The variable development of /s/ + consonant onset clusters in Farsi-English interlanguage

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ABSTRACT

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This thesis investigates the variable production of English /s/ + consonant onset clusters in the speech of 30 adult native Farsi speakers learning English as a second language (L2). In particular, the study examines the development of the homorganic /st/, /sn/ and /sl/ sequences (sC clusters), which are realized variably either via e-epenthesis (e.g., [est]op) or via its target L2 pronunciation (e.g., [st]op). The sentence reading task as well as the picture-based interview utilized in this investigation followed standard sociolinguistic procedures for data collection and analyses, and included a set of linguistic (e.g., preceding phonological environment, sonority profile of the cluster) and extra-linguistic factors (e.g., level of formality, proficiency in English) whose effects were measured statistically via GoldVarb X.

The results reveal that: (1) the proportion of [e]-epenthesis is higher after a word-final consonant or pause than after a vowel (in which case the sC cluster is resyllabified as two separate syllables, i.e. [Vs.CV]); (2) over time (hence with increased L2 proficiency) and in formal situations, the amount of epenthesis decreases, conforming with Major's (2001) Ontogeny Phylogeny Model; and (3) as observed in several studies of L1 acquisition, markedness on *continuancy* – rather than markedness on sonority – is better able to capture the variable patterns of e-epenthesis in the Farsi-English interlanguage data (i.e., the more marked structures /st/ and /sn/, in which the continuancy feature varies (from [+continuant] /s/ to [-continuant] /t/ and /n/) are more likely to trigger the phenomenon of [e]-epenthesis than the less marked nonnative cluster

/sl/, in which continuancy is maintained constant (from [+continuant] /s/ to [+continuant] /l/). Based on these results, I analyze the data within a stochastic version of Optimality Theory, and discuss their implications and pedagogical applications for the teaching of pronunciation.

Dedication

I dedicate this work to my beloved deceased mother, Khadija Boudaoud. She was the strongest motivating force in the completion of this thesis.

Death leaves a heartache

No one can heal;

Love leaves a memory

No one can steal

~from an Irish tombstone

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have done for me. In particular, I would like to say how much I appreciated their compassion and support, especially during a tragic and daunting transition in my life: the death of my mother.

Finally, and most importantly, my parents, Ahmed and Khadija (May mercy be upon her soul), deserve special mention for their deep generosity, love, moral support, and prayers. Their valuable advice, encouragement, and wisdom about life have allowed me to venture farther than I would have dared alone. Their dedication as parents has taught me the most important lesson in my life, and that is to persevere. For this – and more – I am forever grateful to them!

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CHAPTER 1: INTRODUCTION

1.1 General scope and significance of the thesis

It has long been established that interlanguage (IL), the learner's developing second language, is a system characterized by variability (e.g., Bebee & Zuengler, 1983; Cardoso, 2007; Dickerson, 1975; Ellis, 1994; Lin, 2003; Major, 2001; Preston, 1996; Tarone, 1979). This variability has often been approached from two different perspectives: the variable rules approach (e.g., Bayley & Preston, 1996; Labov, 1969), whereby the degree to which contextual factors contribute to the applicability of a rule is identified; and the Dynamic Paradigm (Bickerton, 1973; Gatbonton, 1978), whereby variation in second language (L2) acquisition is seen as a systematic but unstable phenomenon mediating through the gradual 'diffusion' of target-like forms into learners' developing grammars. Irrespective of the approach adopted, however, it is usually agreed that IL variability manifests itself through an alternation of target-like and nontarget-like forms.

In L2 phonology, for example, many English as a Second or Foreign Language (ESL)[1] learners whose native language (L1) prohibits /s/ + consonant clusters (sC henceforth) – e.g., Spanish, Portuguese, Japanese, and most varieties of Arabic – tend to cope with these clusters by inserting an epenthetic vowel before the sC sequence (e.g., /e/ in the case of Iraqi Arabic, and /i/ in the case of Brazilian Portuguese). Farsi learners of ESL are no exception to this general pattern: When these learners are faced with the illicit sC onset sequences, they too have a tendency to apply e-epenthesis (e.g., Karimi, 1987;

[1] For convenience sake, the term 'ESL' will be used as a cover term to designate both English as a Second Language and English as a Foreign Language. Alternatively, the acronym can be assumed to refer to 'English as a Subsequent Language – ESL'.

Yarmohammadi, 1995). This application of e-epenthesis, however, is not categorical as the discussion above suggests. Rather, it is a variable process in which the problematic sC clusters are realized *variably* either via e-epenthesis (e.g., [**esn**]ail) or via its target L2 pronunciation (e.g., [**sn**]ail).

In many ways, the present study is inspired by recent L2 phonological research which has looked into the acquisition of L2 syllables from an integrative approach that incorporates sociolinguistic methodology for data collection and analysis, and current advances in phonological theory (e.g., Cardoso, 2005, 2007, 2008; Escartin, 2005; John, 2006). Escartin's (2005) study, for instance, examined the variable acquisition of all instances of sC onset clusters – /sn/, /sl/, /st/, /sm/, /sp/, and /sk/ – by Mexican Spanish speakers learning ESL. The current study, however, is limited in its scope to investigate the variable development of the homorganic /st/, /sn/ and /sl/ onset clusters – which all share the coronal articulator – in the English IL speech of Farsi speakers.

As will be discussed in chapter 2, by including only a set of homorganic onset clusters, the present study attempts to avoid a possible confounding influence of *place of articulation* on L2 production. Prior studies on L2 syllable patterns have in general overlooked the potential effects that homorganicity can have on the development of nonnative sC clusters, although few of these studies did suggest a link between heterorganicity (i.e., a difference in place of articulation) and difficulty of sC cluster production (e.g., Carlisle, 2006; Greenberg, 1965). Because this so called link has not yet been the object of empirical investigation, the study I propose here provides an opportunity to address this oversight. In sum, to put aside a difference in place of articulation confound, the current investigation will incorporate only the homorganic sets /st/, /sn/ and /sl/.

In addition to its attempt to control for place of articulation effects, the current study also seeks to extrapolate previous knowledge on L2 acquisition of sC onset clusters to a new research population, namely *Farsi* native speakers learning English as a second language. Whereas previous research on L2 phonology has examined the pronunciation of sC clusters from a variety of native language backgrounds (e.g., Spanish, Portuguese), it has nonetheless ignored the investigation of these clusters from an L1 Farsi perspective. An investigation of the phenomenon from the L1 Farsi perspective may potentially extend our understanding regarding the acquisition of sC sequences in general. By the same token, the incorporation of Farsi as a source language (and English as a target language) will allow us to obtain valuable information on IL development for comparison with a wide range of other IL data; in particular, data involving native populations with a similar syllable onset structure as Farsi (e.g., Spanish, Portuguese, and Japanese).

