When Input Frequency Patterns Fail to Drive Learning: The Acquisition of sC Onset Clusters

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1. Introduction

This study investigates the effects of markedness and input frequency in the variable acquisition of /s/ plus consonant (henceforth sC) onset clusters in the speech of Brazilian Portuguese (BP) speakers learning English as a second/foreign language (ESL) in a classroom environment. The study focuses on the development of the homorganic /st/, /sn/, and /sl/ sequences, which are realized variably either via prothesis, a typical BP transfer phenomenon that inserts an [i] before these illicit clusters (e.g., [ist]op, [isl]ide), or via its target L2 pronunciation (e.g., [st]op, [sl]ide). The selection of these homorganic clusters was strategic because they constitute a set in which place of articulation is maintained constant (the three clusters all share the coronal articulator), which allows us to categorize them on the single dimension that distinguishes them: sonority. Moreover, heterorganic clusters (e.g., /sm/, /sk/) are more marked in comparison with those that share their articulators (based on Clements' 1990 Sequential Markedness Principle; see forthcoming discussion in Section 3).

Unlike most frequency-based studies in which there is an overlap between what is predicted by markedness and frequency (e.g., Hale, 1945; Leonard & Ritterman, 1971; Levelt, Schiller & Levelt, 2000; Zamuner, 2003; Trofimovich et al., 2007), these clusters are of particular relevance to test the effects of markedness against input frequency because they make different predictions regarding their order of acquisition. For instance, if L2 learners are sensitive to markedness, they should acquire the least marked /sl/ sequence before the more marked /sn/ and /st/, as predicted by Clements' (1990) Sonority Cycle and its corollary principles Sonority Sequencing and Minimal Sonority Distance (see Section 3). However, if L2 learners are sensitive to the frequency of these clusters in the input, they should acquire the most frequent form /st/ before /sl/ and /sn/ (see Section 4). The frequency data are drawn from an oral corpus specially designed for this study, which consists of the student-directed speech (teacher talk) of an English teacher over a two-month period. A summary of the predictions is illustrated below (where ">" indicates "acquired before" or "more easily articulated than").

(1) Developmental order of sC clusters: Two hypothetical learning paths

a. Markedness effect:	sl	>	sn	>	st
b. Frequency effect:	st	>	sl	>	sn

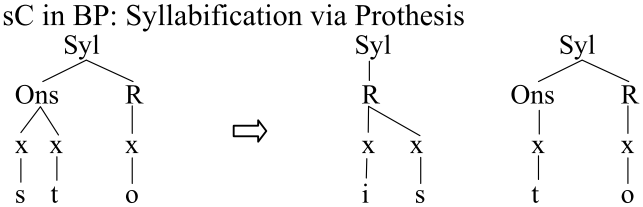
To investigate the effect of markedness and frequency on the acquisition of sC clusters, 10 native BP speakers were interviewed, from two levels of proficiency in English (i.e., low intermediate and advanced). The interviews followed standard sociolinguistic procedures for data collection and were analyzed for a set of linguistic and extralinguistic factors via the statistical program GoldVarb X (Sankoff, Tagliamonte & Smith, 2005). In general, the results indicate that learners are more likely to produce target-like sC sequences in higher proficiency levels and, more importantly, when the clusters are of the /sl/ or /sn/ type. In contrast, the /st/ sequence is not favored for target-like production, suggesting that the sequence is only acquired at a later stage in the acquisition of sC structure. These results conform to the predictions of Clements' (1990) Sonority Cycle and to some of the previous studies on the subject (e.g., Carlisle, 1991ab; Major, 1986; Escartin, 2005). Importantly, they also support the hypothesis that it is markedness in terms of sonority sequencing, and not input frequency, that determines the order of acquisition of sC clusters in second language speech.

The paper is organized as follows: Section 2 provides an introduction to onset clusters in Brazilian Portuguese and in BP-based interlanguage (BPE), and describes the relevant initial and subsequent states in the phonology of these learners. The third section discusses the concept of markedness on sonority sequencing and sonority distance and, based on this discussion, proposes a hypothesis for the developmental order of sC sequences. Section 4 is devoted to the input frequency analysis of sC clusters. In the same section, a similar hypothesis for the developmental order of sC sequences is proposed, based on the frequency distribution of these forms in the input. The fifth section addresses the production study, whose results allow us to assess the two hypotheses for the development of sC clusters. Finally, Section 5 provides a summary of the study and our general concluding remarks.

2. sC sequences in BP and BPE

Word-initial complex onsets in Brazilian Portuguese are restricted to obstruent plus liquid combinations (Ferreira Neto, 2001; Ribas, 2004): /pr/, /br/, /tr/, /dr/, /kr/, /gr/, /fr/, /vr/, /pl/, /bl/, /tl/, /kl/, /gl/, and /fl/. As is the case with closely related Spanish (e.g., Carlisle, 1988 et seq.; Escartin, 2005), BP disallows sC branching onsets in word-initial positions (see (2, (3) and (4)). Word-internally, the sC cluster syllabifies heterosyllabically as a coda-onset sequence, following a set of general principles on syllabification (e.g., de/s+t/oante → de/s.t/oante 'discordant'). In contrast, when the sC cluster appears word-initially, the same sequence can only surface if preceded by an epenthetic [i] (vocalic prothesis), in which case the sC cluster again syllabifies into two separate syllables, as the derivation in (2) illustrates.

