The Acquisition of /s/ + Consonant Onset Clusters: A Longitudinal Study

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Abstract

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The purpose of this research was to establish a developmental path for the acquisition of word-initial homorganic /s/ + consonant clusters (#sC), namely /st-/, /sn-/, and /sl-/ and, consequently, to determine which two hypotheses (one based on input frequency and one on sonority markedness) would better account for the path of #sC acquisition observed in the speech of one English speaking child between the ages of 2;3 and 3;10. The developmental path of #sC clusters was charted longitudinally using a triangulation of methodologies: (1) controlled (audio recorded) elicitations of pseudo-words (via finger-puppet interactions and role-playing involving fictitious characters whose names start with #sC; e.g., Sleed, Snib, Steeg), (2) recordings of child-directed speech (representing the input to which the child is exposed), and (3) a language observation journal. The results from the input corpus showed that, despite the significantly high rate of the SSP-violating #sC cluster (i.e., /st-/) in the speech surrounding the child, input frequency did not provide a satisfactory explanation for the sequence of acquisition, contrary to what a frequency-based account predicts (e.g., Bybee, 2001). Rather, the evidence provided by both the puppet elicitation task and the observation journal suggests a correlation between the order of #sC acquisition and the predictions made by the Sonority Sequencing Principle (SSP: Clements, 1991). Implications for the advancement of research on the acquisition of syllable structure are also discussed.

(226 words)

Dedication

This thesis is dedicated to the participant, without whom none of this would have been possible, and to Nick (my husband) for all of his patience and encouragement. And to the new little one, who slept long enough for me to finish the writing of this project

I would like to extend a heartfelt thank you to my thesis supervisor, Dr. Walcir Cardoso, for all of his support and guidance throughout the writing of this project, and a special thank you to my reading committee, Dr. Beth Gatbonton and Dr. Joanna White.

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CHAPTER 1: INTRODUCTION

Though still controversial, frequency has been proposed as an explanatory tool to explain the development of a variety of linguistic features in children's language. For example, Demuth's (1990) longitudinal study of Lesotho, a Southern Bantu language, found a strong link between the early acquisition of the complex grammatical construction of passives in young Lesotho speaking children between the ages of 2;1 and 4;1, and the high frequency of its use in child-directed speech (hereafter CDS). In another study by de Villiers (1985), a significant correlation between the order of acquisition of certain verbs in two young children and the frequency of their use in CDS was found. Naigles and Hoff-Ginsberg (1998) extended this finding (N=57, mean age= 1;6) showing that not only did the appearance of certain verbs in parental input help ease their acquisition in young children's speech, but hearing verbs that very frequently appeared in syntactically diverse sentences appeared to have allowed the children to also become skilled at using the most frequently appearing verbs.

Proponents of input frequency argue that learners simply cannot ignore a linguistic structure that occurs frequently in parental input. Learners are therefore naturally "forced" to attend to a structure that occurs repeatedly (Demuth, 2007). More nuanced and complex models of frequency exist, however. For instance, Bybee (2006) ascribes to a usage-based definition of grammar as "the cognitive organization of language," which is strongly influenced by a learner's experience with the language. That is, highly frequent linguistic structures not only get forcibly noticed by the learner, but undergo a grammaticization process. This process produces further change to the learner's representation of language, and strengthens her memory representations of words and/or phrases, making them easier to retrieve. Bybee also discusses the various positive effects of token frequency (i.e., how often particular words and specific phrases appear in the input), as opposed to *type frequency,* which refers to how many different lexical items can be applied to a certain pattern, paradigm, or construction (Ellis, 2002). For example, among other things, token frequency is said to have a reducing effect. That is, the more frequent something is, the more it will result in a phonetic reduction or deletion due to the development of neuromotor routines that require increasing efficiency.

With an increase in the availability of computers in the 1980's, linguists and language acquisition theorists were better able to analyze large corpora of naturalistic language. This made searching for specific linguistic items, identifying instances of linguistic patterns, and better controlling for frequency as an influential variable on the course of language acquisition less daunting (Bybee, 2006; Demuth, 2007). Though one would assume that having access to large corpora in digital format would make the task of studying the effects of input frequency on language acquisition more straightforward in some ways, the impact of input frequency on the course of acquisition nevertheless remains a challenging and hotly debated issue for linguistics today. Part of the problem lies in a lack of consensus on the concept of frequency itself: what it actually entails, how it should be defined, and how to adequately measure it (Kupisch, 2007).

There are also claims that refute frequency altogether (e.g., Bennett & Ingle, 1984; Kirk & Demuth, 2005), or question whether frequency perhaps plays an equally influential role alongside other factors (Cardoso & Liakin, 2009).With regards to the latter, for example, Hart (1991), who conducted a longitudinal investigation with a large and socio-economically diverse group of children (*N*=45, ages= 0;7- 3;0 years) found that, at least at the preliminary stages of vocabulary learning, the first words produced mirrored the frequency with which these words occurred in parental input. Interestingly, however, as development proceeded, the children became less reliant on input frequency and more on their cognitive processing to help them acquire new words.

Stites, Demuth, and Kirk's (2004) study is another example that emphasizes an equal role for both frequency and, in this case, markedness, in the early acquisition of phonology. Two young child participants (1 male, 1 female) between the ages of 1 and 2 were involved in a longitudinal investigation of word-final stop coda consonants. This target was strategically chosen for investigation since stop codas are both the most marked and the most frequently occurring coda type in CDS English. Investigating the early acquisition of word final stop codas in 2 child participants allowed the researchers an "ideal-testing ground" to determine whether the participants were sensitive to frequency or markedness. The findings to emerge from this study showed that the female child was sensitive to frequency in her learning path of word-final codas, whereas the male child showed sensitivity to markedness. The researchers concluded that markedness and frequency may play an equal role in the early acquisition of phonology, and may be dependent upon individual learner's sensitivity to each of these two factors. For /s/ + consonant onset clusters in SLA (e.g., /st-/ in /st-/op, /sl-/ in /sl-/ow; hereafter #sC clusters), it has been shown that both markedness and frequency may play a role, but at different components of investigation. For example, Cardoso and Liakin (2009) show a markedness effect in the production of #sC onsets, whereas Cardoso, John, and French (2009), on the other hand, show a frequency effect in the perception of #sC onsets.

The study by Stites et al. (2004) discussed above shows that markedness may be considered both an alternate and competing explanation to frequency in the early acquisition of phonology. An interesting phenomenon in the investigation of the interaction between frequency and markedness is the acquisition of certain homorganic[1] (i.e., sharing the same place of articulation) #sC clusters (i.e., /st-/, /sn-/, /sl-/) because these two constructs make mirror opposite predictions regarding their order of acquisition. For example, words beginning with /st-/ such as *stop,* show both a reversal in sonority and are therefore highly marked in comparison with the other two clusters. Furthermore, when compared to words with other homorganic #sC clusters in the onset like *snow* (/s/ + nasal) and *slow (*/s/ + liquid), /st-/ is also more frequent in English. Not unlike the study conducted by Stites et al. (2004), Cardoso and Liakin's (2009) study offers compelling evidence for markedness as an alternative explanation to frequency for the acquisitional path of homorganic #sC clusters. Examining three homorganic #sC clusters within the context of Brazilian Portuguese speakers of English as a second language, Cardoso and Liakin (2009) found that, based on the acquisitional path for these three homorganic clusters, markedness provided a better explanation for the acquisitional path in 10 mature participants.

To date, there have been no studies that look at #sC development in a young child from a multidimensional perspective. The question that the current research effort sought to address was whether markedness or frequency played a greater role in certain aspects of first language acquisition of phonology than previously supposed. The three homorganic #sC clusters investigated by Cardoso and Liakin (2009) provides a convenient comparison between frequency and markedness for just such a question.

[1] #sC homorganic clusters such as coronal plus coronal /st-/, /sn-/ and /sl-/ are assumed to be easier to articulate than their heterorganic counterparts (e.g., /sp/eak and /sk/ate) because the articulators in the former #sC set remains constant (Yavas, 2006).

What follows in the next chapter, therefore, is an exploration of underlying issues, explanations of key concepts and assumptions (namely sonority and frequency effects), and a review of relevant literature which serves to contextualize the current study. The chapter concludes with a formulation of my research questions. Chapter 3 is dedicated to the methodology employed in the study, introducing the participant, the materials, and procedures adopted. The chapter ends by providing a description of the ways the data were analyzed. Chapters 4 and 5, the final two chapters of the thesis, are dedicated to presenting the results and related discussion of the study, which examined the acquisitional path of three homorganic #sC onset clusters (/sl-/, /sn-/, st-/) in the development of speech in one child acquiring English as a first language (L1). In addition, the participant's development of homorganic #sC onset clusters in general are discussed, as well as the effects of frequency and sonority markedness on #sC acquisition. The thesis closes with a discussion of the limitations of the current study, recommendations for future research and, finally, some concluding remarks.

CHAPTER 2: THEORETICAL BACKGROUND

This chapter lays out the underlying theoretical framework for understanding the development of the three homorganic #sC onset cluster targets. In particular, it defines the relevant terminology, in addition to describing two essential assumptions related to the syllable which aids in both advancing a sonority based analysis of #sC onset clusters and predicting a particular path for their acquisition. Furthermore, this chapter goes into some detail concerning the structural status of #sC onset clusters and its related controversy, and provides a discussion in previous studies in first language (L1) and second language (L2) #sC acquisition. Finally, the chapter concludes with a discussion of the gaps in the previous literature and a statement of the research questions that were addressed.

Defining Markedness in #sC Clusters

Consonant clusters in complex onsets are a frequent source of difficulty in the speech of young children and their acquisition is considered to be a major milestone in their development (Gierut, 1999; Wyllie-Smith, McLeod, & Ball, 2006). Over the last decade or so, and as a response to pre-existing and often unsatisfactory explanations for the phonological development of consonant clusters by children, a body of literature has emerged using the linguistic construct of sonority to account for the phonological development of these consonantal sequences (Ohala, 1999; Someillan & Yavas, 2005; Wyllie-Smith & McLeod, 2002; Yavas & Core, 2006).

Sonority can be seen as the natural counterpart to frequency to explain the course of acquisition of #sC clusters. An understanding of sonority, markedness based on sonority, and the relative markedness of #sC clusters is needed in order to show how the underlying theory for #sC cluster development in L1 acquisition was explored in the current study. A few words therefore are needed to fully distinguish sonority from frequency and to show how the term relates to two widely used syllable-related generalizations, the *Sonority Sequencing Principle* (Clements, 1990) and the *Minimal Sonority Distance* (Broselow & Finer, 1991). Each is dealt with in turn below.

Sonority: A Definition

Despite the fact that the concept of sonority has been around for a long time, some linguists have pointed out that trying to bind sonority into a single, formal definition has proven to be rather difficult (e.g., Cardoso & Liakin, 2009; Kent, 1993; Yavas, 2006). This may be due in part both to the abstract nature of sonority and to the controversy surrounding the structural representation of #sC clusters themselves (Kent, 1993; Yavas, 2006) (see forthcoming discussion below on the structural representation of #sC clusters and its related controversy). Sonority has been variously defined in terms of waveform amplitude or acoustic energy (Goldsmith, 1990), propensity for voicing (Kenstowicz, 1994), and perceptual prominence (Ladefoged, 1993).

The concept of sonority has been around since the end of the 19th century (e.g., Lepsius & Whitney, 1865 - see also Yavas, Ben-David, Gerrits, Kristoffersen & Simonsen, 2008 for similar claims), and is considered important in the analysis of consonant clusters (e.g., Cardoso & Liakin, 2009; Ohala, 1999; Yavas & Core, 2006). Sonority is believed to lend insight into typically developing infants' vocal development and the speech of young children, both with normal speech development and speech delays (Yavas, 2003). For example, the preference for well-formed syllables organized in relation to sonority (i.e., syllables with a maximal rise in sonority) has been noted in infants as early as 7 to 10 months of age from a variety of linguistic backgrounds. These well-formed syllables, referred to as canonical babbling, typically manifest themselves in reduplicated sequences such as [bababa] and [dadada] (Oller & Eilers, 1988; Yavas & Gogate, 1999). Similarly, an explanation for pre-school-aged children's modifications to consonant clusters at the onset during the course of their acquisition has also been explained in terms of sonority (Yavas, 2003). For example, when young children are in the process of learning to produce onset consonant clusters, one strategy commonly used is to reduce the cluster to whichever consonant produces a maximal rise in sonority. As Yavas and Gogate (1999) note, this may be indicate that sonority patterns are perceived at quite an early age, thus implying that sonority may act as an organizing principle for the early acquisition of syllables (see forthcoming discussion on strategies used by young children acquiring consonant clusters).

For the purpose of the current study, we can discuss sonority in more concrete terms that are agreed upon by many: its phonological function (i.e., how segments arrange into syllables), its dependence upon the degree of opening of the vocal tract during articulation (i.e., the more open the vocal tract, the higher the sonority), and a sound's tendency for voicing (i.e., voiced sounds are more sonorous than their voiceless counterparts, even when the degree of opening of the vocal tract remains the same for both voiced and unvoiced sound; consequently, the narrower the opening of the vocal tract, the lower the sonority of a sound). Figure 1 illustrates the sonority hierarchy for the relevant phonemes considered in this study, beginning with the least sonorous /t/ and ending with the most sonorous /l/:

/t/ → /s/ → /n/ → /l/

Figure 1. Sonority hierarchy for relevant segments investigated in the current study

A Sonority-Based Analysis to (#sC) Onset Consonant Clusters

According to San (2002), sonority theory is the only major theory for establishing English onset clusters. In order to advance a sonority-based analysis of onset consonant clusters, it is important first to appeal to two major assumptions related to the syllable: the Sonority

Sequencing Principle (hereafter SSP) and the Minimal Sonority Distance (hereafter MSD). Along the lines of Cardoso (2008) and Boudaoud and Cardoso (2009), the principles of both the MSD and the SSP were adopted so that a markedness relationship between the three #sC target sequences could be determined. As will be shown later, establishing the relative markedness of these target sequences is essential for the formulation of a developmental path for their acquisition based on sonority. This will be the topic of the following sections.