Another important feature of the current study, aside from its focus on homorganicity and Farsi native population, concerns the methodological framework used. In particular, the study adopts a variationist methodology to account for variability in L2 acquisition: It takes into account *both* linguistic factors such as preceding phonological environment (i.e., consonant, vowel, and pause), markedness involving sonority, *and* extra-linguistic factors such as proficiency and level of formality; it also employs knowledge from current research in phonological theory. By including a set of internal and external variable constraints and examining how they individually and interactively influence L2 development, the present investigation hopes to provide a more 'realistic' and comprehensive view of the phenomenon under study (i.e., e-epenthesis). By aspiring to provide a more comprehensive view of IL variation (whereby insights from a variety of linguistic disciplines are involved – L1/L2 acquisition, generative phonology, and sociolinguistics), the investigation ultimately attempts to promote interdisciplinary dialogue between the fields of language acquisition in general and variationist linguistics.

For this study, a semi-experimental, cross-sectional design was used in which speech samples from 30 adult native Farsi speakers categorized across three levels of proficiency in English (i.e. beginner, intermediate, and advanced) were recorded. The recorded samples consisted of sentence reading tasks as well as picture-based interviews and, in accordance with the standard conventions of sociolinguistic research, included a set of internal and external variable constraints whose effects were measured statistically via GoldVarb X (Sankoff, Tagliamonte, & Smith, 2005).

Besides using a sociolinguistic methodology to investigate the Farsi-English data, the present study also employed the framework of Optimality Theory (OT) (Prince & Smolensky, 1993) – in particular, a schotastic approach to OT via a Gradual Learning Algorithm (GLA) (Boersma & Hayes, 2001) – to account for the variable patterns of e-epenthesis. As we shall see in chapter 5, by adopting such an approach to variation, one is able to explain both categorical and variable sociolinguistic phenomena (and their predictability) in a more constrained way, by means of a single grammar (e.g., Anttila, 1997; Cardoso, 2001, 2003, 2007).

The intended contributions of the current study to L2 research are believed to be the following: (1) It focuses on the *homorganic* /sn/, /sl/, and /st/ onset clusters in order to avoid the effect of different places of articulation within the clusters; (2) it extends findings of previous research on the acquisition of L2 sC onsets (e.g., those involving Spanish and Portuguese speakers) to a new research population, namely, Farsi native speakers; and (3) it utilizes a sociolinguistic methodology for data collection and analysis (where an assortment of linguistic and extra-linguistic factors are examined), as well as insights from contemporary phonological theory to analyze variation in learner speech.

1.2 Outline of the thesis

The thesis is structured as follows: The first part of chapter 2 discusses the structure of syllables in general as well as the distribution of this structure across both Farsi and English. In the latter part of chapter 2, a survey of previous research that has examined the effects of linguistic and extra-linguistic factors on the development of IL is provided. This survey of literature ultimately leads to a formulation of a set of research questions and hypotheses that guided the rest of this study.

Chapter 3 presents the research design of the study, a design which is characterized by the use of standard sociolinguistic protocols for data collection and analysis. In particular, the chapter details the selection of the participants as well as describes the administration of the test materials. This chapter also discusses the steps involved in the recording, transcription, and coding of the corpus.

In Chapter 4, the quantitative Goldvarb X analyses of the e-epenthesis patterns found in the Farsi-English data are presented. The results from the multivariate analyses are discussed in this chapter, which suggest that the development of e-epenthesis in the IL speech of Farsi speakers is conditioned by internal factors such as *preceding* *phonological environment*, *type of sC cluster* (sonority), and external factors such as *proficiency* and *style*.

Chapter 5 describes the formal phonological analysis of variable e-epenthesis in the Farsi-English corpus using Optimality Theory (OT) (Prince & Smolensky, 1993). First, the chapter discusses the conceptual details of the theory. Then, it reviews the different approaches suggested to analyze variation in this framework: the multiple grammars, the crucial nonranking of constraints, the rank-ordering model of EVAL, and stochastic OT. Finally, the chapter presents the stochastic analyses of the variable results obtained from this study, drawing in particular on Boersma and Hayes' (2001) Gradual Learning Algorithm (GLA) for modeling linguistic variation.

Chapter 6 highlights the significance of the study's findings for both second language acquisition and L2 pedagogy. More specifically, the chapter includes a brief review of the main contributions of the study, and proposes a set of recommendations for the teaching of sC production. It also suggests some possible directions for future research. The chapter concludes with a summary of the most important results derived from the Farsi-English data analyzed in this study.

CHAPTER 2: THEORETICAL BACKGROUND

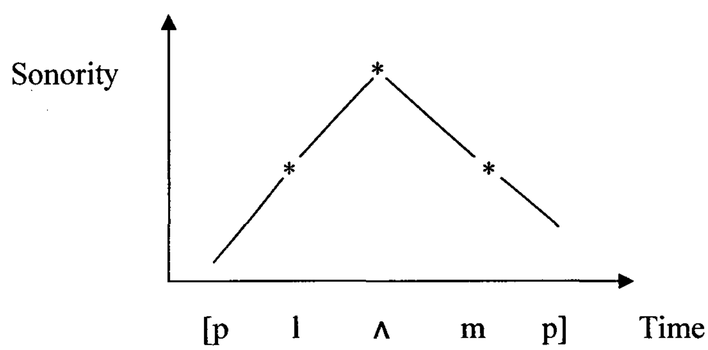
2.1 The syllable

2.1.1 Syllable structure: An overview

Learning the phonology of a language entails mastering not only the pronunciation (and abstract mental representations) of individual segments, but also combinations of segments and their prosodization into syllable constituents. The relevance and application of the syllable constituent to phonological analysis have been widely documented in the acquisition literature – across a number of L1 settings (e.g., Fikkert, 1994; Gierut, 1999; Kehoe & Lleó, 2002; Levelt, Schiller, & Levelt, 1999; Zharkova, 2005) as well as a variety of IL phenomena (e.g., Broselow, Chen, & Wang, 1998; Cardoso, 2007, 2008; Hansen, 2006; Kwon, 2006; Major, 1987; Osburne, 1996; Parrondo-Rodriguez, 1999; Sato, 1987; Tarone, 1976; Young-Scholten, 1993; Young-Scholten & Archibald, 2000). An example of a syllable-based interlanguage phenomenon is the epenthesis of a vowel before sC onset clusters (e.g., /s/low → [e]slow), which is observed in several populations whose L1s disallow such clusters (e.g., Portuguese and Spanish). Because the phenomenon of vowel epenthesis is triggered by restrictions on syllable structure, the following discussion (sections 2.1.2 and 2.1.3) will introduce the syllable constituent in the context of both Farsi and English phonology. Prior to that, however, a general description of the syllable is in order.