(2) sC in BP: Syllabification via Prothesis



Prothesis is a highly productive process in BP phonology: It is observed in sC-initial words originally derived from Latin, as well as in words that have been brought into the language more recently in the form of borrowings, as exemplified in (3) and (4) respectively.

(3) sC clusters in BP: A diachronic view

Latin		Portuguese	
/st/abiliscere	→	[ist]abelecer	'to establish'
/st/ellare	→	[ist]elar	'related to stars'

(4) sC clusters in BP: A synchronic view (via borrowings)

English		Portuguese
/sl/ide	→	[isl]ide
/sn/ob	→	[isn]nobe
/st/and	→	[ist]ande

Assuming that second language acquisition is at least in some aspects filtered through the learner's first language (e.g., Wardhaugh, 1970; Broselow, 1987), a reasonable prediction is that in initial stages of L2 acquisition the learner will merely transfer L1 knowledge onto the target language, and the mere transfer of BP phonology will take place in the form of categorical prothesis. As exposure to the L2 increases, the innovative features are gradually incorporated into the developing system and, consequently, target-like forms emerge. The road to the target language, however, is paved with a high level of variability. The following sections will introduce the rationale behind our two hypotheses for the development of sC clusters, as well as address the following general questions: What linguistic and extralinguistic factors affect the development of sC sequences? In what developmental order are these clusters acquired? Consequently, which of our two hypotheses in (1) best accounts for the acquisition order in which sC are acquired in the interlanguage of BP-based English?

3. Markedness effects on sC clusters: Sonority

Markedness is a notion that was developed by the Prague School of Linguistics in the 1930s, more notably in the works of Trubetzkoy (1939) and Jakobson (1941). The Theory was later embraced by generative linguists from a variety of spheres of inquiry: General phonology (Chomsky & Hale, 1968; Battistella, 1990; Prince & Smolensky, 1993; de Lacy, 2006), L1 acquisition (e.g., Fikkert, 1994; Ohala, 1999; Gnanadesikan, 2004; Goad & Rose, 2004; Bernhardt & Stemberger, 1998), and L2 acquisition (e.g., Carlisle, 1988 et seq.; Major, 1996; Abrahamsson, 1999; Rebello & Baptista, 2006; Escartin, 2005; Yavaş, 2006; Yavaş & Barlow, 2006; Cardoso, 2007). Based on the marked/unmarked dichotomy, the theory typically assigns an unmarked status to linguistic representations that are simpler, less difficult, more frequent and/or more perceptually salient (e.g., Onsets, CV syllable structures). In contrast, representations that have a marked status are assumed to be more complex, more difficult, less frequent, and/or less likely to be perceived (e.g., Codas, CVC syllable structures) (see Eckman to appear for an overview of markedness in explaining L2 acquisition patterns, Battistella, 1990 and de Lacy, 2006 for a comprehensive introduction to the theory, and Haspelmath, 2006 for a critique and a discussion of the "twelve different senses" of the term). In this study, we adopt a strict version of markedness, one that is characterized in terms of sonority as defined and formalized by Clements (1990).

Sonority is an important concept for the analysis of sC clusters as it is considered a determining factor in syllabification (e.g., Sievers, 1881; Pike, 1943; Harris, 1983; Selkirk, 1984; Hogg & McCully, 1987; Clements, 1990; Dogil & Luschützky, 1990; Zec, 1995), and in explaining the acquisition of syllable structure in both L1s (e.g., Ohala, 1999; Yavaş, 2006; Yavaş & Barlow, 2006) and L2s (e.g., Major, 1986; 1996; 2001; Carlisle, 1988 et seq.; Baptista & Silva Filho, 2006; Koerich, 2006). The standard definition of the syllable, for instance, must refer to the concept of sonority: A syllable is comprised of an obligatory head, which constitutes the peak of sonority (usually a vowel), surrounded by segments of decreasing sonority. This sequencing of sonority within the syllable has been formalized as the Sonority Sequencing Principle (SSP; Selkirk, 1984:116):

(5) The Sonority Sequencing Principle:
"In any syllable, there is a segment constituting the syllable peak [usually a vowel] that is preceded and/or followed by a sequence of segments with progressively decreasing sonority values".

Despite its wide use as a tool to explain phenomena that revolve around the syllable, the concept of sonority is notoriously difficult to define, as it can be characterized from a variety of (sometimes overlapping) perspectives that include amplitude (acoustically defined as ‘intensity’ and perceptually as ‘loudness’ – Kent & Read, 1992; e.g., Ladefoged, 1993; Selkirk, 1984; Clements, 1990), openness of the vocal tract (e.g., Donegan, 1985), propensity for voicing (Kenstowicz, 1994), acoustic energy (e.g., Goldsmith, 1989), etc. For a comprehensive discussion of these and more features, see Parker (2002) and Yavaş (2006). With the use of a speech analyzer such as Praat (Boersma and Weenink, 2007), sonority can be visualized via the representation of the amplitude (loudness, intensity) of segments, depicted in a waveform as a bundle of vertical lines: the higher the amplitude, the higher the sonority level. Figure 1 illustrates the waveform for “Sam”, an SSP-abiding syllable that displays the low sonority of [s] and [m] with respect to the vowel [æ], and the relative difference in sonority between the less sonorous [s] and the more sonorous [m].

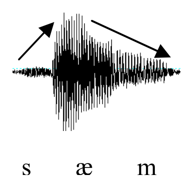


Figure 1. Waveform for “Sam” depicting sonority in terms of amplitude (intensity)

The sonority hierarchy adopted in this study is illustrated in (6), where classes of segments are organized from the least to the most sonorous for expository reasons (“<” indicates “less sonorous than” and the segments underneath these classes highlight the four segments that comprise the set of sC clusters covered by this investigation). For alternative or more detailed sonority hierarchies, see Hogg & McCully (1987) and Parker (2002).