The Sonority Sequencing Principle (SSP)

According to the SSP (Clements, 1990), syllables have a preferred shape. They rise maximally in sonority toward the nucleus (i.e., the vowel) and lower in sonority levels toward the coda. Based on behavioural evidence and findings from laboratory studies, Treiman (1986) has shown that syllables are not simply linear strings of phonemes, but hierarchically organized internally using two major constituents, the onset and the rime. While the onset is made up of an initial consonant or consonant cluster, the rime is made up of a nucleus, usually a vowel, and may also contain a consonant in the coda position. English allows for branching onsets and codas, known as consonant clusters.

Referring to the three targets that were studied here, consonant clusters either abide by the SSP, as is the case with the least marked /sl-/ and /sn-/ (see upcoming discussion in the section on the Minimal Sonority Distance), or violate the principle (as is the case with /st-/). Regarding /st-/, this cluster is considered to violate sonority sequencing because sonority does not rise continuously towards the nucleus. Instead, there is a sonority reversal from the more sonorous /s/ to the least sonorous /t/, as illustrated by the dotted circle in Figure 2 below (see also Figure 1 for the sonority hierarchy for the relevant segments), using waveform representation (where higher amplitude indicates higher sonority). The more syllables deviate from this preferred syllable shape dictated by the SSP, the more complex, more marked, and presumably the more difficult these SSP-violating clusters become for young children to acquire (Eckman, 1977; Ohala, 1999).

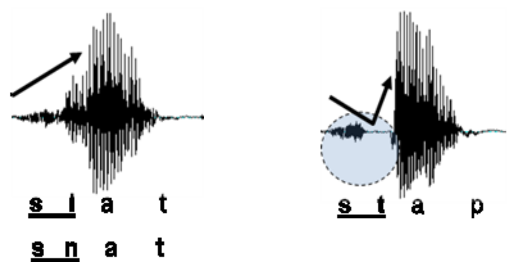

Figure 2. The SSP and its violation in terms of amplitude

In sum, based on the SSP, it is expected that the more marked /st-/ form will be acquired last: /sl-/, /sn-/ → /st-/ (where "→" indicates acquired before). The markedness relationship between the remaining clusters will be determined in the following section.

The Minimal Sonority Distance (MSD)

The MSD (Broselow & Finer, 1991) has been used to help explain learners' developing knowledge of onset consonant clusters (Boudaoud & Cardoso, 2009; Broselow & Finer, 1991; Cardoso & Liakin, 2009). More specifically, the MSD provides the parameters for the markedness of clusters at the onset (Eckman & Iverson, 1993), and suggests a universal tendency for syllables to follow the canonical CV structure (i.e., consonant-vowel structure, hereafter CV) (Cardoso, 2008).

Over the last few decades, several phoneticians have put forth a number of different hierarchies in order to represent varying degrees of sonority for all speech sounds (e.g., Hogg & McCully, 1987; Clements, 1999; Steriade, 1982, etc.). All sonority scales generally agree on the basic ordering of sounds, with only slight differences (Yavas, 2006; Zec, 1995). Vowels (e.g., /a/, /i/, /u/) are considered as having the highest sonority and are therefore given a higher numerical value, followed by sonorants (e.g., /l/, /n/) and obstruents (e.g., /t/, /s/, /d/), which are lower in sonority and thus appear lower on the sonority scale with lower numerical values. Essentially, a sonority scale makes calculating the sonority distance between segments possible. This study has adopted the sonority scale proposed by Clements (1990). Figure 3 (adapted from Clements, 1990) illustrates the hierarchy of segments along a scale, beginning with the least sonorous at the utmost left and the most sonorous to the utmost right. This hierarchy allows syllables to be characterized in terms of a rise and fall in sonority, and thus, in terms of an ideal (CV) syllable shape. This ideal syllable shape is characterized by a maximal rise in sonority at the onset of the syllable (Clements, 1990).

Stops	<	**Fricatives**	<	**Nasals**	<	**Liquids**	<	**Glides**	<	**Vowels**
[t,d]		[s,f]		[m,n]		[l,r]		[w,y]		[a,i]

Figure 3. The Sonority Hierarchy (adapted from Clements, 1990)

According to Cardoso and Liakin (2009) and Boudaoud and Cardoso (2009), support for using the MSD to help establish the markedness relationship based on sonority between /sl-/, and /sn-/ comes from both cross-linguistic data and evidence from L1 acquisition. The MSD stipulates that there must be a maximal rise in sonority between two or more members of a syllable. The wider the sonority gap, the less marked and the more preferred/permissible the cluster is. Hence, /sl-/ is a more preferred cluster than /sn-/ because the sonority distance between /s/ and /l/ in the first cluster is wider than that of /s/ and /n/ (refer to Figure 3 above). Cross-linguistically, onset clusters in many languages prefer a maximal rise in sonority distance between their onset segments (Boudaoud & Cardoso, 2009). The homorganic target /sl-/ is an example of the more universally preferred onset structure since the distance between its segments is maximal in comparision with /sn-/ and /st-/. In contrast, a “bad” consonant cluster in English is one that exhibits a sonority violation. The homorganic target /st-/ is an example of such a violation: the sonority distance between /s/ and /t/ constitutes a sonority reversal (and not a rise towards the nucleus of the syllable).

As already mentioned, additional support for using the MSD to help establish the relative markedness relationship between /sl-/ and /sn-/ also comes from behavioural evidence from L1 acquisition (Gnanadesikan, 2004; Goad & Rose, 2004; Ohala, 1999). For instance, findings from studies involving consonant clusters in young children’s speech have observed that many children typically modify consonant clusters by deleting one of the segments. This deletion is referred to as consonant cluster reduction. Cluster reduction is a common phenomenon in acquisition and is a process that is frequently the hallmark of emerging acquisition for typically developing, delayed, and child L2 learners’ speech. It should be noted that a number of conflicting definitions of consonant cluster reduction exists (McLeod, Van Doorn, & Reed, 1997). For the purpose of this study, consonant cluster reduction is understood to mean the non-adult production of consonant clusters resulting in varying patterns of omission of one or both consonants[2]. Often the omission is of one the consonant elements: either the first consonant (C1)

[2] Greenlee (1974) was one of the first researchers to propose a useful model to account for normally developing children’s patterns for consonant clusters in general at both the onset and

(e.g., / stɑp / ‘stop’ becomes [sɑp]), the second consonant (C2) (e.g., / stɑp / becomes [tɑp]), or by producing a non-target consonant (e.g., / stɑp / becomes [fɑp]) (Wyllie-Smith & McLeod, 2002). Consonant cluster reduction is reported to be a universal process in languages that permit consonant clusters (Gnanadesikan, 2004; Jongstra, 2003), but the strategies used by children for cluster reduction can vary greatly not only within similar cluster categories, but within individual and between individual children (Jongstra, 2003). According to Jongstra (2003), this variation in cluster reduction has never been the subject of close investigation. Based on behavioural evidence in L1 acquisition studies, when learning to produce onset clusters, many children typically delete the more sonorous segment, so their reduction patterns seem to be determined by sonority factors (that is, their production complies with the MSD).

Due to the MSD, it has been noted that cluster reduction, and thus the intermediate stages of the developmental sequence of consonant clusters, may be explained by principles of

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coda positions in their English L1. In this four-stage model, deletion of the entire cluster is characteristic of the first or earliest stage of cluster development. Secondly, and very commonly, reduction occurs to a single consonant. This second stage can be quite drawn out, persisting for a number of months. Thirdly, the number of consonants is retained, but with one or more of the consonants being substituted. Ultimately, children attain full accuracy in cluster production, but not until after the age of three, with even 8-to-9 year olds still struggling with the acquisition of consonant clusters (Kirk, 2008; McLeod, van Doorn, & Reed, 2001). Since Greenlee (1974), other researchers (e.g., Kirk, 2008) have looked at consonant cluster development in monolinguals using her four-stage model of development and have found that Greenlee’s stages of cluster development usually overlap.

markedness and sonority (McLeod et al., 2001). The phenomenon of consonant cluster reduction represents typical developmental errors made by young children and characterizes initial attempts at producing consonant clusters in an adult-like way. In addition, strategies other than reduction may also be used by young children when learning to produce consonant clusters. These strategies may represent distinct or overlapping stages in consonant cluster development in children's speech. These strategies may include, but are not limited to, epenthesis (vowel insertion between consonants within the cluster, for example with *slow*, /slo/ becomes [səlo]), cluster simplification (when two elements of the cluster are produced, but one or both segments are produced in a non-adult way, for example with *green*, /grin/ becomes [gwin]) and coalescence (when the reduced cluster contains a new consonant composed of features from the original consonants, for example, /swIm/ becomes [fIm], where /f/ retains the stridency from /s/ and labiality from /w/). In addition to principles of markedness and sonority, children's developmental errors may also be linked to maturation of the motor speech mechanisms and anatomical development of the oromusculature (McLeod et al., 2001). Due to space constraints and the scope of the current study, this thesis does not go into any great detail concerning these areas of early speech development.

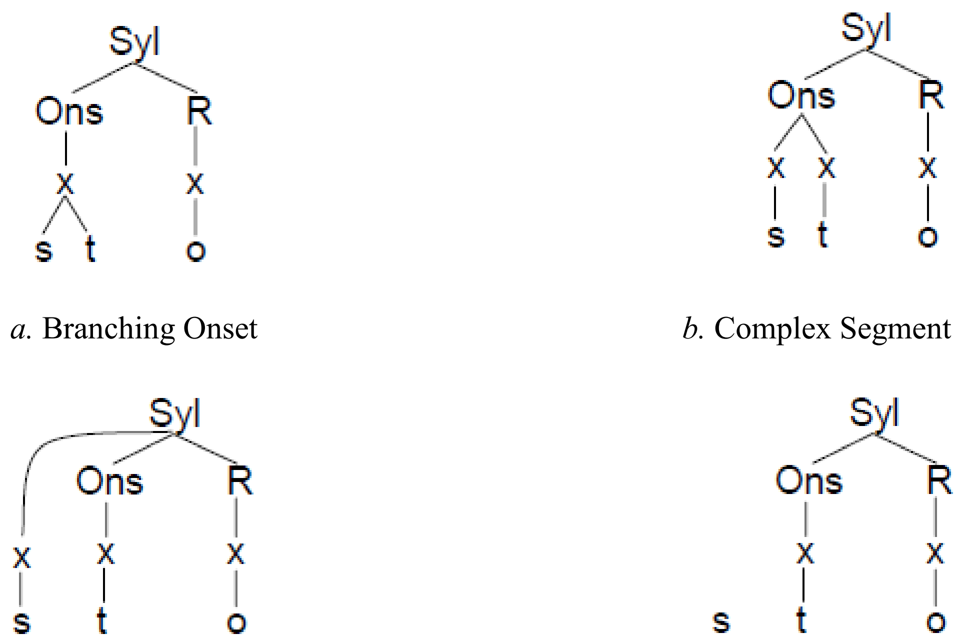
In sum, the markedness relationship to emerge from a merging of the principles of the SSP and the MSD regarding the three homorganic #sC targets predicts the following path of acquisition (where < means less marked and therefore assumed to be acquired first):

/sl-/ < /sn- / < /st-/

Structural Status of #sC Clusters: The Controversy

It has long been known that during the course of acquisition and compared with other consonant clusters, #sC clusters behave atypically. For example, as was discussed above, not only do #sC clusters such as /st-/ violate certain rules regulating against homorganicity at the onset of words and phonotactic constraints that govern the formation of syllables in English, but prior research on child phonology has also shown that articulating the /s/ sound requires a degree of precise articulation not matched by other sounds (Borden & Gay, 1978). As such, word initial /s/ is not only one of the most difficult sounds for children (Borden & Gay, 1978; Templin, 1957), but clusters containing /s/ at the onset are prone to a persistent and pervasive stage of reduction (Smit, 1993). Findings from prior research have shown that when initially learning how to produce #sC sequences at the onset of words, children frequently either lose the /s/ altogether (Stemberger & Treiman, 1986), and may even delete the entire #sC cluster (Yildiz, 2005). Furthermore, when compared with other consonant cluster categories, it has been observed that there is a particularly persistent and pervasive stage of developmental production errors (Smit, 1993). Finally, evidence provided by acquisition and intervention studies on children with speech delays contradict each other, leaving it unclear as to whether #sC clusters are easier or more difficult to acquire than other two member onset clusters, or if they emerge earlier or later (Yavas & Core, 2006).

Current findings regarding the variable development patterns of #sC clusters have fuelled an active debate over their structural status. To date, four main analyses of #sC clusters have been proposed. While most researchers ascribe to the standard analysis of #sC clusters as branching onsets (see figure 4a), thus rendering a structural division between #sC sequences and non-#sC sequences unnecessary (e.g., Cardoso, 2007; Ohala, 1999), others argue for alternative and unconventional analyses to explain the unusual behaviour of #sC clusters. For example, some researchers (e.g., Yildiz, 2005) argue that the initial /s/ in /st-/ clusters is part of a complex segment (see Figure 4b) (note that this analysis is reserved for /st-/ sequences, not /sn-/ and /sl-/). Others, on the other hand, propose that #sC clusters are not true clusters, but adjunct clusters lying outside the constituents of the syllable (see Figure 4c- Barlow, 2001; Yavas & Barlow, 2006a). Finally, others argue that /s/ initial clusters ought to be regarded as an appendix (i.e., extrasyllabic; see Figure 4d - Goad & Rose, 2004; Jongstra, 2003). On the other side of the debate, many researchers believe that setting aside the debate over the structural distinction of /s/-versus non /s/-clusters altogether may allow for “better, more insightful analyses that have more explanatory and predictive power” (Boyd, 2006, p. 40). Furthermore, as Goad (2011) laments, despite the large quantity of work already amassed on the topic, it is doubtful if the issues surrounding their structural representation can ever be resolved.



a. Branching Onset

b. Complex Segment

c. Adjunct

d. Appendix

Figure 4. The Syllabification of Onset Clusters: Four Analyses (Adapted from Cardoso, 2008)

Along the lines of Cardoso (2008), the current study has taken the position that #sC clusters function as branching onsets. Cardoso has pointed out that adopting alternative and unconventional analyses of #sC clusters eliminates the potential to investigate SSP violations. This would ultimately rule out sonority (i.e., markedness) as a variable affecting the order of acquisition for /st-/, /sn-/, and /sl-/, the three homorganic targets that were investigated in the current study. For a full review and critique of the four main analyses of #sC clusters, see Boyd (2006) and Goad (2011), the latter including both structural and perceptual considerations that provide a better understanding of the behaviour of #sC clusters.[3]

To sum up, based on a sonority markedness effect, the relative markedness relationship between the targets /st-/, /sn-/, and /sl-/ derived from principles related to both the MSD and SSP allows one to predict that /sl-/ will be the first to develop in the speech of a monolingual English speaking child. This sequence will be followed by /sn-/ and /st-/ respectively.