The syllable consists of a prominent or sonorous element (more commonly a vowel) which is optionally surrounded by consonants that decrease in sonority towards the edges. The differences in prominence level among the segments of a syllable are illustrated in (1) below. As can be seen, the syllable structure of the English word 'plump' behaves in such a way that there is a steep rise in sonority towards the peak, while there is a decrease in sonority towards the edges. This pattern follows a set of principles, including the Sonority Sequencing Principle (SSP) (e.g., Clements, 1990; Hooper, 1976; Selkirk, 1984; Steriade, 1982). Leaving aside the details pertaining to the SSP for a later discussion, I will now introduce the notion of sonority.

(1) Syllable structure: Differences in sonority level



Primarily, the sonority of a segment is determined by the degree of opening of the vocal tract during its production (e.g., Goldsmith, 1990; Jespersen, 1922; Price, 1980; Wright, 2004, Yavas, 2006a). That is, the more open the vocal tract is for a sound, the higher its sonority will be. Secondarily, this sonority may also be defined in terms of the propensity of a sound for voicing (e.g., Allen, 1973; Chomsky & Halle, 1968; Kenstowicz, 1994; Ladefoged, 1993; Vennemann, 1988; Yavas, 2006a). That is, voiced sounds are more sonorous than their voiceless counterparts. Table 2.1 displays a hierarchy of sonority among English sounds, as it relates to the two criteria mentioned above: vocal tract opening and sound voicing (where the relevant segments appear in bold).[2]

Table 2.1. *Sonority Hierarchy Scale (Adapted from Hogg & McCully, 1987)*

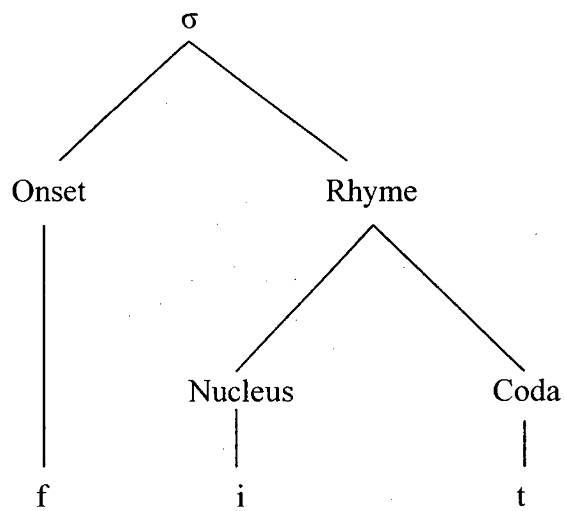
Classes	Examples	sonority
Glides and vowels	/ i, u, o, **ɑ**, æ /	Higher (+)
Laterals	/**l**/	↑
Nasals	/**n**, m, ŋ/	
Voiceless fricatives	/f, θ, **s**/	
Voiceless stops	/p, **t**, k/	Lower (-)

Let us now look at the internal structure of syllables. The internal structure of a syllable is usually thought to comprise two basic units: onset and rhyme, the latter in turn consisting of the nucleus and coda. The nucleus is the only compulsory element in the syllable, and it is the most sonorous segment (usually a vowel); the consonant preceding the nucleus is called onset, and it is optional; the consonant following the nucleus is referred to as coda and is also optional (and often avoided in several languages – e.g.,

[2] It is beyond the scope of this thesis to debate the issues pertaining to sonority and sonority scales. For a comprehensive review of the notion of sonority, see Ohala and Kawasaki-Fukumuri (1997) and Parker (2002). The current investigation adopts the sonority hierarchy scale used by Hogg and McCully (1987), as will be discussed later.

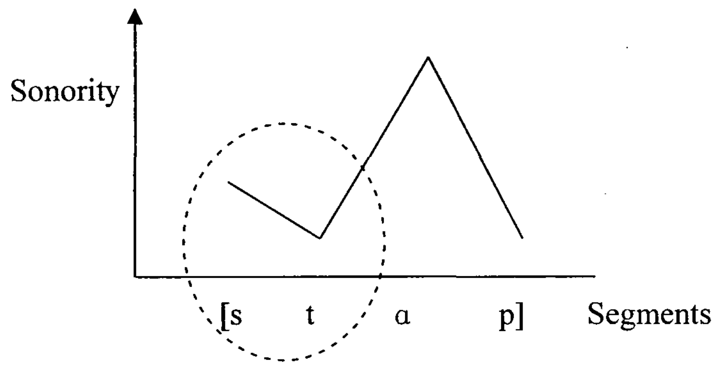
Cardoso, 2007). A schematic representation of the syllable structure is provided in (2) below.

(2) Syllable structure: Hierarchical representation



Recall from our previous discussion that the Sonority Sequencing Principle (SSP) requires that onsets rise in sonority from peripheral segments towards the nucleus (see also (1) above). Despite the relative robustness of this principle, however, the fact is that a number of languages (e.g., English, French, German, Dutch, and Russian) exhibit onset cluster patterns which violate the SSP – a fact which makes the SSP a universal tendency, rather than an absolute universal. For example, in the case of the English word '[st]op', shown in (3), we can easily see (using the sonority scale in Table 2.1) that the sonority level decreases from the first member /s/ to the second member /t/.

(3) The /st/ onset cluster: A violation of sonority



Violation of the SSP, such as the one illustrated in (3), has over the last thirty years sparked a large debate among phoneticians and phonologists, especially with regards to the markedness value of the sC clusters. At the centre of the debate is whether sC clusters – especially SSP-violating clusters such as /s/ + stops – should be treated as being structurally different from non-sC clusters (for a comprehensive review of the issue, see Boyd, 2006). Before getting to the heart of this debate, I will introduce and discuss the concept of markedness.