(6) Sonority Hierarchy (adapted from Clements 1990)

Stops <	Fricatives <	Nasals <	Liquids <	Glides <	Vowels
/t/	/s/	/n/	/l/		

The generalizations regarding the syllable, the SSP and the sonority hierarchy discussed thus far account for syllable structures comprised of a nucleus followed or preceded by a single consonant. They say nothing about sequencing within clusters. In the following two sections, the syllabification of pre-vocalic sC clusters will be discussed. Let us start with the syllabification of /st/.

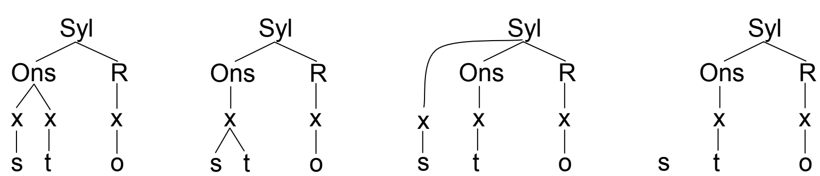
3.1 The problem with /st/: /st/ and the Sonority Sequencing Principle

The special representational nature of sC sequences and, more specifically, of those that violate the Sonority Sequencing Principle (i.e., /s/ + stop sequences) has been the topic of heated debate in phonology over the last three decades (e.g., Fudge, 1969; Vennemann, 1982; Selkirk, 1982; Kaye, 1992; Goad & Rose, 2004; Boyd, 2006). One of the issues that nourish the debate is the fact that, within the set of sC clusters, there is an asymmetry in the sonority profile of its members. For instance, employing the same visual representation for sonority using waveforms and the hierarchy discussed in (6), observe in Figure 2 that while the /sl/ sequence in [slɑt] ‘slot’ strictly abides by the SSP (a similar analysis holds for /sn/), the representation for /st/ in [stɑp] ‘stop’ violates the principle given that cluster first decreases and then increases in sonority towards the peak of the syllable.

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

Another issue concerns the asymmetries observed between sC and non-sC clusters (e.g., stop plus liquid sequences such as [pr], [kl], [br]). While the latter are typically and uncontroversially syllabified as onsets (similar to what is illustrated in (7a); e.g., Goad & Rose, 2004; Boyd, 2006), sC sequences are assumed to have a special status in the grammar because of their idiosyncratic behavior with respect to a variety of phonological phenomena (see Goad & Rose, 2004 for an examination of some of these phenomena from an L1 acquisition perspective). Aside from the standard branching onset analysis in (7a) (e.g., Carlisle, 1988 et seq.; Major, 1996; 2001; Ohala, 1999), the other representations in (7) illustrate some of the less orthodox analyses that have been proposed to account for the peculiar behavior of /s/ in sC clusters: (1) /s/ as the first member of a complex segment (see (7b); e.g., Selkirk, 1982; Lamontagne, 1993; Van de Weijer, 1996); (2) /s/ as Adjunct (see (7c); e.g., Barlow, 2001; Barlow & Dinnsen, 1998 (for /st/ and /sn/ only), Kaye, 1989; Kenstowicz, 1994); and (3) /s/ as Extrasyllabic (or Appendix) (see (7d); e.g., Goad & Rose, 2004; Fikkert, 1994; Giegerich, 1992; Levin, 1985). What is crucial in the alternative representations for onset clusters in (7b) through (7d) is that they eliminate potential SSP violations via the assignment of abstract representations. In this study, along the lines of Boyd (2006), we assume the standard view for the representation of sC clusters in (7a), one that assumes no structural distinction between sC and non-sC consonant sequences. For a review and critique of these alternative approaches, see Boyd (2006).

(7) The syllabification of onset clusters: Four analyses
a. Branching Onset b. Complex Segment c. Adjunct d. Extrasyllabic (Appendix)



In sum, we have established in this section a markedness relationship among sC clusters in which /st/ is more marked than /sn/ and /sl/ because the former violates the SSP. This relationship leads us to hypothesize that BP ESL learners will develop the syllable structure for more marked /st/ at a later stage than less marked /sn/ and /sl/: /sl/, /sn/ > /st/.

3.2 /sn/, /sl/ and the Minimal Sonority Distance

In this section, the hierarchy based on sonority markedness among sC clusters will be further expanded to include another markedness relationship between the two sequences that adhere equally to the SSP: /sn/ and /sl/. To explain the relationship between these two clusters with respect to markedness, we appeal to the concept of the Minimal Sonority Distance (MSD) (Clements, 1990; see also Selkirk, 1984; Baertsch, 1998; and Carlisle, 2006), formalized in (8) below. Simply put, the MSD expresses the sonority differential requirement for tautosyllabic adjacent segments such as branching onsets.

(8) The Minimal Sonority Distance (within complex onsets)
The second segment in an onset cluster prefers a more sonorous segment, “one with the maximal and most evenly-distributed rise in sonority” (adapted from Clements, 1990:303)

Considering the two SSP-abiding sC clusters and assuming the sonority hierarchy discussed in Section 3.1, observe that the sonority distance between /s/ and /l/ (distance = 2) is greater than that between /s/ and /n/ (distance = 1). From a MSD perspective, we may then assume that /sl/ is less marked than /sn/ because in the former the rise in sonority is maximal, as illustrated in the hierarchy in (9).