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[3] It is important to note here that the aim of this study is not to debate the merits of competing representations of #sC clusters, but to investigate how the production of #sC clusters may be affected by frequency, sonority, and training (see forthcoming discussion). The structural debate surrounding #sC clusters is considered peripheral in the current study and, accordingly, it does not intend to explicitly contribute to the debate on the issue. It is nevertheless hoped that this study will provide some insights on the structural controversy that surrounds the syllabification of #sC clusters.

Previous Studies on #sC Cluster Acquisition

The underlying principles that govern consonant cluster acquisition in children, specifically s + consonant clusters at the onset of words, are not yet fully understood. For this reason, the issue has generated considerable interest in the field of language acquisition and linguistics in general. By looking at both children's L1 and L2 acquisition of #sC clusters in English, recent research is beginning to propose different theories (e.g., sonority constraints, factorial typology, and constituent headedness) to account for different patterns in children's developmental errors. The sections that follow look at L1 and L2 research that examines the effects of sonority and frequency to explain the acquisitional path of #sC clusters. Finally, the literature review closes with a discussion of the gaps that the current study has sought to address.

First Language Acquisition and Markedness

Many studies in first language acquisition (FLA) show that markedness has an effect on the development of consonant clusters in young children. For instance, Ohala (1999) was one of the first to apply the construct of sonority to help account for patterns in children's acquisition of consonant clusters. Motivated by a dissatisfaction with pre-existing explanations for the phenomenon of child consonant cluster reductions (e.g., personal preference, randomness, and favouring sounds with a certain manner of articulation), Ohala tested the Sonority Hypothesis (SH) to see if it could explain the underlying governing principle for children's cluster reductions. For example, when a child says [tɑp] for 'stop', he or she is likely reducing the syllable initial cluster /st-/ to the second consonant (C2) based on sonority, making it conform to an optimal syllable shape (1) in which the sonority rises continuously towards the nucleus, as predicted by the SSP and, more importantly, (2) so that the sonority distance between the onset and the following segment is maximized, as predicted by the MSD discussed earlier. Of the three #sC clusters included in Ohala's (1999) study, /st-/, /sk-/, and /sn-/, the SH predicts that for initial fricative + stop clusters (i.e., /st-/, /sk-), each cluster will reduce to C2 (the stop segment). For initial fricative nasal clusters (i.e., /sn-/), the cluster will reduce to the first consonant (C1 - the fricative segment).

Sixteen English-speaking children between the ages of 1;9 and 2;5 participated in this experiment. Picture stimuli consisted of 28 pictures of imaginary animals using non-sense words (i.e., [skub], [stig], [snuf]). The experimenter showed each child a picture of an imaginary animal and said, "This is an X; can you say X?" or, "Say X." The child had to repeat each token only once. The author found that, in general, many of her participants reduced clusters according to sonority (e.g., they reduced the cluster by preserving the least sonorous consonant), suggesting that constraints on syllable shape in English do begin to emerge at an early age. However, her analysis could still not explain why 14% of her trials reduced to C1 when C2 was expected. Furthermore, Ohala required that each token only be repeated (i.e., imitated) once by her participants, leading one to question whether a single repetition is sufficient to be taken as representative of a child's speech.

In 2006, a group of researchers working in parallel published a series of four separate studies in a special issue of the *Journal of Multilingual Communication Disorders* (Volume 4, Issue 3) dealing specifically with the acquisition of #sC clusters, both homorganic and heterorganic, in word-initial position by normally developing children from a variety of L1s. In 2008, these same authors collaborated on a single article published in the journal *Clinical Linguistics and Phonetics* (Volume 22, Issue 6) that revisited the data of their 2006 studies in a comparative, cross-linguistic study (Yavas, Ben-David, Gerrits, Kristoffersen, & Simonsen, 2008). All four studies shared many of the same goals and generally addressed the same research questions. That is, they sought to understand to what degree sonority can be used as an explanatory factor in acquisition, what the reduction patterns for different types of #sC clusters would be in normal development (and hence what implications could be applied to the clinical setting), to locate predictive and implicational relationships between #sC targets in order to apply the knowledge to children with phonological delays or disorders, and, finally, to see if homorganicity played a role on children's production of the cluster. The results of this comparative study will be discussed next.

These four studies investigated the oral production of children of four different languages that permit #sC clusters at the onset: English (Yavas & Core, 2006); Hebrew (Ben-David, 2006); Norwegian (Kristoffersen & Simonsen, 2006); and Dutch (Gerrits & Zumach, 2006). Overall, each study used the same picture-naming task, but differed in number of participants (between 27 and 45) and their age ranges (between 1; 9 and 4; 2).

Though there was a great deal of variability in all four languages, two interesting and apparently paradoxical findings were reported related to sonority distance and /s/ + nasal targets, in particular. First, in the three West Germanic languages (English, Dutch, and Norwegian), #sC clusters with a larger sonority distance between the first consonant (C1) and the second consonant (C2) seemed to be rendered more accurately. This was the case for English /sw-/, Dutch /sl-/, and Norwegian /ʂɭ-/ and /sʋ-/ (p. 426). However, in L2 Hebrew, this trend was not identified. Of all the #sC clusters in Hebrew, /sʁ-/ has the greatest sonority distance between the two consonants, but is structurally similar to the West Germanic cluster /sw-/. The researchers explain this difference by pointing to the fact that Hebrew only has clusters with a small sonority difference between C1 and C2, so it is assumed that Hebrew speaking children do not find #sC clusters either easier or more difficult than other Hebrew clusters (p.426). Furthermore, all the researchers anticipated that their participants' cluster reductions would abide by the Sonority Sequencing Principle (SSP) with a tendency to delete the more sonorous segment of the syllable in order to preserve the optimal syllable shape. However, the SSP was consistently violated in cluster deletion by /s/ + nasal targets in all the languages, except Hebrew.

The researchers concluded two main findings about homorganicity related to the targets /st-/ and /s/ + nasal. First, based on the fact that the homorganic /s/ + stop clusters are similar across all four languages, the authors concluded that homorganicity of #sC clusters had neither a positive nor a negative influence on the production of /st-/ clusters. However, regarding /s/ + nasal targets, homorganicity at first appeared to have affected the accuracy positively, but only in the case of Norwegian. Rather, input frequency of /sn-/ was Norwegian is posited as a possible explanation for this result (see upcoming section on frequency for more details).

Another investigation that also takes into account markedness is a case study conducted by Smith (1973). This study explored many aspects of his son Amahl's phonological growth between the ages of 2;2 and 4;0 within the context of Standard English Pronunciation in the UK. Findings pertaining to sonority and words beginning with /s/ were included even though #sC clusters were not the exclusive focus of this study. Smith noted that a variety of word-initial #sC clusters began to appear in the child's speech and in the following order: /sl-/, /s/ + sonorant clusters, s + plosive clusters, and /st-/ clusters. Smith reports some of Amahl's consonant cluster reductions to be universal since examples in his speech reflected some trends on cluster reduction reported in prior literature. For example, in clusters where one member of the cluster is a stop and the other is not, Amahl reduced the cluster to the stop. There is mention of Amahl's production patterns of both the singleton /s/ and the cluster /st-/. In data captured through recordings, Smith was able to note that over time, Amahl's production of singleton /s/ progressed from [t] to [s], along with intermediary sounds such as the affricate [ts]. The cluster /st-/ was often realized as [s] before mastery of the cluster. Recently, some researchers who have revisited Smith's data (i.e., Jongstra, 2003; Hewlett & Waters, 2004) have noted that Amahl's pattern of production for both the singleton /s/ and the cluster /st-/ is uncommon and not often reported in the literature.

In another case study which also takes markedness into account, Gnanadesikan (2004) followed her daughter Gitanjali's acquisition of onset clusters in word-initial and stressed syllable positions. Gnanadesikan provides an account of L1 acquisition within the framework of Optimality Theory (OT; Prince & Smolensky, 2008). She argues that since there are similar phenomena regarding consonant cluster acquisition in many languages (e.g., Navajo, Sanskrit) such as coalescence and cluster simplification, these are examples of universal constraints. Gitanjali's language development was tracked between the ages of 2;3 to 2;9. Gnanadesikan notes that words beginning with /s/ were treated differently by her daughter depending on whether the /s/ is more sonorous than the following consonant (deleted), or, less sonorous than the following consonant (retained). Thus, Gitanjali produced "syllables that optimize syllable shape not only with respect to segment number (restricting to one onset consonant), but also with respect to sonority requirements" (p. 9).

The construct of sonority in the articles detailed thus far appears to have gained a popular standard by which to measure children's cluster reductions and patterns of acquisition. Unfortunately, however, it seems that sonority may *not* be the all-embracing theory that would otherwise help account for all of children's cluster reductions. While Wyllie-Smith, McLeod, and Ball's (2006) article may at first appear to be an example of yet another study that uses a sonority-based approach to better understand word-initial cluster reductions in young children, there is something that sets this study apart from those discussed thus far. That is, the authors also include cluster reductions to single non-target consonants in their analysis (e.g., *smoke* pronounced as *foke*). This study claims to be the first to include such an analysis of non-target consonants (i.e., coalescence) vis-à-vis the Sonority Hypothesis (SH). Yavas and Core (2006) have pointed out that even though coalescence is a frequently reported phenomenon in children's speech, including this phenomenon in data analysis has been conspicuously absent from the literature (p. 177). Wyllie-Smith et al. (2006) argue therefore that the theoretical construct of sonority has the potential to be a viable theory in helping us to understand the patterns in children's consonant cluster acquisition better, provided that it can be applied to children with typically developing speech, children with impaired speech, *and* cluster reductions to single non-target consonants produced by both groups of children.

To investigate whether children's word-initial consonant cluster reductions to single non-target consonants adhered to the SH, Wyllie-Smith et al. (2006) conducted two separate studies. The first study used monolingual Australian English speaking children with typically developing speech ($N = 16$) between the ages of 2;0 and 2;11. Data for the second study also came from monolingual Australian English speaking children, but they had impaired speech and were between the ages of 3;6 and 5;8. Adherence to the SH was defined as each participant realizing the least sonorous consonant 100% of the time.

There were four cluster categories used in both studies, with homorganic clusters included, but with no explicit discussion of homorganicity as a potential influential factor on the accuracy of #sC production. Though the cluster categories were the same for each group of children (i.e., fricative + stop, fricative + nasal, fricative + glide, and stop + liquid), the inventories for some cluster categories were larger for children with impaired speech. However, the rationale for doing so is not explained. Each target cluster was elicited spontaneously either via an image shown on a laptop or by showing a colour photograph. If the child did not know the word, a clue was offered or delayed imitation was employed, where necessary. Two productions per cluster per child were recorded and transcribed as it was believed to provide a representative sample of each child's current stage of consonant cluster development.

Group analyses of the reductions from both studies showed that, overall, cluster reductions from children with typically developing and impaired speech adhered to the SH. However, considerably more children with speech impairments violated rather than adhered to the SH. Interestingly, all clusters produced by children with typically developing speech adhered to the SH for all clusters, except fricative + stop (i.e., /st-/ and /sk-/). The fact that these two clusters violate certain phonotactic principles in English (i.e., a required rising sonority slope at the onset of syllables) was given as a possible explanation for the individual differences in production errors. Furthermore, the data obtained from non-target reductions overall did not adhere to the SH. The authors conclude that while sonority is helpful in explaining some cluster reductions, it cannot be used as an all-inclusive explanation to account for children's development. Rather, other factors responsible for cluster reductions have yet to be identified. One of these factors will be discussed in the following section.

First Language Acquisition (FLA) and Frequency

There do not seem to be any studies that directly control for input frequency (i.e., the frequency distribution of the forms under investigation in the speech that surrounds the child) in the development of #sC onset clusters in FLA. For example, the main goal of one study by Kristoffersen and Simonsen (2006) (discussed above) was to investigate to what extent sonority plays a role in the course of acquisition in young children acquiring both homorganic and heterorganic #sC onset clusters in their native Norwegian. After ruling out sonority as an influential role for the acquisition of #sC clusters, the authors use frequency only as a *possible* explanation to account for the high accuracy rate of /s/ + nasal onset targets in Norwegian. The researchers speculate in their analysis that the frequency of /sn-/ in the input, and not homorganicity or sonority, might be considered the best explanatory factor for the accuracy in the Norwegian children's productions, since /sn-/ is more frequent than /sm-/ in the target language. However, without a well developed child-directed corpus of East Urban Norwegian, the authors were unable to establish the degree of importance for frequency. This methodological weakness is a design feature that the current study has addressed.

On the other hand, prior studies that directly investigate frequency in the FLA of consonant clusters lack consensus. While some studies investigating consonant clusters do suggest a frequency effect (e.g., Leonard & Ritterman, 1971), others do not show a similar correlation (e.g., Bennett & Ingle, 1984; Kirk & Demuth, 2005). For example, Leonard and Ritterman (1971) looked at both high and low frequency occurrence of words both beginning and ending with /s/. The authors posit that highly frequent consonant clusters in the ambient language may greatly increase the chances for children to both differentiate and produce frequently repeated sounds. Using various corpora to validate possible frequency effects (e.g., Kucera &

Francis, 1967), the authors observed that high frequency /s/-initial consonant clusters such as /st-/ would be produced more accurately. Indeed, in their sample of both typically developing and /s/ defective seven-year old children, their results showed that this was the case.

