives began to receive a [spread glottis] specification – the constraint relaxed enough to allow [continuant] to exert a greater influence the production of target /s/. At this point, /s/ ceased to be realized as a plain stop; now the realization alternated freely between an aspirated and an affricated stop. Thus, the neutralized contrast essentially became narrower, involving only aspirates and fricatives.

Towards the last recorded stages, the effect of the constraint was weaker still, no longer effecting any neutralization at all. Instead, we found isolated instances of /s/ either preceded by an excrescent stop, or, in a cluster, lengthened in an insignificant way (length is certainly not contrastive on cluster-internal fricatives).

The proposals in this thesis have relied upon the assumption that physiological factors can influence the linguistic system. This assumption, in spite of its long-standing history, has yet to be formalized in its relationship with feature geometry theory. To what extent can factors such as neuro-motor control influence the development of phonological representations? In this thesis, I have attempted to show that such an influence does exist, echoing what Goad (1997) stresses: while phonological theory must be able to correctly predict and account for acquisition phenomena, it is essential that the theory be grounded in independent, functional motivations. It may well be that some of these motivations are first, and most clearly, apparent in child language.

References

Archibald, John (ed.). 1995. *Phonological Acquisition and Phonological Theory.* Hillsdale, NJ: Lawrence Erlbaum.

Avery, Peter and Keren Rice. 1989. Segment structure and coronal underspecification. *Phonology* 6(2):179-200.

Bernhardt, Barbara, John Gilbert and David Ingram (eds.). 1996. *Proceedings of the UBC International Conference on Phonological Acquisition.* Somerville, MA: Cascadilla Press.

Blevins, Juliette. 1995. The syllable in phonological theory. In Goldsmith (ed.) pp.206-244

Browman, Catherine and Louis Goldstein. 1986. Towards an articulatory phonology. *Phonology Yearbook 3*:219-252.

Browman, Catherine and Louis Goldstein. 1989. Articulatory gestures as phonological units. *Phonology 6*(2):201-251.

Brown, Cynthia. 1997. Acquisition of segmental structure: consequences for speech perception and second language acquisition. PhD dissertation, McGill University.

Carr, Philip. 1993. *Phonology*. London, Eng: Macmillan Press.

Chin, Steven B. and Daniel A. Dinnsen. 1992. Consonant clusters in disordered speech: constraints and correspondence patterns. *Journal of Child Language 19*:259-285.

Clements, G. N. 1985. The geometry of phonological features. *Phonology Yearbook 2*:225-252.

Clements, G. N. and Elizabeth Hume. 1995. The internal organization of speech sounds. In Goldsmith (ed.) pp.245-306.

Clements, G. N. and S. J. Keyser. 1983. *CV Phonology: A Generative theory of the syllable*. Cambridge, MA: MIT Press.

Demuth, Katherine and E. Jane Fee. 1995. Minimal words in early phonological development. Ms. Brown University and Dalhousie University.

Demuth, Katherine. 1996. Alignment, stress and parsing in early phonological words. In Bernhardt, Gilbert and Ingram (eds.) pp.113-125.

Dinnsen, D. 1996. Context-sensitive underspecification and the acquisition of phonemic contrasts. *Journal of Child Language 23*:57-79.

Fee, E. Jane. 1995. Segments and syllables in early language acquisition. In Archibald (ed.) pp.43-61.

Fee, E. Jane. 1996. Syllable structure and minimal words. In Bernhardt, Gilbert and Ingram (eds.) pp.85-98.

Fikkert, P. 1994. *On the acquisition of prosodic structure*. Leiden: HIL.

Gnanadesikan, Amalia E. 1995. Markedness and faithfulness constraints in child phonology. Ms. University of Massachusetts, Amherst.

Goldsmith, John (ed). 1995. *The Handbook of Phonological Theory*. Cambridge, MA: Blackwell.

Goad, Heather. 1997. Consonant harmony in child language: an optimality theoretic account. In S. J. Hannahs and Martha Young-Scholten (eds.) pp.113-142.

Halle, Morris and William Idsardi. 1995. General properties of stress and metrical structure. In Goldsmith (ed.) pp.403-443.