(9) Markedness hierarchy for SSP-abiding sC sequences: sl > sn

In general, the MSD captures the observation that onsets tend to be maximally low in sonority (e.g., Jakobson’s, 1941 Principle of Maximal Contrast, which results in the following markedness hierarchy with regards to onsets, going from the least to the most marked structure: stops < fricatives < nasals < liquids < glides). The arguments in favor of the MSD as a tool to establish markedness relationships in sC clusters are based on at least two factors. First, the MSD reflects in a subtle way the universal tendency for syllables to follow the canonical CV structure. Having a higher level of sonority, the second element in the sC cluster will resemble the more sonorous peak. Second, there is considerable evidence from L1 acquisition that supports the preference for less sonorous onsets. In the presence of sC clusters, for instance, the more common strategy to modify this complex structure is for the child to delete the more sonorous segment (underlined in the examples that follow) and to preserve the least sonorous one (Sonority-based selection; e.g., Chin, 1996; Gnanadesikan, 2004; Goad & Rose, 2004; Ohala, 1996; 1999; Pater & Barlow, 2003): /s̲t/op → [t]op, /sl̲/eep → [s]eep.

The markedness relationships between the sC clusters under investigation have now been established based on the principles of sonority sequencing and the minimal sonority distance between onset members. The result is a hierarchy in which /sl/ is less marked than /sn/, which are both in turn less marked than the SSP-violating /st/ cluster.

3.3 sC Sequences in second language acquisition: Previous studies

In the previous section, it was shown that one of the strategies commonly used by L1 learners to syllabify complex sC onsets is the deletion of the more sonorous segment. In second language acquisition, on the other hand, the most common strategy to syllabify illicit sC sequences is vocalic epenthesis (Broselow, 1984; Samarajiwa & Abeysekera, 1964; Swift, 1963; Yarmohammadi, 1969). This section provides a succinct overview of some of the relevant studies on the L2 acquisition of sC clusters involving Brazilian Portuguese and one of its closely-related siblings, Spanish. For ease of exposition and due to space limitations, the studies are compiled in a diagrammatic fashion where we illustrate their authors, the number of participants in each study, the L1 and L2 involved, the order of acquisition of the sC sequences (simplified; only relevant clusters are shown), and a rating scheme that illustrates whether the results obtained in that particular study corroborate or challenge the predictions based on markedness involving sonority, as discussed in the preceding section.

Table 1. sC clusters in L2 acquisition

Study	Participants	L1	L2	sC order of acquisition	Rating[c]
a. Carlisle (1988)	14 adults	Sp[a]	Eng	sl > sn, sm	***
b. Carlisle (1991b)	11 adults	Sp	Eng	sl > st	***
c. Carlisle (2006)	17 adults	Sp	Eng	sl > sn > st	***
c. Tropf (1987)	11 adults	Sp	Ger	ʃl, ʃr, ʃn, ʃm > ʃv, ʃp, ʃt	***
d. Escartin (2005)	23 adults	Sp	Eng	sm, sn > sl, sp, sk, st	**
e. Abrahamsson (1999)	1 adult	Sp	Swd	sn, sm > st, sp, sk > sl	**
f. Major (1996)	4 adults	BP	Eng	sp, sk, st > sl (other clusters)	
g. Rebello (1997)	6 adults	BP	Eng	sp, sk, st, sl > sm, sn	*
h. Rauber (2006)	10/9 adults	BP[b]/Sp	Eng	sm, sn, sl, sw > sp, st, sk	***

[a] Sp= Spanish, BP = Brazilian Portuguese, Eng = English, Ger = German, Swd = Swedish;
[b] In BP, there was no significant difference across the sets of clusters
[c] Rating scale: *** (as predicted by the SSP) to no asterisks (contradictory results)

Leaving aside the intricacies particular to each analysis and focusing on what is displayed in Table 1, two general patterns can be delineated: One in which the development of sC structure follows the path predicted by sonority (represented by the majority of the studies involving Spanish in (a) through (e)), and one in which the results remain inconclusive with respect to sC development (represented by Brazilian Portuguese in (f) through (h)). What cannot be deduced from Table 1 are some of the factors or issues that were not considered or controlled for in the studies. Here are some of the oversights that are being addressed in the present investigation: (1) With the exception of some of Carlisle's investigations, these studies ignore the effect that heterorganicity may have on the production of sC sequences. For instance, while /sn/ and /sm/ are equally marked with respect to sonority sequencing, they differ in place of articulation. Considering Clements' (1990:313) Sequential Markedness Principle ("For any two segments A and B and any given context X_Y, if A is simpler than B, then XAY is simpler than XBY") and the fact that the coronal /n/ is less marked than the labial /m/, it follows that the /sn/ sequence is the less marked of the two clusters. Obviously, the homorganic sC clusters violate a phonotactic constraint against homorganicity (the Obligatory Contour Principle for Place – OCP-Place: Adjacent identical place features are prohibited; McCarthy, 1988; Barlow, 2001; Goad & Rose, 2004; Yildiz, 2005; see also Carlisle, 2006), which is strongly operative in English as the following unattested sequences show: *dl, *tl, *pw, *fw. (2) None of these studies examined the role of input frequency in determining the path of development of sC clusters. Consider the results of Major (1996), for instance. Assuming that the incidence of /s/ + stop sequences in English is considerably higher than that of /s/ + liquid clusters (see Section 4 for the actual distribution), it is plausible to hypothesize that the former will emerge first in the acquisition of the target language (this hypothesis, however, will be refuted in Section 5). Accordingly, (3) none of these studies attempted to examine and assess the explanatory power of both input frequency and markedness as analytical tools to explain the development of sC clusters in interlanguage.