However, there are also studies that do not show a frequency effect. For example, similar to Leonard and Ritterman's (1971) study, Bennett and Ingle (1984) looked at word frequency of occurrence as a potential influential variable on the articulation of /s/ in fifty children being treated through articulation therapy for a functional articulation disorder of /s/. However, unlike Leonard and Ritterman (1971), Bennett and Ingle (1984) did not find any positive correlation between word frequency of occurrence for word initial /s/ consonant clusters and correct articulatory production. Participants imitated 100 frequently occurring words taken from school text books which also displayed similar frequencies of word-occurrence in the adult corpus used in the study conducted by Leonard and Ritterman. The words, which included the homorganic #sC clusters /st-/, /sn-/, /sl-/ (but not exclusively) were modelled by a speech-language pathologist and imitated by the participants. Results were analyzed in terms of articulatory proficiency related to word frequency of occurrence. The researchers concluded that the misarticulation of /s/ was not significantly related to the frequency of occurrence with which the relevant forms occurred in the children's input.

Second Language (L2) Research: Markedness and Sonority

Another productive area of consonant cluster research involves examining cross-linguistic influences pertaining to sonority in the production of #sC consonant clusters in bilinguals (e.g., Eckman & Iverson, 1993; Someillan & Yavas, 2005; Yavas & Barlow, 2006; Yavas &

Beaubrun, 2006). Many of these researchers have explored the acquisition patterns of word-initial English #sC onset clusters in participants whose native language does not permit such clusters. However, as some researchers have pointed out (e.g., Boudaoud & Cardoso, 2009; Cardoso, 2008), a major shortcoming of these prior studies is that they have unwittingly created a confounding influence of place of articulation effects since homorganic clusters are investigated alongside heterorganic clusters. Cardoso and Liakin (2009) and Boudaoud and Cardoso's (2009) studies, on the other hand, claim to be the first to deliberately attempt to control for place of articulation effects by limiting their investigation to the homorganic #sC onset clusters /st-/, /sn-/ and /sl-/. Boudaoud and Cardoso's study (2009) involved 30 university-educated native speakers of Farsi (a language which completely prohibits onset consonant clusters of any type) learning English. Their methodological framework included, among other things, non-linguistic factors (i.e., proficiency level, level of formality, etc.) and, importantly, an examination of markedness involving sonority, in order to obtain a better understanding of e-epenthesis, a phenomenon which involves adding an epenthetic vowel before #sC onset clusters (e.g., /stɑp/ → [*e*s.tɑp]). This phenomenon has been observed to be typical of Farsi ESL speakers, and is believed to be triggered by restrictions on syllable structure. Using sentence-based reading tasks, picture-based interviews, and a relational scale established on markedness involving sonority, the researchers predicted that the developmental path for the homorganic #sC clusters would follow the subsequent developmental sequences predicted by Clements' (1990) SSP (also adopted in this study, as discussed earlier): /sl-/ (easiest to acquire because it has the most universally preferred CV structure, and of the three #sC targets has the largest sonority distance between /s/ and /l/); followed by /sn-/ (more marked in relation to /sl-/); and /st-/ (the most marked of the three homorganic clusters, and which would trigger the most instances of e-epenthesis as a result).

Surprisingly, the results for /sn-/ conflicted with what had originally been predicted. It was found that an exclusively sonority-based account cannot fully explain the patterns of homorganic #sC acquisition since /sl-/ and /sn-/ patterned together, followed by /st-/. Instead, the authors appeal to a phonetically based account for acquisition. That is, they proposed a markedness relationship involving the feature continuancy, which takes into account this feature in the articulation of the homorganic #sC targets. In their analysis, there is "a higher effort cost" involved when producing /sn-/ and /st-/ since they are both articulated by making a [+ continuant] sound for [s] and then stopping the flow of air during the articulation of [-continuant] [n] and [t]. Conversely, the situation is the opposite for /sl-/ where there is no obstruction of air flow going from [s] [+continuant] to [l] [+continuant] thus resulting in a possibly smaller effort in terms of articulation. While the abovementioned studies fully or partially confirm the effects of sonority on acquisition, they have not addressed the issue of frequency. This is the topic of the following section.

Second Language (L2) Research: Markedness and Frequency

The current study takes inspiration from Cardoso and Liakin's (2009) study. Similar to Boudaoud and Cardoso's (2009) study which has sonority markedness as its theoretical underpinning, Cardoso and Liakin's investigation is the only one that takes into consideration the effects of both markedness and frequency in the L2 acquisition of #sC onset clusters. Motivated by a lack of an "all-encompassing explanation" for the acquisition of #sC clusters within the context of Brazilian Portuguese (BP) speakers learning English as a foreign language (EFL), this study examined the effects of sonority and input frequency in the development of #sC onset clusters. As discussed earlier, the markedness hypothesis predicts that acquisition will progress from least to more marked #sC sequences, in the following order: /sl-/ → /sn-/ → /st-/. The input frequency hypothesis, on the other hand, predicts a developmental order in opposition to that predicted by markedness: /st-/ → /sn-/ → /sl-/. To test the latter hypothesis and to compile input frequency data from which to draw, a study was designed that involved assembling an oral corpus of one EFL instructor's 'teacher talk' over a period of three months, totalling 30 hours. To elicit data to test the possible effects of markedness, a picture-naming task was used to elicit #sC-initial words from ten adult BP English speakers (average age: 23), grouped together into two proficiencies. Stimuli included 12 pictures representing all the target clusters /sn-/, /sl-/, st-/.

The results indicated that while the frequency of /st-/ (87.4%) was found to be higher than for /sl-/ (6.4%) and /sn-/ (6.2%) in the oral corpus generated by teacher talk (a fact that was further validated by examining the target clusters in question in various other corpora; e.g., Kucera & Francis, 1967), the results showed that markedness, not input frequency, determines the order of #sC clusters in L2 acquisition: the least marked /sl-/ and /sn-/ sequences were acquired before /st-/.

Conclusion

Many of the studies reviewed above have provided a number of general and interesting insights into consonant cluster acquisition. For example, some studies have shown that there may be discrete and overlapping stages of consonant cluster development (Greenlee, 1974; Kirk, 2008), with the possibility that some older, yet typically developing children may still struggle with consonant cluster acquisition (McLeod et al., 2001). Wyllie-Smith et al.'s (2006) study is the first to incorporate children's non-target consonant cluster reductions (i.e., coalescence) in an analysis vis-à-vis the Sonority Hypothesis, and observed that sonority cannot be used as an all-inclusive explanation for the acquisition of consonant clusters.

However, investigations pertaining to homorganic #sC onset clusters are still limited in what they can tell us about phonological development over time. With the exception of a few case studies (e.g., Gnanadesikan, 2004; Smith, 1973), there are no longitudinal studies investigating #sC clusters. Even then, these two case studies examine a set of #sC clusters alongside other non-#sC cluster categories.

Furthermore, and more importantly, the studies conducted by Yavas et al. (2008) did not yield a consensus on the order of acquisition for #sC clusters across the four first languages examined (i.e., English, Norwegian, Hebrew, and Dutch). This may possibly be due to the fact that these studies did not control for place of articulation effects since they included all types (homorganic and heterorganic) of #sC clusters permissible as syllabic onsets. While Ohala (1999) was the first to apply the construct of sonority to help explain children's consonant cluster acquisition patterns, her study failed to include any spontaneous speech samples (see forthcoming discussion on the debate regarding spontaneous versus imitative speech). Though including imitative speech is sometimes a necessity in data collection (as is clearly the case when using unfamiliar imaginary animal names included in Ohala's experiment), the problem with including this type of speech in data analyses may lead researchers to get an inaccurate picture concerning a child's true phonological ability (Goldstein, Fabiano, & Iglesias, 2004).

Moreover, it appears that investigations into the effects of the ambient language on the course of #sC acquisition are restricted to only a handful of studies (i.e., Cardoso & Liakin, 2009; Leonard & Ritterman, 1971; Bennett & Ingle, 1984). What's more, the inclusion of children with articulation disorders in two of these frequency-based studies (i.e., Leonard & Ritterman, 1971; Bennet & Ingle, 1984) makes it difficult to generalize their results to a population of typically developing children acquiring their L1. With the exception of one study (i.e., Cardoso & Liakin, 2009), the two other studies have only consulted pre-existing written corpora in order to gain a measure of potential frequency effects on the course of acquisition. No spontaneous interactions between the actual participants involved in the studies and their respective caregiver(s) was ever recorded. The current study has addressed this design limitation by consulting with both pre-existing corpora, and has created a corpus of ambient recordings between the participant and her parent(s). This has ensured that frequency effects for #sC can be better accounted for and measured.

In addition, there are no studies in FLA that investigate the effects of both markedness and frequency effects on the development of #sC clusters in an L1. The current study helps broaden our understanding of the L1 acquisition of #sC onset clusters by extending findings of previous research to a new context by examining the language development of one monolingual English speaking child.

The current study has intended to fill some of the gaps in the previous L1 literature reviewed above by: 1) focusing exclusively on the homorganic onset clusters /st-/, /sn-/, and /sl-/ in order to avoid place of articulation effects; 2) unlike the majority of previous studies exploring the acquisition patterns of consonant clusters, being longitudinal in nature, permitting a closer look at any u-shaped development that might occur with regard to #sC production; 3) potentially shedding light on the debate concerning the structural status of #sC onset clusters by providing further empirical evidence; and 4) using three data collection methods (triangulation) in order to better account for the development of #sC (see Chapter 3).

The research questions this study has sought to address are as follows:

1) What is the developmental path of #sC clusters in one monolingual, English speaking child?

2) Which of the two hypotheses is the best predictor of the acquisition order?

   Frequency (input): /st-/ → /sn-/ → /sl-/

   Markedness (sonority): /sl-/ → /sn-/ → /st-/

CHAPTER 3: METHODOLOGY

This chapter presents the methodology that was adopted in order to address the research questions given in Chapter 2. Accordingly, it introduces the participant who was recruited for the study, the materials that were employed, and the procedure used. Finally, the chapter concludes by providing a description of the ways the data were analysed.

The Participant

One female toddler served as a participant in this longitudinal study. Her age at the onset of the study was 2;3. For a number of important reasons, the benchmark of two years was chosen for the start of data collection. For one, it has been pointed out by a variety of researchers (i.e., French, 1989; Lleo & Prinz, 1996; Watson & Skukanec, 1997) that children as young as two years of age have the ability to produce word-initial consonant clusters in a variety of languages that permit them (i.e., English, German, Spanish, etc). However, it has also been pointed out that the attempts to produce these clusters may not necessarily accurately reflect the ambient language (McLeod et al., 2001). Furthermore, there seems to be a direct link between the typical "word spurt" phase of the two-year old child and their emerging awareness and analysis of phonology as it pertains to receptive vocabulary and, more specifically, as it relates to consonant clusters (Ingram, 1991). This, Ingram points out, represents a shift in the young child's phonotactic awareness from the earlier, simple word shapes of CV, VC, or CVCV to more complex phonotactic constraints such as CCVVC (where C = Consonant, V = Vowel). Furthermore, consonant mastery is "one of the most widely used metrics of phonological acquisition and phonological disorder" (Edwards & Beckman (2008).

The participant was from a monolingual, English-speaking home and had no siblings. She began early canonical babbling at the end of her tenth month, which is within the range of normal, though most children begin to babble between the ages of six and eight months (Clark, 2003). The participant's first attempts at consonant clusters was observed around the age of 1;11 when she said [bu] for /blue/. She attended a French nursery school 2-3 mornings a week at a local Montreal community center in the Cote-des-Neiges area. The participant had her hearing screened as a newborn, and there were no parental concerns regarding her speech, language, or hearing development. The singleton consonant /s/ (as "s" in soup, seussy) had already been mastered by the participant, which was a basic requirement for the current study. This was to ensure that any consonant cluster reduction or simplification strategies used by the participant were not simply due to a lack of production ability for word initial /s/.[4] Data collection continued until the participant had acquired all three homorganic #sC targets. The benchmark of 80% or greater accuracy was used to determine acquisition (Ota & Green, 2011).

In order to ensure greater reliability and to substantiate claims of #sC acquisition, three different data collection methods were used. The first of these methods was a weekly puppet elicitation task of #sC-initial pseudo words in order to elicit target structures. The second was to create a corpus of speech to which the participant was exposed in order to measure frequency effects. The third involved a language observation journal where the participant's linguistic

[4] Recent research has shown that evidence regarding whether phonemes are actually mastered in singleton contexts before clustered contexts is still inconclusive (McLeod, van Doorn, and Reed, 2001).

progress in general was taken note of, also on a weekly basis. Each will be discussed in turn and in detail below.

Instruments and Procedure

Puppet-elicitation Task

Because puppet play is met with enthusiasm from two-year old children (Segal & Adcock, 1985), a puppet-name elicitation task was employed to elicit the three homorganic #sC consonant clusters considered in this study (/st-/, /sn-/, and /sl-/). In order to obtain a representative sample of consonant cluster production, and more importantly, to ensure that there were no confounding word familiarity and frequency effects, an elicitation protocol was created whereby six finger-puppets were given six mono-syllabic, pseudo-English names containing the targeted homorganic #sC clusters (i.e., /s/ + stop, /s/ + nasal, and /s/ + liquid). Two of each #sC cluster type were used in naming the puppets. The six pseudo-English names are as follows: [sliːd], [slɛg], [snɪb], [snu:d], [stu:b], [stiːg] (see the puppet pictures in Figure 5 with their associated orthographic and phonetic representations). These pseudo-words obey the following s-initial English syllable structures: sCVVC (e.g., [sti:g]), or sCVC (e.g., [snɪb]). The rationale for adopting pseudo-words was to ensure that the participant was not familiar with any of these names, thus reducing the possibility of both a familiarity effect on the one hand, and a frequency effect on the other, since the participant was only exposed to the target #sC-initial pseudo-words during the puppet elicitation task. The puppet-elicitation task took place on a weekly basis, taking approximately five minutes each time.