First developed by Prague School phonologist Nicholas Trubetzkoy (1939), the concept of markedness has since become widely used in linguistics. The theory, which has been employed to describe a variety of linguistic features (e.g., voicing, nasalization, and syllable structure), essentially involves an asymmetry relationship in the form of *marked* versus *unmarked* oppositions. A marked form is usually taken to be nonbasic (i.e., atypical), less salient, less natural, or less frequent; conversely, an unmarked form is considered to be basic, more salient, more natural, and more frequent (e.g., Battistela, 1990; Eckman, 2008; Hansen, 2006). To illustrate, let us take the following set of oppositions as examples (Eckman, 2008): voiced/voiceless consonants, nasalized/non-nasalized vowels, closed (e.g., CVC) / open (e.g., CV) syllables. In accordance with the general principle of markedness outlined above, all items to the left of the '/' sign are deemed marked compared to the items located on the right side, which are unmarked because they are usually more common cross-linguistically. For instance, the closed syllable template CVC is thought to be more marked than the open syllable CV, the latter enjoying a wider distribution not only within specific languages but also across different varieties of languages.

One of the most influential and successful models that attempted to explain the relationship between markedness and L2 acquisition phenomena is Eckman's (1977) Markedness Differential Hypothesis (MDH): 'The areas of difficulty that a language learner will have can be predicted on the basis of a systematic comparison of the grammars of the native language, the target language and the markedness relations stated in universal grammar' (p. 321). The importance of Eckman's model to L1 and L2 acquisition research, as the previous statement implies, cannot be overstated; unlike the Contrastive Analysis Hypothesis (CAH) (Lado, 1957), which claims that *only* structures distinct from the L1 would be difficult to acquire, Eckman's MDH incorporates markedness as a potential source of learning difficulty. Following this markedness-oriented conception for explaining learning difficulty, a number of studies, especially those investigating the nonnative acquisition of consonant clusters, have tested and invariably demonstrated the influence of markedness universals on the structuring of IL phonology (e.g., Abrahamsson, 1999; Anderson, 1987; Broselow & Finer, 1991; Cardoso, 2007, 2008; Carlisle, 1988, 1997; Davidson, 2003; Eckman, 1991; Escartin, 2005; Rauber, 2006; Tropf, 1987). For a detailed account of the effects of markedness on L2 acquisition of sC clusters, see section 2.2.1.

Having shown the relevance of the *markedness* construct to the analysis of IL, I will now examine the markedness relationships among the sC sequences included in the current study: /st/, /sl/, /sn/. As noted earlier, because the first onset sequence /st/ violates the SSP, it is assumed to be the most marked and therefore the most difficult to acquire (Eckman, 1977). This leads us to predict that the /st /structure will surface later in the IL speech of Farsi speakers, as illustrated in (4), where '>' means 'easier than and thus acquired before.'

(4) Markedness hierarchy between SSP-following and SSP-violating sC sequences:

/sl/, /sn/ > /st/

In addition to the markedness relationship between SSP-violating versus SSP-abiding sC clusters, a markedness hierarchy also exists between the two sequences that follow the SSP, namely, /sn/ and /sl/. To account for this type of hierarchy, I will invoke another well-known principle of sonority markedness: the *Minimal Sonority Distance* (MSD) (e.g.,. Broselow & Finer, 1991; Clements, 1990; Harris, 1983; Selkirk, 1982; Steriade, 1982). The core idea behind the MSD is that onset sequences across a large variety of languages exhibit a tendency whereby the second segment has *higher* sonority than the first segment. That is, cross-linguistically, onset clusters prefer to maximize the sonority distance between their member segments. Based on this generalization, and in order to ascertain which of the SSP-abiding sC clusters – /sl/ or /sn/ – is more marked, the sonority distance between the segments in each cluster is calculated using the sonority scale discussed in Table 2.1 above. The result reveals a larger sonority difference for /sl/ than for /sn/, suggesting that /sl/ is more universally preferred, and thus less marked, than /sn/. That /sl/ is more universally preferred than /sn/ reflects a well-established view in linguistics: Syllables across many languages prefer CV structure and the wide sonority distance between /s/ and /l/ closely resembles that structure.

Another justification for the relevance of the MSD principle to account for sC cluster markedness can be traced to L1 acquisition. When children attempt to produce the target sC clusters, they usually modify them by deleting one member in the sequence, often the most sonorous segment. In other words, the reduction patterns observed in children are determined by sonority factors (e.g., Barlow, 1997; Gnanadesikan, 2004; Goad & Rose, 2004; Ohala, 1999, Pater & Barlow, 2003; Yavas, 2006b). Thus, in the case of /s/ + stop and /s/ + sonorant sC clusters, the predicted reduction pattern is toward the 'stop' and /s/ segments, respectively (e.g., /stil/ 'still'→ [til]), and /slim/ 'slim'→ [sim]).

In sum, the account regarding the markedness relationship between /sl/ and /sn/ (which is derived from the MSD principle discussed above) allows us to predict that /sl/ will develop earlier in the IL of the Farsi learners, as illustrated in (5) below. Combining this MSD-based account (i.e., (5)) with the SSP-related perspective (i.e., (4)), the learning path in (6) is anticipated for the three target sC clusters.

(5) Markedness hierarchy between SSP-abiding sC sequences:

/sl/ > /sn/

(6) Developmental path of sC onset sequences based on markedness:

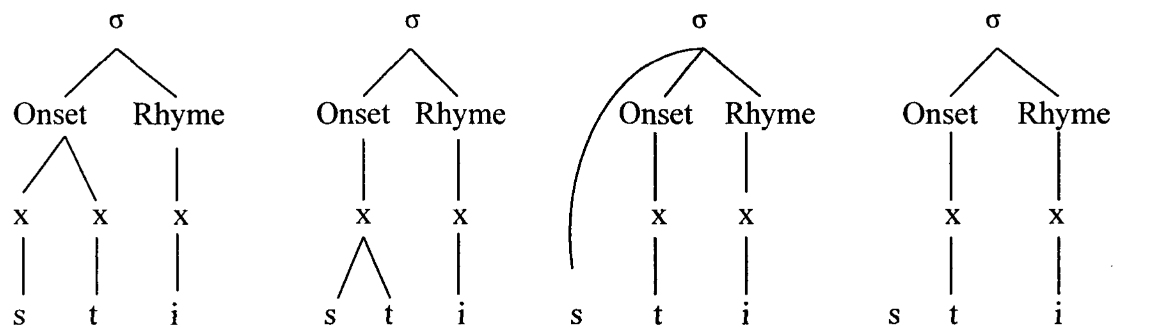
sl/ > /sn/ > /st

Let us now return to the issue introduced earlier in this section – whether sC sequences, particularly SSP-violating sequences such as /s/ + stops (e.g., [stif] 'stiff'), should be considered as being structurally different from non-sC sequences. In an attempt to address this issue, several different proposals for the representation of sC clusters have been put forward, as illustrated in (7). As the structures indicate, except for the standard view represented in (7a), whereby both sC and non-sC clusters are regarded as being structurally identical (Belvins, 1995; Boyd, 2006; Cardoso, 2008; Carlisle, 1988, 2006; Major, 1996), all other proposals (i.e., 7b, 7c, and 7d) presuppose a different structural representation for sC sequences – a representation which purportedly avoids any potential sonority violations of the target sequences. For example, taking the view illustrated in (7d), many researchers argue that the /s/ in sC clusters does not syllabify directly under the onset node, but stems directly from a higher prosodic element – the prosodic word or foot. That is, the /s/ is extra-syllabic or an appendix to the syllable (Fikkert, 1994; Giegerich, 1992; Gierut, 1999; Kenstowicz, 1994).