3.4 Conclusions

In this section, we have shown that an all-encompassing explanation for the development of sC clusters in interlanguage is far from conclusive, especially in the context of Brazilian ESL learners.

With regards to sonority and its effect on sC sequences, we have established that: (1) /st/ is the most marked of the set of sC clusters under consideration: It not only violates sonority sequencing, but the sonority distance between its two members is not maximal (it involves in fact a sonority reversal); and (2) the /sn/ cluster is more marked than /sl/ because the sonority distance between the two members of the former is smaller than that of the latter. Assuming that unmarked structures are acquired before more marked ones, the following learning path for the development of sC clusters is predicted:

(10) Developmental order of sC clusters – Markedness effects: sl > sn > st

4. Frequency effects on sC sequences

An alternative way of predicting developmental outcomes is via an approach that recognizes that language users are highly sensitive to the frequency with which certain linguistic structures occur in the language (e.g., Leonard & Ritterman, 1971; Gass, 1997; Bybee, 2001; Demuth, 2001; Munson, 2001; the volumes edited by Bybee & Hopper, 2001; Bybee, 2007; Trofimovich et al., 2007). In this approach, it is assumed that linguistic knowledge (competence) is mediated by frequency (quantified in *probabilistic* rather than absolute terms, as is customary in standard generative linguistic theory): Learners build linguistic representations according to the frequency of structures or patterns in the input. However, there is also ample evidence that frequency has little or no effect in accounting for certain linguistic phenomena (e.g., Moore, Burke & Adams, 1976; Bennet & Ingle, 1984; Spada & Lightbown, 1993; Lightbown & Spada, 1999; White, 1991; Labov, 2003; Davidson, Jusczyk & Smolensky, 2004; Kirk & Demuth, 2005; Davidson, 2006). In addition, some studies emphasize an equal role for both frequency and markedness in determining the course of language acquisition, depending mostly on individual differences (e.g., Levelt, Schiller & Levelt, 2000; Stites, Demuth & Kirk, 2004).

We will now present how we employed the concept of input frequency to predict the developmental stages in the acquisition of sC sequences in BPE.

4.1 The L2 corpus

The L2 corpus collected for the frequency study consists of approximately 30 hours of audio recordings of one highly proficient ESL teacher's input to adult learners in two standard language classrooms (beginning and intermediate levels), over a period of two and a half months. The audio recordings were conducted at a private language school in the city of Belém, Brazil. The collected corpus of teacher's speech was transcribed by two research assistants using Transcriber (Version 1.5.1), which yielded 837 instances of sC sequences. Because a preceding vocalic environment (V) is more likely to trigger the resyllabification of the cluster into two separate syllables (e.g., /st/ → [Vs.t]op; see Carlisle, 1988 et seq. for Spanish, and Rauber, 2006; Rebello, 1997; and Rebello & Baptista, 2006 for BP), only instances in which the cluster was preceded by a pause or a consonant were counted for the frequency analysis. The frequency computation of the data that we collected was conducted via *ConcApp* version 4 (http://www.edict.com.hk/PUB/concapp), a text analysis suite that includes a concordancer and a word frequency analyzer; the Brown Corpus analysis was completed via the concordancer in Cobb's *The Compleat Lexical Tutor* version 5 (URL: http://www.lextutor.ca). For the recording, a Zoom H4 Flash Recorder (with a built-in pair of microphones in an X/Y configuration) was utilized. The recorder was placed on the teacher's desk so that it could capture with greater precision the closest sound source, the speech produced by the teacher.

4.2 Results and discussion

The results of the corpus-based analysis are presented in (11), where we show the frequency with which each cluster appears the student-directed speech produced by the English teacher (input). Observe that the frequency of /st/ in the corpus is considerably higher (87.4%) than for the /sl/ and /sn/ clusters (6.4% and 6.2% respectively). For illustrative and comparison purposes (see forthcoming Figure 5), these results are repeated graphically in Figure 3.

(11) Distribution (*N* and %) of sC clusters in student-directed speech

sC Sequences – Total: 837	
st	731 (87.4%)
sl	54 (6.4%)
sn	52 (6.2%)

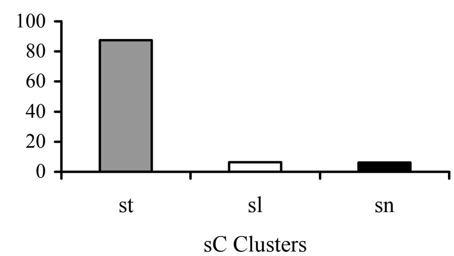


Figure 3. The distribution of sC clusters in the Input (%)

Convinced that the results in (11) merely depicted the limited and relatively simplified oral environment of a BP-based ESL classroom, we conducted three additional frequency analyses, using three different corpora. The first corpus (L2 Textbook: Written) consisted of an analysis and computation of all written instances of sC sequences in communicative activities in the textbook that was used by the teacher and the students who participated in the study. These communicative activities were the focus of most of the student-teacher and student-student interactions (approximately 75% of class time), and they were also included in the audio-recordings (by native or highly fluent English speakers) on the CD that accompanies the textbook. The second corpus analysis involved a frequency count of all sC-initial words in the Brown Corpus (Brown Corpus: Written; Kucera & Francis, 1967), a corpus of a million words that has been extensively used in the field of corpus linguistics. Finally, the third corpus analyzed was one compiled by Concordia University's ALERT project (ALERT Corpus: L2 Oral; Collins, Trofimovich, White, Horst & Cardoso, 2006), a corpus of video and audio recordings of three English teacher's input to Francophone ESL learners in an intensive program. Table 2 summarizes the results obtained and illustrates that the probabilistic distribution of sC in the input is not an idiosyncrasy of BP-based interlanguage, since data from completely unrelated corpora including written (a-b) and oral (c) language as well as French-based ESL speech (c) demonstrate the same pattern in which /st/ is considerably more frequent than its SSP-abiding pairs.