  

Sleed [sliːd] **Sl**eg [slɛg] **Sn**ib [snɪb]

  

Snood [snu:d] **St**oob [stu:b] **St**eeg [stiːg]

Figure 5. Puppets used in the Puppet-Elicitation Task

Procedures

Puppet elicitation task

The entire interaction described here between the researcher and the participant was recorded using a high-quality digital recording device (Marantz PMD660 Compact Flash Recorder). It began with an invitation to play with the puppets and voice recorder. If the child responded in the affirmative, consent was assumed to have been given by the child. Written consent from the participant's father was obtained and kept on file prior to the commencement of the study. If the child refused to play or showed a lack of enthusiasm, the elicitation task was deferred to a time when the child consented fully and enthusiastically.

To ensure the child participant's continued enjoyment of the elicitation task over the duration of the study, the task was designed to combine aspects of puppet play, peek-a-boo and hide-and-seek, play elements that maintain their appeal throughout the toddler years. In concrete terms, the elicitation task began with the puppets' faces concealed from view by placing them face down on the floor. The researcher then called one of the puppet's names and enlisted the participant in helping to locate the named puppet by also calling the puppet's name. The researcher said the name of the puppet again, or put her hand to her ear to encourage the participant to provide a second and third attempt at pronouncing the puppet's name. This repetition had a threefold purpose. First, it ensured that the participant received a clear model of the target. Secondly, it ensured that the researcher gained an accurate picture of what the participant could produce by eliciting two or three samples of the target word for the audio recorder. Finally, the cue to call the puppet again added to the enjoyment of the task by implying that the puppet was hard of hearing, timid, or uncooperative, and by calling again more loudly and more clearly, the challenge of finding the puppet promoted the participant's sense of her own agency and importance to the task. To ensure reliability, however, it should be noted that each #sC cluster received the same degree of input enhancement. That is, the name of each puppet was repeated the same number of times so as to avoid inadvertent frequency effects. Once the puppet's name was successfully elicited, the participant was invited to try to locate the corresponding puppet by selecting it from the rows of face down puppets on the floor (the hide-and-seek aspect of the task), turning it over (the peek-a-boo aspect), and putting it into a hat (puppet-play aspect). In this way, the elicitation task was repeated until all puppets were called, found, and placed in the hat. The puppets were then put away until the next data collection period to ensure that the set of puppets remained complete and that the task did not lose its appeal because of an over-familiarity with the puppets.

Evidence concerning differences in the effects of imitative versus spontaneous speech on the accuracy of children's responses (both typically used to measure consonant cluster mastery) is said to be both inconclusive and outdated (Edwards & Beckman, 2008). It has been pointed out that while some much older studies have claimed no differences between the two types of elicitation protocols (i.e., Templin, 1947), others have claimed that imitated productions may only be appropriate for assessing certain sounds and not others (i.e., Kresheck & Socolofsky, 1972). A more recent study claims still that including imitative speech in data analyses may lead researchers to get an inaccurate picture concerning a child's true phonological ability (Goldstein, Fabiano, & Aquiles, 2004). Since there is lack of consensus on the topic, both elicitation protocols, imitative and spontaneous, were used in the semi-experimental (i.e., controlled) setting.

Firstly, eliciting an initial imitative production at the beginning of each data collection session was essential for the "researcher to control the phonetic context" (Edwards & Beckman, 2008) and for the participant to "know" what the target #sC cluster was. Seeking out subsequent and spontaneous productions after an initial repetition or two of the target limited the possibility of a training effect and ensured more natural speech samples from the participant.

In addition, to further limit the possibility of any training effects, each weekly data collection session began with a different #sC cluster category from the last. Furthermore, the researcher did not say the targeted clusters more frequently than the participant. Finally, the participant was not allowed to interact with the puppets outside of the weekly recording sessions.

Ambient recordings

In order to gain a measure of the language to which the participant was exposed (input frequency), 15-30 minutes of weekly audio recordings between the participant and one or both of her parents, were conducted. These conversations took place during playtime, meal time, and story time. The audio recorder was placed out of sight, and no elicitation of the targets, either formal or informal, occurred.

Observation journal

Observations of the participant's general linguistic development were kept by the researcher in an observation journal. The goal was to write in the journal on a weekly basis, or whenever the participant produced versions of the relevant #sC structure. In this case, the researcher took note of the participant's linguistic progress in general, with an emphasis on the acquisition of the target #sC sequences. This less formal approach to data collection aimed to capture aspects of the context of acquisition that would otherwise have been missed by the more controlled elicitation task and the input focus of the ambient recordings. These observations then served to further contextualize the other two data collection methods.

Analysis

Puppet Elicitation Task

The puppet elicitation task was analysed for pronunciation accuracy and checked by two raters. The quantitative results obtained in this task were then analyzed using descriptive statistics. Acquisition was defined as the participant accurately producing the #sC clusters 80% or more of the time. In addition, the analysis of the puppet elicitation task followed along the lines of McLeod et al. (2001), who have identified a gap in the traditional assessment and analysis of children's speech in prior research. That is, rather than simply regarding the path of acquisition for consonant clusters as simply a "steady progression," with the mastery of correct adult-like pronunciation and age of acquisition at which this occurs as being central to speech development, this study also took close note of the gradual sequence of development for all #sC targets. As Macken (1993) has pointed out, "phonological change is marked by regression, a non-linearity that signals getting better (phonologically) by getting worse (phonetically)" (p. 435). Since this study was longitudinal in nature, it permitted for a more fine-grained approach to analysis and a closer examination of the "frequent reversals and revisions," and "regressions" which McLeod et al., (2001, p.105) and Macken (1993) have identified as being characteristic of phonological acquisition in general. Therefore, any intermediary sounds on the road to acquisition or u-shaped development shown by the participant were taken close note of.

Ambient Recordings

The 15-30 minutes of weekly audio recordings of the ambient language in the home was labelled and organized for transcription. The parents' speech data were then compiled and prepared for corpus analysis (vocab profiler) using the ConCapp concordancer. Every instance of the three target clusters (/st-/, /sn-/, /sl-/) was counted and sorted according to types and tokens. The frequency distribution of each target was then compared to the frequency distribution in two English corpora: the ALERT corpus of teacher talk (Collins, Trofimovich, White, Cardoso, & Horst, 2006), an available spoken learner English corpus, and the Brown corpus (Kucera & Francis, 1967), a written corpus. The goal was to compare the ambient speech available for input in the child's home with the frequency distribution of #sC clusters in learner and standard English, and to establish that parental speech does not differ from the speech found in other corpora.

Observation Journal

After all of the #sC targets had been acquired by the participant, data collected from the observation journal was revisited in order to contextualize both the accuracy and the frequency data. The main goal of the observation journal was to substantiate some of the claims related to # sC acquisition (e.g., to compare whether a given #sC pattern observed in the puppet experiment was reflected in the child's general oral development).

CHAPTER 4: RESULTS

In the previous chapters, we reviewed the literature on #sC clusters. Rather than yield a picture of a definitive path of acquisition, the review of past studies proved to be inconclusive and contradictory. The two concepts of markedness and frequency were explored and two paths of #sC acquisition were proposed: either /sl-/ → /sn-/ → /st-/ driven by markedness, or /st-/ → /sn-/ → /sl-/ driven by frequency. I then described a triangulated method for testing these two predictions. This chapter presents the results of the study in which three instruments were employed to collect data: ambient recordings were made to establish input frequency in child-directed parental speech; puppet-elicitation data were collected to establish the order of acquisition of #sC targets for the participant; and finally, an observation journal was kept to triangulate and contextualize the data collected from the two aforementioned instruments. Results for each of these data collection instruments are presented in turn below.

Ambient Recordings

A total of 30 hours of ambient recordings were made of parental speech in the participant's home over a period of 19 months. The recordings were transcribed by a research assistant, double-checked by the researcher, then compiled and prepared for corpus analysis (Vocab Profiler) using the ConCapp concordancer. The input corpus consists of electronic transcriptions of spoken communication between the child participant and both of her parents. However, the majority of the interaction took place between the participant and her mother (accounting for 61.37% of the words spoken), while the transcriptions of the interaction between the participant and her father accounts for a smaller percentage of the corpus (38.63%). In addition, the reading and playing of audio texts (i.e., children's storybooks) also account for a small percentage of the corpus (4.03%). The corpus consists of 28,072 words in total, with #sC onset clusters representing 259 of these tokens (0.92% of the words found in the input). The results of the corpus-based analysis are presented in Table 1, where the frequency of each #sC cluster is shown. Frequency has been calculated for both tokens and types. Observe that the token and type frequency count of the SSP-violating /st-/ is considerably higher (68.73% and 70.83% respectively) than for the SSP-abiding /sl-/ (21.23% and 14.58% respectively) and /sn-/ (10.04% and 14.58% respectively). Data from the input corpus establishes that of the three targets investigated in this study, the SSP-violating #sC cluster /st-/ occurs the most frequently in child-directed parental speech, followed by /sn-/ and then /sl-/.

Table 1

Distribution (N and %) of #sC in Child-Directed Input Corpus (size = 28,072)

	/st-/	/sn-/	/sl-/	Total
Tokens	178 (68.73%)	55 (21.23%)	26 (10.04%)	259
Types	34 (70.83%)	7 (14.58%)	7 (14.58%)	48

As already mentioned, in order to establish a measure of *token frequency* for #sC homorganic clusters at the onset of words, the ConCapp concordancer searched for all words beginning with /st-/, /sn-/, and /sl-/. *Type frequency,* on the other hand, was measured by counting the number of different words in the corpus beginning with /st-/, /sn-/, and /sl-/.

In order to verify that parental speech is indeed representative of the English language, the three frequency patterns observed for the homorganic #sC targets (i.e., /st-/, /sn-/, /sl-/) were compared to the frequency distribution in two existing English corpora: the ALERT (spoken) teacher English corpus (Collins, Trofimovich, White, Cardoso, & Horst, 2006), and the Brown corpus (Kucera & Francis, 1967), a written corpus. As Table 2 illustrates, the frequency distribution of #sC tokens in the ambient recordings observed in the current study is consistent with the frequency distribution found in both the Brown and the ALERT corpora. Along the lines of Tognini-Bonelli (2001) then, it is reasonable to assume that the corpus from the current study, especially with respect to the distribution of homorganic #sC onset clusters, is possibly representative of other English parental corpora.

Table 2

The Distribution of #sC Tokens across Different Corpora

Corpus	#sC Total (N)	#sC initial words (%)		
		/st-/	/sn-/	/sl-/
Brown: L1 Written (Kucera & Francis, 1967)	10, 900	87.9	9.3	2.7
ALERT: L2 Oral (Collins et al., 2006)	1,020	90.7	5.7	3.8
Current study	259	68.7	21.2	10.0

Let us now return to Bybee (2001) and her reasoning about tokens and types: "the productivity of a pattern [...] is largely determined by its type frequency: the more items encompassed by a schema, the stronger it is, and the more available it is for application to new items" (p. 13). According to this view, and based on the results obtained, the child participant should acquire /sn-/ at the same time as /sl-/ if the child is sensitive to type frequency. However, if the child is sensitive to token frequency, we should see /sn-/ acquired before /sl-/ since there is double the number of tokens for /sn-/ in comparison to the number of tokens of /sl-/ (see Table 1). With regard to /st-/, this form is expected to be acquired more easily than the other clusters, regardless of the analysis adopted. See Table 3 for a type versus token frequency prediction for the three #sC under investigation. As will become clearer in the next section, these results indicate that neither a type nor a token frequency analysis accounts for the patterns observed in this study.

Table 3

Type versus Token Prediction: #sC clusters

Sensitivity	Prediction
Type	/st-/ → /sn-/ = /sl-/
Token	/st-/ → /sn-/ → /sl-/

= indicates both items are acquired at the same time
→ indicates the item on the left is acquired before the item on the right

Puppet-Elicitation Task

Data collection for the puppet-elicitation task took place on a weekly basis for 19 months when the participant was between the ages of 2;3:28 and 3;10:9. At the outset of the study, the participant could produce /s/ as a singleton onset, but was yet unable to produce any #sC clusters. Data collection ended shortly after the child participant had acquired the last of the three #sC onset cluster targets. However, there were times when illness, travel, or occasional uncooperativeness on the part of the participant, interfered with weekly audio recordings. In such cases, data collection resumed the following week. Once the participant produced puppet names containing one of the three onset cluster targets correctly in 80% of utterances, then it was deemed that she had achieved a command of the target structure. The benchmark of 80% acquisition might be better expressed as 4 out of 5 accurate productions from five recorded samples of the puppet elicitation task. The age at which each target met the 80% or greater benchmark was noted (see Figure 6). In this way, an order of acquisition was established for the target clusters, as will be discussed next.

|------------------------321days (3;10) /st-/ ---|

|--------------------90 days; (2;10:31) /sn-/--------------------------------|

|---------57 days (2;9:31) /sl-/--------------------|

Vowels	**>**	**Glides**	**>**	**Liquids**	**>**	**Nasals**	**>**	**Fricatives**	**>**	**Stops**
[a,i]		[w,y]		[l,r]		[m,n]		[s,f]		[t,d]

Figure 6. Time to acquisition and degrees of sonority

Data from the puppet-elicitation task recordings indicate that /sl-/ was acquired at 2;9:7, /sn-/ was acquired at 2;10:31, and /st-/ was acquired at 3;10:9 As such, the data confirms a markedness-driven path of acquisition: /sl-/ → /sn-/ → /st-/ rather than a frequency-driven path. Table 4 below presents the results from the experimental puppet-elicitation task (*i.e.,* the trajectory of #sC development based on markedness and age of acquisition for each of the target clusters). Looking more closely at the data, one can quantify how many days it took the participant to acquire each #sC target and, based on the sonority scale adapted from Clements (1990), the varying degrees of sonority associated with each cluster. For example, it took the participant 190 days to go from producing /s/ as a singleton onset to /sl-/ (two degrees of sonority). 57 days later, she acquired /sn-/ (3 degrees of sonority), and finally, 321 days later, she acquired /st-/ (6 degrees of sonority). From the beginning of data collection to the end, it took the participant 378 days to go from acquiring the least marked and sonority abiding cluster /sl-/, to the most-marked and sonority-violating cluster /st-/.