Before closing this section, I would like to point out that the current study makes no claims as to which of the views outlined above is correct. Suffice it to say that the study adopts the standard view held by Boyd (2006), in which there is no structural distinction between sC clusters and non-sC clusters.

(7) Structural representation of sC onsets: Four models (Adapted from Yildiz, 2005)

a. Branching Onset b. Complex Segment c. Adjunct d. Extrasyllabic (Appendix)



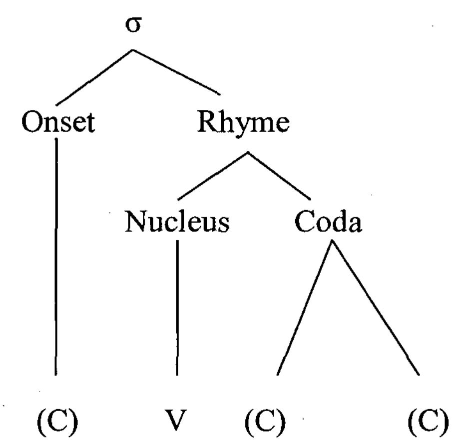
To summarize, in this section, I have introduced and discussed several concepts relating to the syllable constituent: Sonority, the Sonority Sequencing Principle (SSP), and Minimal Sonority Distance (MSD). Overall, I have suggested that these concepts are able to account for the behavior of syllable constituents. In particular, I have appealed to the two sonority-based generalizations, the *Sonority Sequencing Principle* and the *Minimal Sonority Distance,* to establish the relative markedness of the target sC clusters. Finally, I have discussed an important model of L2 acquisition, Eckman's Markedness Differential Hypothesis (MDH), and emphasized its relevance for predicting and explaining a variety of L2 phonological phenomena, particularly the acquisition of nonnative sC onset clusters.

In the following section, I will discuss the syllable structure of Farsi, a language with strict constraints on what may syllabify as onset.

2.1.2 Farsi syllable structure

A segmental representation for the syllable structure in Farsi can be formulated as (C) V (C) (C) (where segments between parenthesis are optional) (e.g., Karimi, 1987; Yarmohammadi, 1995). This means that Farsi syllables cannot contain more than four segments, which naturally restrains the number of segments permitted in onset and coda positions. Singleton (i.e., 1-segment) onsets can essentially contain any consonantal segment (i.e., those with the feature [+consonantal]) in the phoneme inventory, except for the segment [w]). The figure in (8) below illustrates the (maximal) syllable structure of Farsi.

(8) Syllable structure in Farsi



The phonotactics of Farsi syllables permits words such as [bâ] 'with' (i.e., CV); [sir] 'garlic', [xar] 'thorn', [læb] 'lip', and [yar] 'companion' (i.e., CVC); and [râst] 'right' (i.e., CVCC). Although the /w/ phoneme cannot occur in onsets, it can occur as a first member of a final consonant cluster (i.e., coda cluster). In addition, Farsi does not allow onset clusters of any type, including sC sequences. The only sC sequences found in the language, cluster cross-syllabically (e.g., [**es.te**.kân] 'cup'), where '.' indicates a syllable boundary.

Given that Farsi syllables allow only singleton onsets, there is always a rise in sonority from the onset towards the nucleus in the language. This is not always the case with the English language, as we will see in the next section.

2.1.3 Syllable structure in English

The structure of the syllable shape in North American English (NAE) can be represented as (C) (C) (C) V (C) (C) (C) (C). This suggests that NAE allows more complex syllable sequences than Farsi – up to three onset consonants, and as many as four codas. As was the case with Farsi, almost all [+consonantal] segments in the inventory can syllabify as 1-member onsets; the only exceptions being /ŋ/ and /ʒ/.

Most English 2-segment onsets consist of sequences of stop + liquid (e.g., '**bl**ouse', '**gr**eat'); some English 2-member onsets are made up of sequences of stop + semivowel (e.g., '**tw**in', '**pu**re'). In addition to allowing /s/ + liquid and /s/ + nasal onset clusters, which abide by the Sonority Sequencing Principle (SSP) discussed earlier in section 2.1.1, English also permits /s/+ stop onset clusters, which violate the same principle. This co-occurrence of SSP-violating versus SSP-abiding sC onset clusters in English is illustrated in Table 2.2.

Table 2.2. *2-member sC Onsets in English: SSP-abiding versus SPP-violating Clusters*

SSP-abiding		SPP-violating
s + liquid (sl)	s + nasal (sn, sm)	s + voiceless stop (sp, st, sk)
slave	**sn**ail, **sm**ile	**sp**are, **st**ill, **sk**im

Finally, 3-segment onset clusters in English can be represented as a sequence of /s/ + voiceless stop (p, t, k) + an approximant (r, l, j, w). Although the combinations can yield up to 12 logical possibilities, only 7 of these are permissible, as illustrated in Table 2.3.

Table 2.3. *3-Member Onset Clusters in English*

sp + [r, l, j, w*]	st + [r, l*, j*, w*]	sk + [r, l*, j, w]
[**spr**]awl, [**spl**]een, [**spj**]ew	[**str**]ive	[**skr**]oll; [**skj**]u, [**skw**]able

Note. * indicates very rare or non-existent combinations for varieties of North American English.

For the sake of completion, I now briefly describe English rhymes, which can be comprised of one to four segments. 2-segment rhymes consist of a vowel followed by any [+consonantal] segment, except for /h/; 3-segment rhymes consist of a vowel followed by a sequence of a nasal + obstruent (e.g., 'ju**mp**' [dʒʌ**mp**]) or liquid + obstruent (e.g., ‘**bulb**’ [bʌ**lb**]). In addition, 4-segment rhymes contain a sequence of vowel + nasal or liquid + 2 sets of voiceless obstruents. It should be noted that English 4-member rhymes can be found in both suffixed forms (i.e., morphologically complex words such as ‘sixth’ [si**ksθ**]) as well as non-suffixed forms (i.e., morphologically simple words such as ‘sculpt’ [scʌ**lpt**]).