Table 2. The distribution of sC clusters across different corpora

Corpora	Total (*N*)	sC-initial words (%) *St*	*sl*	*sn*
a. L2 textbook: Written	140	90.7	5.7	3.8
b. Brown Corpus: Written (Kucera and Francis 1967)	10,900	87.9	9.3	2.7
c. ALERT Corpus: L2 oral (Collins et al. 2006)	1,020	90.7	5.7	3.8

From the distribution of sC sequences in (11) and Table 2, we may conclude two important points: Firstly, the results clearly show that frequencies from different corpora correlate fairly highly when broad-grained categories of frequency are used (see also Jurafsky 2003 for a similar view). Secondly, assuming that "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" (Bybee, 2001:13; see also Vitevitch, Luce, Charles-Luce & Kemmerer, 1997; and Flege, Takagi & Mann, 1996), the following learning path for sC clusters is predicted, in which the considerably more frequent /st/ is predicted to develop before (or be more easily articulated than) its less frequent counterparts /sl/ and /sn/:

(12) Developmental order of sC clusters – Frequency effects: st > sl > sn

5. The acquisition of sC in interlanguage: A variationist analysis

To contrast the two hypotheses regarding the developmental path of sC sequences in BPE, a production study was designed, involving some of the students of the teacher who was audio recorded for the frequency study described in the previous section. The production study adopts a sociolinguistic (variationist) methodology for data collection in order to obtain a reliable corpus of variable data such as those encountered in developing languages. This way, this investigation promotes a multidisciplinary and integrative approach that combines theoretical and methodological tools from three linguistic disciplines (i.e., sociolinguistics, second language acquisition and formal phonology), in an attempt to develop a "socially realistic linguistics" (Wilson & Henry, 1998) or, in Pennington's (2002:418-419) terms, a "real language phonology." As is customary in variationist studies, the study also includes separate tasks to elicit distinct levels of formality. It is cross-sectional and involves the participation of 10 English learners, stratified into two proficiency groups. Following the standard sociolinguistic view that "the individual doesn't exist as a unit" because language is the property of the community (Labov's answer to an interview question in Gordon, 2006:341), we assume in this study that proficiencies constitute different speech communities and, consequently, that the patterns of inherent variable behavior within the individual (i.e. the participant) are similar to those encountered within the group (i.e., proficiency). For data and analyses that confirm this claim in a second language environment, see Bayley (1991), Regan (1996, 2004), and Young (1991).

5.1 Data collection procedures

The methodology for data elicitation was to some extent inspired by Labov's (1966) seminal investigation of the pronunciation of (r) in coda position in three New York City department stores. Briefly, Labov attempted to elicit the phrase "fourth floor" from sales representatives by asking for the location of items found on the *fourth floor*. Whenever a response was provided (casual speech), Labov would search for a more careful repetition of "fourth floor" by pretending not to hear the salesperson's response (careful speech). The current study followed a similar procedure for data elicitation, except that the target phrase "fourth floor" was replaced by sC-initial words, elicited via a picture-naming task consisting of 12 pictures representing words that start with the relevant clusters (e.g., [sn]ake, [st]op, [sl]eep).[1] In this task (which we will occasionally refer to as picture-naming), participants were sporadically asked questions such as "What's this?", "What do you see?". They were also asked to pronounce only the word shown (i.e., without articles or other vowel-final words, in which case the sC onset could syllabify into two separate syllables). Mimicking Labov's tactic, the interviewer pretended not to hear the participant's response by using body language or asking questions such as "Can you say that again?". For convenience and in the spirit of the variationist methodology adopted, the first and more spontaneous utterance was interpreted as *less formal (first reply)* while the second, more careful response (in which more attention is paid to speech) was coded as *formal (careful reply)* (see Labov, 1972; Cardoso, 2001; Eckert & Rickford, 2001; Diaz-Campos, 2006; Escartin, 2005; John, 2006 for similar approaches to defining style). Finally, another more standard type of interview was used to collect more spontaneous speech: *Informal (interview with pictures)*. In this task, the participants were engaged in conversation based on the pictures provided. For instance, when shown the picture of a snake, they were asked questions such as "Do you like these animals?", "Have you even seen one?", "Do you know someone who has eaten one?".