Table 4
Puppet-Elicitation Task: #sC Target and Age of Acquisition

Age	#sC acquired (80% or greater accuracy)
2;3:28	singleton /s/
2;9:7	/sl-/
2;10:31	/sn-/
3;10:9	/st-/

Observe that despite the significantly high rate of /st-/ in the ambient speech available to the participant (68.7%) described in the previous section, the frequency of #sC in the input did not have an effect on the order of acquisition for the three homorganic #sC clusters under investigation. In stark contrast, the evidence provided by the puppet elicitation task supports the claim for a sonority-based markedness effect. Recall that the main aim of the current study was to determine which of the two hypotheses, frequency (input) or markedness (sonority), would be the best predictor of the order of acquisition in one monolingual English speaking child. The results of the puppet-elicitation task confirm the hypothesis that a sonority-based account best explains the developmental order, starting with the less marked SSP-abiding clusters (i.e., /sl-/ and /sn-/, respectively), followed by the more marked SSP-violating onset sequence (i.e., /s/ + stop). Furthermore, the data shows that there is a clear and discrete order of acquisition for /sn-/

and /sl-/, refuting the type versus token refinement proposed by Bybee (2001). In this study, the acquisition in production of #sC was not determined by its type frequency, since the most frequent /st-/ was acquired last, and the two remaining clusters /sn-/ and /sl-/ did not follow the prediction established by the author (the more type frequent /sn-/ was acquired 57 days after /sl-/).

#sC Onset Clusters: Reversals and Regressions

The current study has not only allowed for the identification of a developmental order for the #sC targets based on one of the two hypotheses (in this case markedness based on sonority), but its longitudinal nature has also permitted the collection of a comprehensive data set. Recall from Chapter 3 that prior research on phonological acquisition has found that the process is prone to "regressions," and "frequent reversals and revisions" (McLeod et al., 2001; Macken, 1993), often characterized by deletion of one of the two consonants, assimilation, and other phonetic processes. In order to track the participant's gradual sequence of #sC clusters, a coding protocol similar to Ohala (1999) was used. For example, data from the puppet task was coded as follows: first consonant in the cluster produced (hereafter C1); second consonant in the cluster produced (hereafter C2); consonant cluster correctly produced in an adult-like fashion; the use of coalescence or assimilation – e.g, /snIb / → [pIb]); or other (for example, the use of epenthesis – e.g., /səlɛg/ → [səlɛg]), or, non-responses from the participant, which happened on occasion, were also included in the latter category). Targets were analyzed cluster by cluster, beginning with the two pairs of the least marked clusters (i.e., /sl-/, /sn-/) and ending with the most marked cluster (i.e., /st-/).

/sl-/ (sleg [slɛg] *and sleed* [sliːd]*)*

The coding protocol described above allowed for a fine-grained analysis of the puppet elicitation data. It revealed the characterization of early phonological growth being marked by regressions and reversals, at least for the SSP-abiding clusters (i.e., /sl-/ and /sn-/; Macken, 1993; McLeod, 2001), to be valid. For example, after her initial acquisition of /sl-/ within the context of the pseudo-English puppet name *sleed* [sliːd] (i.e., marked by an accuracy rate of 100% at age 2;9;7), the participant's production was then marked by a worsening in her performance over the next 5 weeks. During this 5 week period, the participant's production accuracy went well below the threshold used to determine acquisition, ranging anywhere between 0 – 50% accuracy. The participant also reverted to using such early avoiding strategies as consonant cluster reduction, a strategy which was prevalent between the ages of 2;3 and 2;8, before her initial #sC acquisition was noted. For example, the participant's preferred reduction strategy for /sl-/ was reduction to C1 so that *sleg* was pronounced as [sɛg]. On occasion, the participant also produced clusters that differed from the original consonant in C2 position, substituting /w/ for /l/ so that she produced [swɛg]. Epenthesis (i.e., [səlɛg]) was noted on one occasion only. However, this five week period was then followed by a period of improvement over the course of the next five recording sessions (i.e., one month). During these five recording sessions, the participant's production accuracy for /sl-/ remained consistent at 100%, before regressing again (i.e., ranging between 0 – 75% accuracy) over the next seven consecutive recording sessions, between the ages of 3;0:12 and 3;2:16. Again, during this time, the participant reverted to using the same early avoiding strategies, namely consonant cluster reduction to C1 /s/. Finally, between the ages of 3;3:9 and the end of data collection at 3;10:9 (i.e., over the course of six months), the participant's production of /sl-/ remained steadily consistent with an accuracy rate ranging between 80 - 100%.

The participant's production accuracy for /sl-/ within the context of the second, pseudo-English puppet name *sleed* [sliːd], also went through similar periods of accuracy, interspersed with stages of reversals and regressions before retaining accuracy again. However, while the participant's initial acquisition of /sl-/ within the context of the puppet name *sleg* [slɛg] was noted at the age of 2;9:7, /sl-/ in *sleed* [sliːd] was noted one month later, at the age of 2;10:16, thus suggesting an effect of phonological environment. Her preferred reduction strategy for /sl-/ within this particular context was also to C1 so that *sleed* [sliːd] was realized as *seed* [siːd]. On occasion, the participant also produced clusters that differed from the original consonant in C2 position, substituting /w/ for /l/ (e.g., /sli:d/ → [swiːd]). /sl-/ in *sleed* [sliːd] began to show consistently accurate production patterns (i.e., 100%) to that of /sl-/ in sleg [slɛg] between the ages of 3;3:26 and 3;10:9 (i.e., over the course of six months).

/sn-/ (snib [snɪb] *and snood* [snu:d])

As with the /sl-/ cluster just discussed, within the context of the pseudo-English puppet name *snood* [snu:d], the SSP-abiding /sn-/ also showed a pattern marked by frequent reversals and regressions. In *snood* [snu:d], the acquisition of /sn-/ was noted at the age of 2;10:31. However, unlike /sl-/, /sn-/ did not show the same degree of consistent production accuracy toward the end of data collection. That is, while /sl-/ showed a pattern of steady production accuracy ranging between 80-100% between the ages of 3;3:26 and 3;10:9, /sn-/ was still prone to many regressions. For example, the participant's production accuracy of /sn-/ was marked by both highly accurate periods of production (i.e., 100%) interspersed with periods of inaccurate production ranging anywhere between 0 – 66% accuracy. For example, the participant's preferred consonant reduction strategy was to C1 (e.g., *snood* [snu:d] was realized as [su:d]). Occasionally, however, the participant also reduced /sn-/ to C2 (e.g., /snu:d/ → [nu:d]).

Acquisition for the target /sn-/ in *snib* [snɪb] was noted one week later than *snood* [snu:d], at the age of 2;11:2 (accuracy rate 100%). Similarly, /sn-/ within this specific context was reduced to C1, though the participant also reduced to C2 on occasion (i.e., /s*nɪb*/ → [nɪb]). Prior to acquisition, the participant rarely used either coalescence or deletion followed by assimilation (*i.e.,* [fɪb] and [pɪb])[5].

/st-/ stoob [stu:b] *and steeg* [stiːg]

Interestingly, while /sl-/ and /sn-/ showed a number of highly accurate periods of production, interspersed with periods marked by frequent regressions, /st-/ showed an altogether different picture of gradual development. Acquisition of the SSP-violating target within both pseudo English puppet names (i.e., *stoob* [stu:b] and *steeg* [stiːg]) was not only noted much later than for the SSP-abiding targets (i.e., two weeks prior to the end of data collection at the age of 3;9:20), but production accuracy for /st-/ remained at 0% almost consistently throughout (except for two occasions where production accuracy for /st-/ was noted between 16% - 50%, 6 months prior to the end of data collection). In other words, the SSP-violating target /st-/ did not undergo regressions to the same extent as the SSP-abiding targets. The participant's preferred type of

[5] It should be noted that this analysis is ambiguous because the developmental forms [fɪb] and [pɪb] for /snɪb/ can be analyzed as two distinct (but related) phenomena: /s/ and /n/ coalesce to a single coronal, which then undergoes place assimilation from word-final /b/, or /n/ assimilates to labial /m/ and the resulting /sn-/ coalesce to /p/.

consonant cluster reduction was to C1 so that *steeg* [sti:g] and *stoob* [stu:b] were realized as [si:g] and [su:b], respectively. As was the case with /sn-/, less common for this particular target was either coalescence, or deletion followed by assimilation (i.e., *foob* [fu:b]).

To sum up, despite the participant showing many reversals and regressions during the development of #sC clusters, particularly for the SSP-abiding #sC clusters /sl-/ and /sn-/, based on the benchmark of acquisition set up for the current study (80% or greater), the order of acquisition for the three onset cluster targets remains unchanged.

Observation Journal

Results from the observation journal show that the ages at which the SSP-abiding targets (i.e., /sl-/, /sn-/) were acquired by the participant differed slightly from what was observed in the puppet elicitation task. For example, it was noted in the observation journal that /sl-/ was acquired two months after what was noted in the puppet-elicitation task (i.e., 2;9:7 vs. 2;11:6). In the case of /sn-/, acquisition was noted six months later when compared to the results from the puppet elicitation task (i.e., 2;10:31 vs. 3;4:1). The results for /st-/ in both the observation journal and the puppet elicitation task, however, were noted at the same time (3;10:9). The results of the observation journal are presented in Table 4, where the results from the puppet elicitation task are provided for comparison.

Table 5

#sC Observation Journal Results

#sC Acquired	Puppet Elicitation Task: Age of Acquisition	Journal: Age of Acquisition
/sl-/	2;9:7	2;11:6
/sn-/	2;10:31	3;4:1
/st-/	3;10:9	3;10:9

It was noted that the participant's early attempts at producing /st-/ progressed in the following order: /**f**/op → /**s**/op → /st-/op (where '→ ' indicates acquired before). The participant first used coalescence, and then reduced to C1, before gaining full command of the target /st-/. Once the participant had full command of /st-/ at the age of 3;10:9, it was observed that she still had difficulty producing /st-/ within trilateral clusters (i.e., ***str****oller,* ***str****ing,* etc). It was also observed that at the age of 2;11:6, when she could still not produce /st-/, the participant began adding /t/ to certain words ending in /s/ (e.g., /kjuri↔s/ → [kjuri↔s**t**] 'curious'; /krIs/ → [krIs**t**] 'Chris). However, the participant never seemed to epenthesize /t/ at the ends of words like 'yes' and 'kiss'.

While the participant was in the process of acquiring the three target #sC clusters, she was also attempting to produce other /s/ plus consonant onset clusters, including /sw-/, /sm-/, /sp-/, and /sk-/. The preferred early avoiding strategy employed by the participant for these #sC cluster types was coalescence, with the exception of /sk-/, which the participant preferred to reduce to C1 (e.g., /skaj/ → [saj]). Some examples of coalescence include: /sp/aceship →

/f/aceship; /sp/oon → /f/oon; /sp/ots → /f/ots; /sw/imming → /f/imming; /sm/okey → /f/okey; /sm/arties → /f/arties[6]. By the age of 2;11 onwards, the participant reduced the use of coalescence for words beginning with /sw-/ and /sm-/ (e.g., *swimming*, *smarties*), and by the age of 3;8, she had full command of the cluster /sk-/. Furthermore, once she had acquired /st-/ at the onset at the age of 3;9, it was noted that the participant would sometimes self-correct when she heard herself use coalescence with other clusters. For example, it was noted that the participant immediately corrected herself after she said "*Fit it out*" instead of "*Spit it out*."

In sum, despite the discrepancy in age noted between the naturalistic observations made in the journal and the puppet elicitation task for the SSP-abiding targets, both instruments yielded an order of acquisition that remains consistent with a markedness effect, where the SSP-abiding clusters (/sl-/ and /sn-/) were acquired before the SSP-violating cluster (/s/ + stop).

[6] The examples illustrated here are all instances of coalescence since traces of both original sounds are preserved in the output form (e.g., /sp/ → [f]). The [f] has the fricative (stridency) from the /s/ and place of articulation (labial) from the /p/. Combined, they form [f].

CHAPTER 5: DISCUSSION, LIMITATIONS, AND CONCLUDING REMARKS

Summary

The purpose of this research was to establish a developmental path for the acquisition of homorganic #sC clusters and, consequently, to determine which hypothesis (i.e., input frequency or sonority markedness) would better account for the path of acquisition observed in the speech of one English speaking child between the ages of 2;3 and 3;10. The results from the input corpus showed that, despite the significantly high rate of the SSP-violating #sC cluster (i.e., /s/ + stop) in the speech surrounding the child, input frequency did not provide a satisfactory explanation for the sequence of acquisition. Rather, the evidence provided by both the puppet elicitation task and the observation journal suggests that the order of acquisition is consistent with a markedness (sonority) effect. Furthermore, since the data and results show that the participant's order of acquisition obeyed sonority, it seems that alternative analyses of #sC onset clusters (previously pointed out in Chapter 2), while not a goal of the study, are irrelevant. Though prior research into input frequency and L1 acquisition (e.g., de Villiers, 1985; Naigles & Hoff-Ginsberg, 1998; Stites, Demuth, & Kirk, 2004) has provided evidence to suggest that frequency can sometimes play a major role in determining the path of acquisition for certain linguistic structures (e.g., for the development of codas; Stites et al, 2004), for #sC sequences, the results obtained in this study support the hypothesis that markedness (sonority) plays an influential role on the course of phonological development.

The remainder of this chapter is divided into the following sections, each discussing one of the following topics: the participant's development of homorganic #sC onset clusters in general, the effects of frequency and sonority markedness on #sC acquisition (followed by recommendations for future research), the limitations of the current study and, finally, some concluding remarks.