Given that the syllable structure in Farsi disallows sC onset clusters altogether, and that some English sC onsets clusters violate the Sonority Sequencing Principle (in which preferred syllables display both a continuous rise in sonority towards the peak and a decrease in sonority towards the edges), it is no wonder that Farsi speakers have difficulty producing these clusters (see also Yarmohammadi, 1995 for a similar view). In an attempt to resolve this difficulty, these speakers typically insert an epenthetic [e] to break up the illicit clusters, as mentioned in chapter 1. Also, as noted earlier, the vowel insertion patterns characterizing the Farsi-English IL speech is an inherently variable process, one that is triggered by linguistic (e.g., sonority markedness, preceding phonological environment) and extra-linguistic factors (e.g., proficiency and level of formality). Let us begin by examining the linguistic factors that may have an effect on the structuring of Farsi / English interphonology.

2.2 Previous L2 research

2.2.1 Influence of linguistic factors on IL phonology

This section is devoted to presenting some of the previous studies which have examined the effects of linguistic factors (e.g., sonority profile of the cluster, L1 transfer, preceding phonological environment) on the L2 development of consonant clusters.

Although a considerable amount of research has been done to investigate the acquisition of nonnative sC onset clusters in general (e.g., Spanish / English IL phonology – Carlisle, 1988, 1997, 2006; Portuguese / English IL phonology – Cardoso, 2008; Major, 1996; Texeira Rebello, 1997; Korean / English IL phonology – Kim, 2000; Kwon, 2006; Spanish / Swedish IL phonology – Abrahamsson, 1999; Spanish / German IL phonology – Tropf, 1987), there is only one study that investigates the L2 acquisition of the clusters by native *Farsi* speakers (that of Karimi, 1987 – see forthcoming discussion). In addition, aside from one recent study by Cardoso (2008), which involves the development of English sC sequences in the IL speech of Brazilian-Portuguese speakers, we are not aware of any other research examining the acquisition of *homorganic* sC clusters from a variationist perspective, one that incorporates sociolinguistic methodology for data collection and analysis as well as current developments in phonological theory.[3]

The only study that examined Farsi / English IL phonology was conducted by Karimi (1987). In that study, the researcher investigated the production of English sC onset clusters in the speech of four Farsi speakers (three females and a male, ages 19-55 years old), using sociolinguistic methodology which included data from three different styles: word-list reading, paragraph-reading task, and informal interview. Overall, the results from this research indicated that the word list, the most formal task, yielded the slightest proportion of errors (i.e., e-epenthesis), followed by paragraph reading and informal conversation. Most important, the findings also suggested that, in attempting to pronounce English sC clusters, the Farsi speakers had consistently used e-epenthesis.

[3] It is important to note here that when the current study was originally conceptualized, there had been no published research addressing the question of homorganicity of sC onset clusters within the variationist paradigm.

There are some problems in Karimi's study above. For one thing, the sample size involved was relatively small: It included *only* four participants. In addition, the researcher did not supply enough information as to how proficiency had been measured; in fact, she simply mentions that all her informants had had English in tutored settings from three to six years before coming to the United States. Furthermore, Karimi did not explicitly address the question of how linguistic knowledge (e.g., *markedness on sonority*, *phonological environment*) affects the order of acquisition of the nonnative sC sequences. Finally, the author did not provide the exact percentage values pertaining to the patterns of e-epenthesis observed in the Farsi-English data.

Before proceeding any further with the literature review, two points need to be made. First, the term *epenthesis*, as employed in Karimi's study, will be utilized in the present investigation to refer simultaneously to two types of situations: one in which the inserted vowel occurs before a consonant cluster (i.e., sC→/e.sC/) – a process otherwise known as *prosthesis*; and another where the intrusive vowel splits the consonant sequence (i.e., sC→/seC/) – a phenomenon also termed *anaptyxis*. Second, and most important, the development of the target sC clusters in my study will be investigated via the transfer phenomenon of e-epenthesis, the assumption being that sC development and e-epenthesis represent the two facets of the same phenomenon.

In a study involving Spanish / English interphonology, Carlisle (1988) investigated the production of /sl/, /sn/, and /sm/ onset clusters, which are in a markedness relationship based on an implicational relationship between obstruent + liquid onsets and obstruent + nasal onsets (Greenberg, 1965) – the latter presupposing the presence of the former and thus being more marked and, consequently, less preferred.

Drawing on this implicational universal, Carlisle predicted that /sn/ and /sm/ clusters should be modified via e-epenthesis more frequently than /sl/ sequences. To test the prediction, fourteen native speakers of Spanish each read 435 topically unrelated and randomly ordered sentences, each containing one occurrence of the three onsets. The reading task was carefully designed by the researcher to allow tighter control of the preceding phonological environments (i.e., vowels and consonants) that occurred before each onset. In accordance with the hypothesis, the results of the study revealed that the Spanish speakers modified onset clusters that are more preferred universally significantly less frequently than they did those that are less preferred (i.e., /sl/: 29 %; /sn/: 33%; and /sm/: 38%).

Two different explanations were offered by Carlisle (2001) to account for these results. One explanation may be derived from Clements' (1990) Sequential Markedness Principle, which states that if segment A (in our case, the anterior coronal /n/) is less marked than segment B (i.e., the labial /m/ in our example), and given any context XY, it follows that XAY (i.e., /sn/) is less marked than XBY (i.e., /sm/). Another explanation, according to the researcher, can be inferred from Greenberg's (1965) claim regarding the potential effect of homorganicity on the acquisition of consonant clusters in general; it could be that because the two segments in the /sl/ onsets are homorganic, they are easier to articulate.[4] Building upon this last analysis, the current study includes a set of *homorganic* onset clusters only: /st/, /sn/, and /sl/, in order to avoid the potential influence of different places of articulation, as will be discussed later on.

[4] Though more explicit with regard to codas, Greenberg's (1965) insight may well be applied to onsets.

In another study, Carlisle (2006) examined the acquisition of English /st/, /sn/, and /st/ clusters by 17 adult native Spanish speakers.[5] The main purpose of the study was to determine whether syllable universals – i.e., Sonority Sequencing Principle (SSP) and Minimal Sonority Distance (MSD) (Clements, 1990) – have an effect on the acquisition of the target clusters. Two main hypotheses guided Carlisle's study: (1) /sl/ and /sn/ would be modified less frequently than /st/, the latter violating the SSP; and (2) /sl/ would be modified less often than /sn/, the former exhibiting a higher MSD value. Overall, the results strongly confirm the role of Clements' (1990) principles based on markedness (i.e., the Sonority Sequencing Principle and the Minimal Sonority Distance) in predicting order of acquisition of the sC clusters; the percentage values of e-epenthesis across the three clusters being: /sl/: 35.6 %; /sn/: 45.8; and /st/: 53.6 %.