(13) Pictures used in the interviews: A sample

The use of pictures in the interview was found to be a convenient way of obtaining a significant number of relevant tokens across different styles: Not only is learner speech characterized by monostylism in earlier stages of acquisition (Cardoso, 2007), but the incidence of coronal sCs is considerably low in natural speech (compare the 837 sC-initial words observed in approximately 30 hours of teacher talk with the 1003 tokens collected in nearly eight hours of sociolinguistic interview – see forthcoming Section 5.2; see also Kirk & Demuth, 2005 for the probabilistic distribution of complex onsets and codas in child-directed speech). The selection of the words for inclusion in the study followed four criteria: (1) motivated by the notion that certain prominent positions (e.g., stressed syllables) are more likely to maintain contrasts and thus less likely to undergo phonetic changes (e.g., Beckman, 1998; Trubetzkoy, 1939), the words selected for the interviews were all monosyllabic (and consequently stressed) to ensure that the clusters under investigation occurred exclusively in positions of prominence; (2) accordingly, the words represented in the pictures had to conform to a sCV(X)(C) syllable shape (where X stands for either a coda consonant – e.g., [p] in sto[p] – or the second element of a tense/long vowel or diphthong – e.g., [j] in sn[ejk]); (3) they had to be highly frequent in English (i.e., within the 1,000 list of the most frequently-used words in the corpora consulted, or highly frequent in the student-directed speech corpus collected) in order to minimize word-frequency effects: One could argue, for instance, that

[1] The pictures used in the data collection and illustrated above were downloaded from Yotophoto and are not subject to copyright: "These are images that are either in the Public Domain or released under Creative Commons, GNU FDL or similar licenses […] to help educators, bloggers and digital artists find photos they can use" (http://yotophoto.com).

learners are more likely to produce the cluster correctly in more frequently-occurring words (e.g., Bybee, 2001; Flege et al., 1996; Vitevitch et al., 1997; Trofimovich et al., 2007; see also Almeida, Knobel, Finkbeiner & Caramazza (in press) for the effect of word frequency in picture-naming tasks);[2] and finally, (4) to diminish the effect of L1 transfer, the words depicted in the pictures could not be words that had been borrowed into Portuguese or used in popular brand names.

The ten participants were post-pubescent (five male and five female) native BP speakers, with an average age of 23. The participants were divided into two groups based on their proficiency in English, established via a combination of criteria that include time of exposure to ESL in a classroom environment (established as the most relevant criterion), their placement within the school's proficiency system, and a background questionnaire (see forthcoming Figure 4, where we show that these criteria to determine proficiency closely correspond to the expected distribution of sC production across the ten participants): (1) Low Intermediate, consisting of six students with an average of 70 hours of classroom experience learning the language; and (2) Advanced, composed of four participants with more than 200 hours of in-class exposure to English. The data were collected by the author at a private language school in the city of Belém, Brazil, where English is rarely used outside of the learning environment. The interviews were audio recorded via a Marantz Flash Recorder PMD660 and an Audio-Technica AT831b lavaliere microphone, and were later transcribed using Transcriber (Version 1.5.1) and, whenever needed, Praat for more refined speech analyses. Two research assistants assisted in these tasks. The 1,003 tokens collected were coded according to the variables listed in Table 3, which were then submitted for statistical analysis.

Table 3. Factor groups for Goldvarb X analysis

Factor Groups	1	2	3
Dependent Variables	No prothesis (sC)	Prothesis (VsC)	
Proficiency	Low Intermediate	Advanced	
Type of Task/Style	Formal (careful reply)	Less Formal (first reply)	Informal (interview with pictures)
Sonority Profile	/st/	/sn/	/sl/
Participants		1-10	

5.2 Goldvarb statistical results and discussion

For the analysis of the BPE corpus, we adopted Goldvarb X (Sankoff et al., 2005), a statistical package expressly designed to handle the types of data derived from studies of language variation, which are characterized by unbalanced data (see Cedergren & Sankoff, 1974 and Tagliamonte, 2006 for an introduction to this statistical analysis technique for linguistic investigation, and Bayley & Preston's 1996 volume on the application of Goldvarb to variationist L2 acquisition). Briefly, the results of a typical Goldvarb analysis should be interpreted as holding over the entire corpus that is being investigated and, to the extent that this is a representative sample, to all similar speakers and linguistic and extralinguistic

[2] The computation of word frequency was conducted via VocabProfile in Cobb's *The Compleat Lexical Tutor* V. 5 (URL: http://www.lextutor.ca). VocabProfile is based on Laufer and Nation's Lexical Frequency Profiler, an application that classifies the words of texts into first and second thousand levels, academic words, and off-list for the remainder words.

contexts. The relevant output of a typical Goldvarb analysis contains the following information: (1) The raw number and the percentage of rule application involving each factor; (2) The factor weight, which measures the influence of each factor in the process under investigation, based on the corpus analyzed and, therefore, provides the most accurate view of the likelihood of variant occurrence. It consists of a value associated with each factor independently of others in the same factor group, which indicates the degree to which a factor promotes the occurrence of each variant (these are the results reported in Table 4). In the context of this study, values closer to 1 favor sC production, while values closer to zero should be interpreted as not having a positive effect on the accurate production of the cluster; and finally, (3) the input probability (or Overall Tendency), which is the likelihood that the variable under investigation (sC production in the context of our study) has of occurring in general, regardless of the specific contribution of the other factors included in the analysis. The final results, containing the factors that were selected in both the stepping-up and stepping-down runs of Goldvarb (i.e., *proficiency* and *sonority profile*; significance at above the $p < .05$ level), are shown in Table 4 (where the parenthetic information illustrates the percentage of target-like sC production). For illustrative purposes, the factors that favor sC production are shaded.