The Developmental Path of Homorganic #sC Onset Clusters

Early Avoiding Strategies

As mentioned above, prior L1 research (see Chapter 2; e.g., Greenlee, 1974; Kirk, 2008; Smit, 1993; Ohala, 1999) has shown, for instance, that when in the process of acquiring consonant clusters, young children typically go through persistent and pervasive stages of developmental production errors. Results from the current study conform to some of the findings in the aforementioned studies. For example, Greenlee's (1974) model of consonant cluster development for English L1 includes a drawn out stage of development for substitutions and reductions to a single consonant, persisting for a number of months. As was shown earlier (see Chapter 4), this certainly was the case for the acquisition of the SSP-abiding targets (i.e, /sl-/ and /sn-/). On the other hand, in contrast to some prior L1 studies, (e.g., Stemberger and Treiman, 1986; Yildiz, 2005; Borden & Gay, 1978) despite the fact that /s/ is quite commonly a troublesome sound for young children, the participant never lost the /s/ in her production of #sC clusters or deleted the entire #sC cluster altogether (see upcoming discussion on the participant's preferred reduction strategies).

As described in Chapter 4, within the context of the puppet elicitation task, the participant's preferred reduction strategy for the SSP-abiding targets (i.e., /sl-/ and /sn-/) was to delete C2 and thus preserve the least sonorous /s/ (e.g., /slid/ → [si:d] '*sleed*'; sleg → [sɛg] *'sleg'*; /snɪb/ → [sɪb] *'snib'*; /snud/ → [su:d] '*snood*'). These reductions are consistent with behavioural evidence noted in prior L1 research (e.g., Ohala, 1999; Goad & Rose, 2004), where young children typically delete the more sonorous segment (i.e., /l/ and /n/) so that reduction patterns comply with the principles of the Maximal Sonority Distance (MSD). According to the MSD, when learning to produce onset clusters, many children typically delete the more sonorous segment so that the selected form begins lowest in sonority, resulting in an existing form that constitutes a wide sonority rise, and thus, an optimal syllable shape.

However, the participant's preferred reduction strategy for the SSP-violating cluster (i.e., /s/ + stop) was to delete C2 (i.e., /stiːg/ → [siːg] '*steeg'*; /stub/ → [su:b] *'stoob')*, a behaviour that conforms to the the MSD principle. Interestingly, the participant's preferred reduction strategy for /st-/ complies with Smith's data for Amahl (the child participant), who also preferred to reduce /st-/ to C1 (Smith, 1973). Researchers who have revisited Amahl's data have reported this type of strategy to be "uncommon" and "not often reported in the literature" (see Chapter 2). As Wyllie-Smith et al. (2006) have pointed out, while sonority may be helpful in explaining some cluster reductions, it clearly cannot be used as an all-inclusive explanation to account for all children's developmental errors. It may thus be that a better explanation for these cluster reductions within the context of the puppet-elicitation task has to do with the salience of the first consonant in the cluster, and not with the MSD principle. That is, it may be possible that perceptual salience (defined as loudness or distinctness from an acoustic perspective), played a role in eliciting the preservation of /s/, which *vis-à-vis* /t/, is acoustically more salient, similar to what was reported in Cardoso, Liakin and French (2009) and Cardoso (2011). To investigate the effects of salience in #sC acquisition, future research may want to include a perception study that directly assesses 1) whether the higher salience of /s/ in #sC clusters corresponds to higher perceptibility, which might then influence their production; and 2) whether the salience of each cluster plays a role in their acquisition. See Cardoso et al (2009) for a study that investigates #sC perception from an L2 perspective.

Future research should also investigate and analyze non-target utterances (i.e., coalescence, epenthesis) to help explain the gradual sequence of development of #sC onset clusters over time, as there may be other factors involved in the gradual sequence of #sC development. For example, the explanation of first consonant /s/ salience does not take into account the other types of behaviour (though rare) noted in the puppet elicitation task. This behaviour includes: substitution (i.e., /slɛg/ → [swɛg] *'sleg'),* reductions to C2 (i.e., /sti:g/ → [tiːg] '*steeg';* /snu:d/ → [nuːd] '*snood'*), epenthesis (i.e., /slɛg/ → [səlɛg] '*sleg'),* and coalescence (i.e., /snɪb/ → [fɪb] '*snib';* /stu:b/ → [fu:b] *'stoob')*. Equally, with the SSP-abiding #sC targets (i.e., /sl-/ and /sn-/), there was evidence of frequent reversals and revisions, which the current model was not able to account for.

/t/ Epenthesis in Words Ending in /s/

The observation journal brought to light a curious phenomenon in the participant's developing speech. The participant appended /t/ to the coda of words ending in /s/, including words such as *Chris*, *curious*, and *close*. On the surface, it suggests that coda /-st/ is acquired one year earlier than onset /st-/. In addition, this pattern is consistent with the sonority sequencing principle. The application of the Sonority Sequencing Principle to rhymes predicts an earlier acquisition for sequences that display a smooth fall to the coda. The appearance of /-st/ in the coda is an example of a gradient sonority decline towards the right edge of the syllable, contrary to what happens with /st-/ in the onset. This may suggest that the participant was overgeneralizing the newly acquired segmental structure to a syllabic environment that is less marked and therefore more easily acquired (in addition to coda /-st-/ fulfilling SSP requirements, /st-/ coda clusters surface before onset clusters in L1 acquisition – e.g. Kirk & Demuth, 2005). It is beyond the scope of this study to say definitively whether this phenomenon is an artefact of the study (see forthcoming discussion on training effects), an idiosyncratic behaviour of the participant, or a normal part of phonological development. Future studies may wish to explore this issue by employing a more principled and systematic approach to language journal observations in relation to the development of /-st/ in both coda and onset positions in the development of syllable structure in young children.

Input Frequency

Distribution of #sC and Comparison with Other Corpora

In the present study, and based on the other corpora that were examined, the frequency distribution of the #sC onset targets was consistently /st-/ > /sn-/ > /sl-/ (where ">" indicates more frequent than). It is therefore reasonable to assume that the current corpus is representative of English in general since there do not seem to be any differences in the general frequency distribution of the #sC targets in either written (Brown) or spoken corpora (ALERT and the child-directed corpus collected for this study). In short, the distribution of the target #sC structures in English is the same regardless of the corpus one considers.

The results of this study indicate a markedness effect, and therefore the only conclusion possible is that input frequency, as described and analyzed in Chapters 3 and 4 respectively, is irrelevant to the acquisition of homorganic #sC onsets. If we had seen an acquisition order in which /st-/ was acquired before the other target clusters, this would have served as evidence of a frequency effect whereby /st-/ → /sn-/ → /sl-/ would thus have complied with a prediction that favours a token frequency analysis. In contrast, the following acquisition order: /st-/ → /sn-/ = /sl-/ would have constituted evidence for a type frequency prediction (see Bybee, 2001). Since neither of the two orders of acquisition were observed, all claims for either a type or token frequency effect for the three homorganic #sC clusters are irrelevant and warrant no further discussion. It will be up to future researchers to determine, for instance, whether input frequency will play any role with regards to the homorganic #sC clusters for different varieties of developing English and for other languages that also permit homorganic #sC clusters in the onset position (e.g., Romanian, Russian, Italian).

Markedness

Order of Acquisition Based on Markedness (Sonority)

The second hypothesis adopted in this study assumed a markedness (sonority) effect, and posited that an English speaking child should acquire the #sC onset targets in the following sequence: /sl-/ → /sn-/ → /st-/. The results from the puppet-elicitation task and the observation journal provided evidence for an order of acquisition based on the sonority effect. In particular, as predicted by the sonority-based markedness hypothesis adopted, the participant acquired the less marked and sonority-abiding onset clusters first (i.e., /s/ + liquid and /s/ + nasal), while the sonority violating onset cluster (i.e., /s/ + stop) was acquired last. This hypothesis is based on Clements' (1990) Sonority Sequencing Principle (SSP) and Broselow and Finer's (1990) Minimal Sonority Distance (MSD) (both discussed in chapter 2 and alluded to in the previous discussion). As reported in Chapter 2, Smith (1973) observed the same sequence of acquisition for his child participant in his longitudinal study. Due to the dearth of longitudinal studies investigating these targets, the question remains whether this path of acquisition is typical or particular to the participants in Smith's (1973) study and the study reported here.

Training Effects

Evidence for an order of acquisition based on sonority markedness was supported by the results from both the puppet-elicitation task and the observation journal. Interestingly, however, it was formally noted in the puppet elicitation task that the acquisition for the SSP-abiding targets (i.e., /sl-/and /sn-/) occurred earlier than what was noted in the observation journal. The journal showed that /sl-/ and /sn-/ were acquired at 2;11:6 and 3;4:1, respectively, and that /sl-/ and /sn-/ in the puppet elicitation task were acquired at 2;9:7 and 2;10:31 respectively. A possible explanation for why the SSP-abiding target forms appeared earlier in the puppet elicitation task than in natural speech may be due to a word familiarity effect, or a training effect whereby the practicing of the pseudo-words over a long duration (i.e., over the course of 19 months) accelerated their mastery. Considering the fact that word familiarity effects may have played a role in influencing which words containing a particular #sC form are mastered first, it should be pointed out that relying on naturalistic observation alone would have been problematic to pinpoint stages of acquisition based on time. For instance, as Eisenbeiss (2010) has pointed out, the lack of researcher control in naturalistic speech sampling can make it difficult to study low-frequency phenomena (i.e., phenomena that involve forms that rarely occur in typical spontaneous speech – in the present study, for instance, the low incidence of /sn-/-initial forms such as “snow”), which was one of the goals of the current study. Since this study investigated the frequency effects of consonant cluster targets which occur at different degrees of frequency in English, relying on naturalistic data collection alone for the purpose of taking proficiency measures and avoiding word-familiarity effects would have necessitated a greater data set which would have been more intrusive upon the participating family’s privacy. For example, the researcher would have had to follow the child around with a microphone for many hours a week, placed microphones in every corner of the child’s home, or fitted the child with a vest containing a hidden microphone, for equally long periods of time. For this reason, the puppet elicitation task was preferable in that it was able to establish in weekly five minute sessions what would have taken many hours in naturalistic speech sampling. However, the problem of the training effect produced by the puppet elicitation task should be addressed in future research. In addition, since there was a training effect observed, it is reasonable to assume that this type of over-production of the problematic forms may affect the development of #sC clusters in children with a speech pathology or delay that involve these clusters.

Markedness and SLA

In light of the results from the current study, /st-/ may certainly pose a challenge for L2 learners whose L1 does not permit #sC clusters (e.g., Cardoso & Liakin, 2009; Boudaoud & Cardoso, 2009). Considering how marked /st-/ is and how difficult it may be to acquire, even in the L1, teachers should emphasize this cluster in pronunciation training. Special importance should also be placed in teacher training programs so that future teachers become aware and consequently more prepared to help students produce these highly marked structures.

Other Limitations

While a strength of this study is the quantity of data and fine-grained analysis made possible by a triangulated longitudinal case study, having only one participant is a significant limitation when trying to generalize its findings to a larger population. As such, it is unclear if the observed path of acquisition might have been influenced by a gender effect, as has been suggested in the L1 acquisition literature (e.g., Stites et al., 2004); see also discussion in Chapter 2. It is not clear, therefore, whether a markedness effect is typical for females, atypical, or universally observable for all English monolinguals of either sex. Replication of this study or a close variation is needed with a larger number of participants of both sexes to establish a normative path of acquisition.

Concluding Remarks

This study investigated the longitudinal acquisition in production of #sC onset clusters in the speech of one monolingual English speaking child between the ages of 2:3 and 3:10. It also examined the effects of two hypotheses for the development of homorganic #sC onsets: one based on a markedness effect and another based on an input frequency effect. While the markedness hypothesis predicts that acquisition should progress from the least marked to the relatively more marked structures (i.e., /sl-/ → /sn-/ → /st-/), the distribution of the target clusters in the child-directed input predicts that the order of development will be the opposite (i.e., /st-/ → /sn-/ → /sl-). In order to assess these two hypotheses, three data collection instruments were used. The first instrument consisted of creating and analyzing a corpus of child-directed speech (ambient recordings in the home) between the parents and the participant in order to establish the relative frequency of /st-/, /sn-/, and /sl-/. The second consisted of a weekly puppet-elicitation task in order to elicit the three #sC targets and to establish an order of acquisition. The third instrument consisted of a language observation in order to contextualize the data from the two abovementioned instruments and to substantiate claims of #sC development over time. Though the results from the child-directed corpus showed that of the three targets the SSP-violating /st-/ was the most frequently occurring cluster (followed by /sn-/ and /sl-/ respectively), the results of both the puppet-elicitation task and the observation journal showed that the participant's order of acquisition followed a path predicted by sonority-based markedness. In sum, results from two of the instruments used in this study (i.e., the puppet-elicitation task and the observation journal) yielded an order of acquisition that was consistent with a markedness effect.

REFERENCES

Barlow, J. (2001). A preliminary typology of initial clusters in English. *Clinical Linguistics & Phonetics*, *15*, 9-13.

Ben-David, A. (2006). On the acquisition of Hebrew #sC onsets. *The Journal of Multilingual Communication Disorders*, *4*(3), 205-217.

Bennett, C. W., & Ingle, B. H. (1984). Production of /s/ as a function of word frequency, phonetic environment, and phoneme position. *Journal of Communication Disorders*, *17*, 361-369.

Borden, G., J., & Gay, T. (1978). On the production of low tongue tip /s/: a case report. *Journal of Communication Disorders*, *11*, 425-438.

Boudaoud, M., & Cardoso, W. (2009). The variable acquisition of /s/ + consonant onset clusters in Farsi-English interlanguage. In M. Bowles (Ed.), *Proceedings of the 10th Generative Approaches to Second Language Acquisition Conference* (pp. 86-104).Somerville, MA: Cascadilla Proceedings Project.