There are two main shortcomings with the Carlisle studies above. First, these studies have generally been concerned with the examination of *linguistic* variables only, to the neglect of extra-linguistic variables and the interaction between the two. Arguably, an approach to L2 data analysis that focuses exclusively on linguistic factors cannot satisfactorily inform us of the various facets and processes involved in the acquisition of L2 phenomena; on the other hand, a multidisciplinary perspective (such as the one adopted in my study), where both internal and external constraints are examined in tandem, is more likely to offer a more comprehensive account of IL patterns. A second issue with Carlisle's research is that it tends to investigate only the *proportion* of e-epenthesis, with no examination of the actual patterns of variation that characterize the

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[5] In a sense, Carlisle's (2006) study is a combination of two of his earlier studies: Carlisle (1988), in which the onset clusters /sl/, /sn/, and /sm/ were investigated; and Carlisle (1991b), where the /st/ and /sl/ sequences were examined.

acquisition of sC onsets. Yet, these patterns of variation, as the analysis of the English-Farsi data in my study will demonstrate (see chapter 5), are an important aspect of IL study and, indeed, an inherent part of linguistic knowledge (e.g., Auger, 2001; Cardoso, 2001, 2003, 2007; Labov, 1969).

Notwithstanding the omissions above, Carlisle's (2006) study seems to exhibit a unique feature: its inclusion of a homorganic set of clusters (/st/, /sn/, and /sl/), which all share the coronal articulator. Somewhat surprisingly, however, there appears to be no evidence from Carlisle's research suggesting that the choice of the homorganic sC sequences was an overt attempt (on the part of the investigator) to control for place of articulation. Unlike Carlisle's research, and along the lines of Cardoso (2008; see following discussion), an important aspect of my study lies in its exclusive and explicit focus on the *homorganic* /st/, /sn/, and /sl/ onset clusters, the rationale being that this would avoid any confound effect of *place of articulation* on the production of the clusters.

As implied in our previous discussion, the only sC cluster acquisition study that has attempted to control for place of articulation is the one carried out by Cardoso (2008). Using a sociolinguistic methodology for data collection and analysis (typical of variationist research), Cardoso examined the variable development of the *homorganic* /st/, /sn/, and /sl/ onset clusters in the IL speech of 10 native Brazilian Portuguese (BP) learning English as a foreign language. An important contribution of this research (as suggested earlier) concerns the researcher's selection of homorganic sC clusters: As emphasized by the author, the choice of this specific type of sC sequences was intended as a heuristic measure to ensure that sonority was the only markedness feature upon which the three target clusters differed. Putting Cardoso's study in its broader context, it could be said that the strategy related to the choice of the homorganic sC clusters is an implementation of Greenberg's (1965) earlier idea that heterorganic sequences may be harder to learn than their homorganic counterparts – an idea that can also be captured in terms of Clements' (1990) Sequential Markedness Principle, as discussed earlier.

As was the case in Carlisle (1988), Eckman and Iverson's (1993) study also sought to examine whether onset clusters that are more preferred universally are modified less often than those that are less preferred. In that study, Eckman and Iverson made the following three main predictions, based on Clements' (1990) Sequential Markedness Principle: (1) that voiceless stop + liquid onsets (e.g. [tr]) are the *least* marked; (2) voiceless stop + glide (e.g. [tj]), the *most* marked; and (3) voiced stop/voiceless fricative + liquid (e.g., [br] and [sl], respectively) are intermediate on the markedness hierarchy.

To verify the predicted markedness sequence, Eckman and Iverson interviewed eleven adult participants, three native speakers of Cantonese and four speakers each of Japenese and Korean. To measure their participants' performance, the researchers used 80% correct production as a criterion threshold: If participants produced a given onset correctly 80 % of time, then that onset was considered acquired; if, on the other hand, the frequency of accurate production was less than 80%, the onset was considered not yet acquired. Accordingly, it was predicted that more marked onsets (e.g., [br]) would not reach the criterion level unless the corresponding less marked onsets (e.g., [tr]) reached that criterion level. The general findings do confirm the hypothesis that a more marked onset would reach the criterion threshold only if a corresponding less marked onset had reached that threshold. I hypothesize, based on these results, that Farsi speakers will acquire the less marked (and more universally valued) onsets – /sl/ – before the more marked (and less valued) ones – /sn/. I also predict that these speakers will master the less marked (SSP-abiding) /sl, sn/ clusters before they do the more marked (SSP-violating) /st/ sequences.

Findings from Abrahamsson (1999)'s longitudinal case study of one L1 Spanish / L2 Swedish learner appear to contradict the results reported in Carlisle's (1988, 1997) research, particularly with regard to the effects of sonority markedness. Indeed, at odds with the hypothesis that a high degree of sonority in the segment following the /s/ would trigger lower proportions of e-epenthesis, Abrahamsson reported that /sl/ clusters were epenthesized *more* often than were /sn/ clusters, though the difference was not statistically significant. These idiosyncratic findings aside, Abrahamsson nonetheless acknowledged that his corpus contained only 44 instances of /sl/ against 67 instances of /sN/ (with N designating the /n, m/ nasals). Although the researcher did find, in accordance with Carlisle (1991a), that epenthesis occurred significantly more frequently before word-final consonants than after word-final vowels, he had not actually controlled for the type and number of preceding environments. Clearly, this may have skewed the results. For instance, if a greater proportion of word-final consonants occurred before /sl/ than before /sN/, then a higher proportion of epenthesis would be expected before /sl/. To help control for preceding environment, the reading (formal) task designed for my study includes a list of sentences containing the target onset clusters /st, sn, sl/, *equally* distributed among the three different environments – vowel, pause, consonant (see Appendix C for details).

To trace the relative effects of L1 transfer and markedness principles on IL phonology, Broselow (1983) investigated the L2 acquisition of English onset clusters by speakers of two varieties of Arabic – Egyptian Arabic and Iraqi Arabic. With regard to Iraqi speakers, the researcher found that the general tendency was to insert an epenthetic [i] before sC clusters, irrespective of whether or not these clusters abide by the sonority principle (i.e., /sC/ → /i.sC/). This particular finding was interpreted by Broselow as strong evidence in favor of the influence of L1 transfer.[6] With regard to Egyptian speakers, the investigator found that the regular pattern was to insert an epenthetic [i] b*efore* sC clusters which violate sonority (i.e., /sC/ → /i.sC/), and an epenthetic [i] *between* the segments of sC clusters which abide by sonority (i.e., /sC/ → /siC/). Comparing the two modification patterns outlined above, Broselow concludes that the latter pattern observed among Egyptian speakers (i.e., /sC/ → /siC/) could not possibly be ascribed to a native phonological rule; hence the importance of markedness criteria in the IL speech of yet another group of learners – native speakers of Egyptian Arabic.