Table 4. Likelihood of sC Production – Significant Results (GoldVarb weight/%)

Factor Groups		**Factors**	
Proficiency	Low Intermediate .38 (34.9%)	Advanced .68 (64.9%)	
Sonority	/st/ .39 (37.3%)	/sl/ .61(56.8%)	/sn/ .54 (50%)
Input Probability		.47	

Chi-square/cell 0.070

Note that the factor group *participants* was excluded from the final statistical analysis to prevent interference with the significant *proficiency* factor, since every participant inherently belongs to a proficiency group and, more importantly, because the distribution of sC sequences across the ten participants (see Figure 4) shows a very low level of inter-proficiency variation. Ignoring the unexpected behavior of informant 5 (a low intermediate participant whose production mimics that of the advanced learners), accurate sC production is only favored in the speech of advanced learners (Participants 7 through 10). These results also confirm the aforementioned variationist view that language is the property of the community and "the individual doesn't exist as a unit". Surprisingly, another factor group that was removed from the final Goldvarb analysis was *type of task/style*, since the weights obtained for the two tasks encompassed by the group (around 0.5) indicate that they have no effect on variable sC production. Accordingly, this factor group was discarded in both stepping-up and stepping-down runs of Goldvarb.

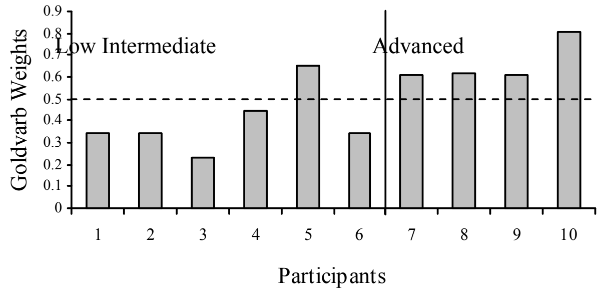


Figure 4. The distribution of sC cluster production across 10 participants

The significant Goldvarb results in Table 4 indicate a very good fit between the model of variation and the data collected. More importantly, they show that the production of sC sequences is favored in the speech of more advanced learners, and when the sC cluster is /sl/ or /sn/ (.61 and .54 respectively). Figure 5 below summarizes the results of the effect of sonority on the development of sC clusters.

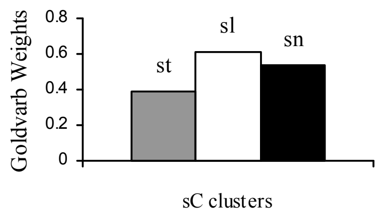


Figure 5. sC cluster production in BPE

Comparing the results in Figure 5 with the predictions made by both markedness on sonority sequencing (14a) and the frequency of sC clusters in the input (14b) (see also Figure 3), it is clear that the learning path to the development of these clusters mirrors the one predicted by markedness: The least marked (and less frequent) /sl/ and /sn/ sequences are acquired before the most marked (and considerably more frequent) /st/ cluster. In contrast to Bardovi-Harlig's (1987) claim that input frequency can overrule the relative difficulty of learning marked features (see also Flege et al., 1996 for a somewhat similar view), the results presented here portray the exact opposite.

(14) Developmental order of sC clusters: Two hypothetical learning paths

a. Markedness effect: sl > sn > st

b. Frequency effect: st > sl > sn

In sum, the results above unambiguously show that the frequency of English sC forms in the speech that surrounds the L2 learner has no effect in determining the order of development of sC clusters. They do not suggest, however, that frequency should be refuted across the board as a tool to analyze language acquisition and related phenomena – the evidence in support of frequency effects is uncontestable, as was discussed in Section 4. Along the lines of Ellis (1994), Goldschneider & DeKeyser (2001), and Gass & Mackey (2002), we suggest instead that explaining second language developmental phenomena is a complex task, one whose outcome is mediated by a variety of factors that include L1 transfer, perceptual salience, articulatory complexity, phonetic or allomorphemic regularity, and frequency.[3] Our results simply indicate the need to include the concept of markedness on this list.

6. Conclusions

This study examined the effects of two hypotheses for the development of English homorganic sC onset clusters in BP-based interlanguage: Markedness in terms of sonority sequencing and sonority distance (Selkirk, 1984; Clements, 1990), and input frequency (e.g., Bybee, 2001; 2007). While the markedness hypothesis predicts that acquisition should progress from the least marked to relatively more marked structures (i.e., /sl/ > /sn/ > /st/), the distribution of these clusters in the input (the frequency hypothesis) predicts that the developmental order will be the reverse (i.e., /st/ > /sl/ > /sn/).

For the assessment of these two hypotheses, two studies were conducted: The first study consisted of the organization and analyses of a corpus of student-directed speech (teacher talk) of an English teacher in a standard language classroom, which served as a measure of the input frequency of sC clusters. The second study consisted of a cross-sectional, variationist investigation involving the participation of ten students from the same classroom used in the first study. The results of a multivariate statistical analysis via Goldvarb showed that sC clusters develop as a function of increased proficiency and, more importantly, that the development of sC clusters follow a path similar to that predicted by the markedness hypothesis.

Our discussion concluded by acknowledging that there may be variables aside from markedness affecting the course of interlanguage development, including input frequency:

> Perhaps the safest conclusion is that input frequency serves as *one* of the factors influencing development, often in association with other factors such as L1 transfer and communicative need. Ellis (1994:271, emphasis in the original version).

In our particular study of the development of sC clusters in BP-based interlanguage, however, input frequency was not *one* of the factors influencing the development of English sC clusters in BP-based interlanguage.

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[3] Interestingly, the "fuzzy" or multi-faceted nature of markedness is to some extent compatible with these authors' claim that explaining L2 acquisition is a complex task, one that involves the interaction of factors such as perceptual salience, articulatory complexity, phonetic or allomorphemic regularity, and frequency. Coincidentally, these are some of the same criteria used to define markedness (see Haspelmath, 2006).

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