Boyd, J. (2006). On the representational status of /s/ clusters. *San Diego Linguistic Papers*, 2, 39-84.

Broselow, E., & Finer, D. (1991). Parameter setting in second language phonology and syntax. *Second Language Research*, *7*(31), 35-39.

Bybee, J. (2001). *Phonology and language use*. Cambridge: Cambridge University Press.

Bybee, J. (2006). From usage to grammar: the mind's response to repetition. *Language*, *82*(4), 711-733.

Bybee, J. (2007). *Frequency of use and the organization of language*. New York: Oxford University Press.

Cardoso, W. (2008). The development of sC onset clusters in interlanguage: markedness vs. frequency effects. In R. Slabakova (Ed.), *Proceedings of the 9th Generative Approaches to Second Language Acquisition Conference* (pp. 15-29). Somerville, MA: Cascadilla Proceedings Project.

Cardoso, W. (2011). The development of coda perception in second language phonology: a variationist perspective. *Second Language Research*, *27*(4), 433-465.

Cardoso, W., & Liakin, D. (2009). When input frequency patterns fail to drive learning: evidence from Brazilian Portuguese English. In B. Baptista, A. Rauber, & M. Watkins (Eds.), *Recent research in second language phonetics/phonology: perception and production* (pp. 174-202). Newcastle Upon Tyne: Cambridge Scholars.

Cardoso, W., John, P., & French, L. (2009). The perception of sC onset clusters in second language phonology: a variationist perspective. In B.Baptista, A. Rauber, M. Watkins (Ed.), *Recent Research in Second Language Phonetics/Phonology: A Variationist Perspective* (pp. 203-233). Newcastle Upon Tyne: Cambridge Scholars.

Clark, E. V. (2003). *First language acquisition*. Cambridge University Press.

Clements, G. N. (1990). The role of the sonority cycle in core syllabification. In J. Kingston & M. Beckman (Eds.), *Papers in laboratory phonology I: between the grammar and the physics of speech* (pp. 283-333). Cambridge: Cambridge University Press.

Clements, G. N. (1999). Item order in language and speech. In B. Joseph & B. Palek (Eds.), Proceedings of LP 98 (pp. 271–299). Presented at the LP 98.

Collins, L., Trofimovich, P., White, J., Cardoso, & W., Horst, M. (2006). *Acquiring language efficiently: research and teaching (ALERT corpus)*. Funded by the Fonds québécois de la recherche sur la société et la culture (FQRSC): Concordia University.

de Villiers, J. G. (1985). Learning how to use verbs: lexical coding and the influence of the input. *Journal of Child Language*, *12*, 587-595.

Demuth, K. (1990). Subject, topic, and Sesotho passive. *Journal of Child Language*, *17*, 67-84.

Demuth, K. (2007). The role of frequency in language acquisition. *Frequency effects in language acquisition: defining the limits of frequency as an explanatory concept*, Studies on Language Acquisition (Vol. 32, pp. 383-388). Berlin: Mouton de Gruyter.

Denzin, N. K. (1978). *The research act: a theoretical introduction to sociological methods*. New York: McGraw-Hill.

Eckman, F. (1977). Markedness and the contrastive analysis hypothesis. *Language Learning*, *27*, 315-330.

Eckman, F., & Iverson, G. K. (1993). Sonority and markedness among onset clusters in the interlanguage of ESL learners. *Second Language Research*, *9*(3), 234-252.

Edwards, J., & Beckman, M. E. (2008). Methodological questions in studying consonant acquisition. *Clinical Linguistics & Phonetics*, *22*(12), 937-956.

Eisenbeiss, S. (2010). Production methods in language acquisition research. In E. Blom & S. Unsworth (Eds.), *Experimental methods in language acquisition research*, Language Learning & Teaching (pp. 11-34). John Benjamins Publishing Company.

Ellis, N. C. (2002). Frequency effects in language processing: a review with implications for theories of implicit and explicit language acquisition. *Studies in Second Language Acquisition*, *24*, 143-188.

French, A. (1989). The systematic acquisition of word forms by a child during the first-fifty-word stage. *Journal of Child Language*, 16, 69–90.

Gerrits, E., & Zumach, A. (2006). The acquisition of #sC-clusters in Dutch. *Journal of Multilingual Communication Disorders*, *4*(3), 218-230.

Gierut, J. A. (1999). Syllable onsets: clusters and adjuncts in acquisition. *Journal of Speech, Language, and Hearing Research*, *42*, 708-726.

Gnanadesikan, A. (2004). Markedness and faithfulness constraints in child phonology. In R. Kager, J. Pater, & W. Zonneveld (Eds.), *Constraints in phonological acquisition* (pp. 73-108). Cambridge: Cambridge University Press.

Goad, H. (2011). The representation of sC clusters. In M. van Oostendorp, C. Ewen, E. Hume, & K. Rice (Eds.), *The Blackwell Companion to Phonology* (pp. 2-40). Malden, Massachusetts: Wiley-Blackwell.

Goad, H., & Rose, Y. (2004). Input elaboration, head faithfulness and evidence for representation in the acquisition of left-edge clusters in West Germanic. In R. Kager, J. Pater, & W. Zonneveld (Eds.), *Constraints in phonological acquisition* (pp. 109-157). Cambridge University Press.

Goldsmith, J. A. (1990). *Autosegmental and metrical phonology*. Cambridge, MA:: Basil Blackwell.

Goldstein, B., Fabiano, L., & Iglesias, A. (2004). Spontaneous and imitated productions in Spanish-speaking children with phonological disorders. *Language, Speech, and Hearing Services in Schools*, *35*, 5-15.

Greenlee, M. (1974). Interacting processes in the child's acquisition of stop-liquid clusters. *Papers and Reports on Child Language Development*, *7*, 85-100.

Hart, B. (1991). Input frequency and children's first words. *First Language*, *11*, 289-300.

Hewlett, N., & Waters, D. (2004). Gradient change in the acquisition of phonology. *Clinical Linguistics & Phonetics*, 18, 523–533.

Hogg, R., & McCully, C. B. (1987). Metrical phonology: a course book. Cambridge: Cambridge University Press.

Ingram, D. (1991). Toward a theory of phonological acquisition. In J. Miller (Ed.), *Research on child language disorders: a decade of progress* (pp. 55-72). Austin, TX: Pro-Ed.

Jongstra, W. (2003). Variable and stable clusters: variation in the realisation of consonant clusters. *Canadian Journal of Linguistics*, *48*(3/4), 265-288.

Kenstowicz. (1994). *Phonology in generative grammar*. Cambridge, MA: Blackwell Publishing.

Kent, R. D. (1993). Sonority theory and syllable pattern as keys to sensory-motor-cognitive interactions in infant vocal development. *Developmental neurocognition: speech and face processing in the first year of life*, D: Behavioural and social sciences (pp. 329-339). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Kirk, C. (2008). Substitution errors in the production of word-initial and word-final consonant clusters. *Journal of Speech, Language, and Hearing Research*, *51*(1), 35-48.

Kirk, C., & Demuth, K. (2005). Asymmetries in the acquisition of word-initial and word-final consonant clusters. *Journal of Child Language*, *32*, 709-734.

Kresheck, J. D., & Socolofsky, G. (1972). Imitative and spontaneous articulatory assessment of four-year old children. *Journal of Speech and Hearing Research*, *15*, 729-733.

Kristoffersen, Kristian Emil, & Simonsen, H. G. (2006). The acquisition of #sC clusters in Norwegian. *Journal of Multilingual Communication Disorders*, *4*, 231-241.

Kucera, H., & Francis, W. N. (1967). Computational analysis of present day American English (the Brown corpus). Providence: Brown University Press.

Kupisch, T. (2007). Testing the effects of frequency on the rate of learning: determiner use in early French, German, and Italian. *Frequency effects in language acquisition- defining the limits of frequency as an explanatory concept*, Studies on Language Acquisition (pp. 83-113). Mouton de Gruyter.

Ladefoged, P. (1993). *A course in phonetics*. Fort Worth:: Harcourt Brace Jovanovich College Publishers.

Leonard, L. B., & Ritterman, S. I. (1971). Articulation of /s/ as a function of cluster and word frequency of occurrence. *Journal of Speech and Hearing Research*, *14*, 476-485.

Lleo, C., & Prinz, M. (1996). Consonant clusters in child phonology and the directionality of syllable structure assignment. *Journal of Child Language*, 1, 31–56.

Lepsius, R., & Whitney, W. D. (1865). On the relation of vowels and consonants. *Journal of the American Oriental Society,* 8, 357–373.

Macken, M. A. (1993). Developmental changes in the acquisition of phonology. In B. Boysson-Bardies, Schonen, P. Jusczyk, & P. McNeilage (Eds.), *Developmental neurocognition: speech and face processing in the first year of life*, Nato ASI Series (pp. 435-450). Kluwer Academic Publishers.

McLeod, S., van Doorn, J., & Reed, V. A. (2001). Normal acquisition of consonant clusters. *American Journal of Speech-Language Pathology*, *10*, 99-110.

McLeod, S., Van Doorn, J., & Reed, V. A. (1997). Realizations of consonant clusters by children with phonological impairment. *Clinical Linguistics & Phonetics*, *11*, 85-113.

Naigles, L., & Hoff-Ginsberg, E. (1998). Why are some verbs learned before other verbs? Effects of input frequency and structure on children's early verb use. *Journal of Child Language*, *25*, 95-120.

Ohala, D. K. (1999). The influence of sonority on children's cluster reductions. *Journal of Communication Disorders*, *32*, 397-422.

Oller, D. K., & Eilers, R. E. (1988). The role of audition in infant babbling. *Child Development*, *59*(2), 441-449.

Ota, M., & Green, S. (2011). *New sound patterns are learned first in frequently heard words.* Presented at the International Child Phonology Conference.

Prince, A., & Smolensky, P. (2008). Optimality theory: constraint interaction in generative grammar. In J.J. McCarthy (Ed.), Optimality theory in phonology: a reader. Oxford, UK: Blackwell Publishing Limited.

San, D. (2002). Two Theories of Onset Clusters. *Chinese Phonology*, *11*(97).

Segal, M., & Adcock, D. (1985). *Your child at play: two to three years* (1st ed.). New York: Newmarket Press.

Smit, A. B. (1993). Phonologic error distributions in the Iowa-Nebraska articulation norms project: word-initial consonant clusters. *Journal of Speech and Hearing Research*, *36*, 931-947.

Smith, N. V. (1973). *The acquisition of phonology: a case study*. Cambridge University Press.

Someillan, M., & Yavas, M. (2005). Patterns of acquisition of /s/-clusters in Spanish-English bilinguals. *Journal of Multilingual Communication Disorders*, *3*(1), 50-55.

Stemberger, J. P., & Treiman, R. (1986). The internal structure of word-initial consonant clusters. *Journal of Memory and Language*, *25*(2), 163-180.

Steriade, D. (1982). Greek prosodies and the nature of syllabification (Doctoral Dissertation). Massachusetts Institute of Technology, New York.

Stites, J., Demuth, K., & Kirk, C. (2004). Markedness vs. frequency effects in coda acquisition. *In Alejna Brugos, Linnea Micciulla, and Christine E. Smith (Eds.), Proceedings of the 28th annual Boston University Conference on Language Development* (pp. 565-576). Cascadilla Press.

Templin, M. C. (1947). Spontaneous vs imitated verbalization in testing articulation in preschool children. *Journal of Speech Disorders*, *12*, 293-300.

Templin, M. C. (1957). *Certain language skills in children: their development and interrelationships*. Minneapolis: The University of Minnesota Press.

Tognini-Bonelli, E. (2001). *Corpus linguistics at work*. Studies in Corpus Linguistics. John Benjamins Publishing Company.

Treiman, R. (1986). The division between onsets and rimes in English syllables. *Journal of Memory and Language*, *25*(4), 476-491.

Watson, M. M., & Scukanec, G. P. (1997). Profiling the phonological abilities of 2-year-olds: a longitudinal investigation. Child Language Teaching and Therapy, 13, 3–14.

Wyllie-Smith, L., & McLeod, S. (2002). *Application of the sonority hypothesis to children's non-target reductions of consonant clusters*. Presented at the International Clinical Linguistics and Phonetics Association Conference, Hong Kong.

Wyllie-Smith, L., McLeod, S., & Ball, M. J. (2006). Typically developing and speech-impaired children's adherence to the sonority hypothesis. *Clinical Linguistics & Phonetics*, *20*, 271-291.

Yavas, M. (2003). Role of sonority in developing phonologies. *Journal of Multilingual Communication Disorders*, *1*(2), 79-98.

Yavas, M. (2006). *Applied English phonology*. Malden, MA: Blackwell Publishing.

Yavas, M., & Barlow, J. (2006). Acquisition of #sC clusters in Spanish-English bilingual children. *Journal of Multilingual Communication Disorders*, *4*(3), 182-193.

Yavas, M., & Beaubrun, C. (2006). Acquisition of #sC clusters in Haitian Creole-English bilingual children. *Journal of Multilingual Communication Disorders*, *4*(3), 194-204.

Yavas, M., & Core, C. (2006). Acquisition of #sC clusters in English speaking children. *Journal of Multilingual Communication Disorders*, *4*(3), 169-181.

Yavas, M., & Gogate, L. (1999). Phoneme awareness in children: a function of sonority. *Journal of Psycholinguistic Research*, *28*(3), 245-260.

Yavas, M., Ben-David, A., Gerrits, E., Kristoffersen, K. E., & Simonsen, H. G. (2008). Sonority and cross-linguistic acquisition of initial s-clusters. *Clinical Linguistics & Phonetics*, *22*(6), 421-441.

Yildiz, Y. (2005). The structure of initial /s/-clusters: evidence from L1 and L2acquisition. (M. Tzakosta, C. Levelt, & J. van der Weijer, Eds.)*Developmental Paths in Phonological Acquisition. Special issue*, Leiden Working Papers in Linguistics, *2*(1), 163-187.

Zec, D. (1995). Sonority constraints on syllable structure. *Phonology*, *12*(1), 85-129.