Hannahs, S. J. and Martha Young-Scholten (eds.). 1997. *Focus on Phonological Acquisition.* Philadelphia PA: John Benjamins.

Hanson, R. 1999. Fusion and the acquisition of s-nasal clusters. Ms. University of Calgary. To appear, University of Maryland linguistics department Undergraduate Essay Prize in Linguistics website.

Hanson, R. 2000. VOT in English onsets: Phonetics and phonology interact. Ms. University of Calgary.

Hirose, Hajime. 1999. Investigating the physiology of laryngeal structures. In W. J. Hardcastle and J. Laver (eds.), *The Handbook of Phonetic Sciences.* Malden, MA: Blackwell. pp.116-136.

Ingram, David. 1996. Some observations on feature assignment. In Bernhardt, Gilbert and Ingram (eds.) pp.53-61.

Ingram, David. 1976. *Phonological Disability in Children.* London: Edward Arnold.

Kaye, Jonathan, Jean Lowenstamm and Jean-Roger Vergnaud. 1990. Constituent structure and government in phonology. *Phonology* 7(2):193-231.

Kiparsky, P. 1993. Blocking in non-derived environments. In S. Hargus, and E. Kaisse (eds.), *Phonetics and Phonology, Volume 4: Studies in lexical phonology.* San Diego, CA: Academic Press. pp.277-313.

LaCharité, Darlene and Carole Paradis. 1993. Introduction: The emergence of constraints in generative phonology and a comparison of three current constraint-based models. *The Canadian Journal of Linguistics Special Issue: Constraint-Based Theories in Multilinear Phonology.* pp. 127-153.

Ladefoged, Peter and Ian Maddieson. 1996. *The Sounds of the World's Languages.* Cambridge, MA: Blackwell.

Lévesque, Claire. 1992. Hachismo, or the behavior of /s/ in the Spanish of Seville. Honors thesis, University of Calgary.

Levin, J. 1988. A Place for lateral in the feature geometry. Ms. University of Texas, Austin.

Macken, Marlys. 1995. Phonological acquisition. In Goldsmith (ed.) pp.671-696.

Macken, Marlys. 1996. Prosodic constraints on features. In Bernhardt, Gilbert and Ingram (eds.) pp.159-172.

McCarthy, John. 1988. Feature geometry and dependency: a review. *Phonetica* 43:84-108

Paradis, C. and J.-F. Prunet (eds.). 1991. *Phonetics and Phonology 2: The Special status of coronals. Internal and external evidence.* New York: Academic Press.

Piggott, G. 1992. Variability in feature dependency: The case of nasality. *Natural Language and Linguistic Theory 10*:33-77.

Piggott, G. 1993. The geometry of sonorant features. Ms. McGill University.

Pollock, K. 1983. Individual preferences: case study of a phonologically delayed child. *Topics in Language Disorders 3*:10-23.

Rice, Keren and Peter Avery. 1995. Variability in a deterministic model of language acquisition: a theory of segmental elaboration. In Archibald (ed.) pp.23-42.

Rice, Keren and Peter Avery. 1991. On the relationship between laterality and coronality. In C. Paradis and J.-F. Prunet (eds.) pp.101-124.

Salidis, J. and J. Johnson. 1997. The production of minimal words: a longitudinal case strucy of phonological development. *Language Acquisition 6* (1):1-36.

Slobin, D. I. 1973. Cognitive prerequisites for the development of grammar. In C. Ferguson and D. I. Slobin (eds.), *Studies in Child Language Development.* New York: Holt, Reinhart and Winston. pp.175-208.

Smith, N. V. 1973. *The Acquisition of Phonology: A case study.* Cambridge: Cambridge University Press.

Steriade, D. 1987. Redundant values. In A. Bosch, B. Need, and E.Schiller (eds), *Parasession on autosegmental and metrical phonology.* Chicago: Chicago Linguistic Society. pp.339-362.

Velleman, Shelley. 1996. Metathesis highlights feature-by-position constraints. In Bernhardt, Gilbert and Ingram (eds.) pp.173-186.

Yip, Moira. 1990. Two cases of double-dependency in feature geometry. Ms. University of California at Irvine.

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