A major problem in Broselow's (1983) study is her tendency to reduce markedness to violation of sonority. Obviously, there is more to markedness than just violation of sonority. For instance, both /sl/ and /sn/ (which are included in the current study) abide by sonority, and yet the former is less marked than the latter because it has as its *second* element a liquid – /l/ – which has a higher sonority value (closer to that of a vowel). On the other hand, the second segment in the /sn/ cluster – /n/ – has a lower

[6] It is noteworthy that, unlike Egyptian Arabic, which proscribes initial consonant clusters altogether, Iraqi Arabic optionally allows them. In Iraqi Arabic, clusters are often realized variably: either via i-epenthesis (e.g., [iθn]een) or through its target L2 pronunciation (e.g., [θn]een – Iraqi equivalent for the English word 'two'). This implies that insertion of an epenthetic [i] before onset sequences is a productive rule of Iraqi Arabic.

sonority value (which is farther away from that of a vowel), making it less preferred and thus more marked. That is, in line with the Minimal Sonority Distance principle reviewed earlier, a strong universal tendency exists for the second segment in an onset cluster to be *high* in sonority – a tendency which is also in accordance with the view that syllables across many languages prefer CV structures.

Escartin's (2005) study, discussed in chapter 1, is worth reviewing in detail, as it may offer insights into the influence of linguistic variables (e.g., *markedness on sonority* and *preceding environment*) on L2 phonological acquisition. Using a variationist design, Escartin investigated the development of all sC English onset clusters in the speech of Mexican Spanish learners of ESL. Although Escartin predicted, based on sonority markedness, that e-epenthesis before sC onsets would be lower the higher the degree of sonority of the segment following the /s/ (i.e., /sl/ > /sn/ > /st/), the statistical results showed no significant difference between /sl/ and /st/ sequences (.52 and .54, respectively). This is quite surprising given that /st/ clusters, which violate sonority sequencing, were expected to be modified more often than the sonority-abiding /sl/ clusters.

Escartin (2005) accounts for the unexpected results in terms of the interaction effects between the variable constraints sC sonority and preceding environment. In particular, Escartin argues (based on the cross-tabulation between the two linguistic factors) that the relatively high proportion of e-epenthesis in /sl/ clusters after *consonants* (44%) suggests that preceding environment is a more powerful factor than sC sonority markedness in inducing e-epenthesis.[7] The researcher also invokes word frequency effects, claiming that the infrequent occurrence of /sl/ clusters in English (e.g., in teacher talk) might have had a negative effect on the observed results.

Escartin (2005) also found that, in line with several other studies (e.g., Carlisle, 1991a, 1997, 2006; Cardoso, 1999, 2007, 2008), preceding consonants induced the highest proportion of epenthesis (.59), and preceding vowels the lowest (.34). In addition, and contrary to Abrahamson's (1999) findings that preceding pauses have a 'neutral' effect on the amount of epenthesis, Escartin reported a relatively high level of vowel epenthesis after pauses (.55). Based on these results, and along the lines of Cardoso (1999), I hypothesize that consonantal and pause environments will have a relatively similar effect of increasing the likelihood of e-epenthesis, and that vocalic environments will have a comparatively lowering effect, inducing the lowest proportion of epenthesis.

Two other studies involving Lusophone speakers learning ESL (Major, 1996; Texeira Rebello, 1997) have reported quite unpredictive results regarding the influence of sonority markedness on the production of nonnative sC clusters – namely that the SSP-following onset clusters were modified more often than their SSP-violating counterparts. For example, in Major's study, which involved four native Brazilian Portuguese (BP) participants, it was found that /s/ + liquid onset clusters contributed more significantly to error than /s/ + stop onset sequences did (45.7 % for /sl/ against 18.3 % for /st/, /sp/, and /sk/). Likewise, Texeira Rebello, who examined the production of three biliteral (i.e., 2-member) onsets that abide by the SSP (i.e., /sn/, /sm/, and /sl/) versus three that do not (i.e., /sp/, /st/, and /sk/), reported that her six participants modified 63% of the less

[7] Unlike Escartin (2005), Carlisle (1991b) reported a significantly lower proportion of e-epenthesis before /sl/ (.25) than before /st/ (.36).

marked onsets compared to 54% of the more marked onsets. Even more striking in Rebello's research was the finding that the three biliteral onsets abiding by the SSP were modified more often than the five triliteral onsets found in English, a finding which is in sharp contrast with the results of several other studies establishing that triliteral onsets are modified significantly more frequently than bilateral onsets due to their marked nature (e.g., Anderson, 1987; Carlisle, 1997; Eckman, 1991). Based on evidence provided by Major and Texeira Rebello, it appears that the so called anomalous findings were the result of the positive transfer of two interacting rules in BP which induced target-like sC production (for details about these rules, see Carlisle, 2006).

Despite the unexpected results reported in the two studies above, the general findings of previous research reveal that onset clusters not abiding by the SSP are epenthesized more often than those abiding by it. In addition, the findings also suggest that preceding consonantal environments induce the highest proportion of e-epenthesis, while vocalic environments yield the lowest. Let us now turn to the effects that extra-linguistic factors may have on IL phonology.

2.2.2 Influence of extra-linguistic factors on IL phonology

In addition to the linguistic factors discussed above, extra-linguistic factors (e.g., style, proficiency, gender, ethnicity, and social class) have also been known to contribute to variation in L2 acquisition. For instance, nonnative speaker variation research has shown that, in general, the more formal the register or style, the less L1 transfer and the greater the frequency of target-like forms, usually because of more focused attention to form (e.g., Bayley, 1996; Cardoso, 2005, 2007; Dickerson & Dickerson, 1977;

Gatbonton, 1978; Sato, 1985; Tarone, 1979, 1988). Several other studies, however, indicate that more formal registers may not always relate to greater target accuracy (Beebe, 1980; Lin, 2001, 2003; Major, 1996, 2001; Weinberger, 1987). For instance, Major (2001) describes cases where a less formal register can trigger more target-like forms because of L1 transfer.[8]

To better understand the effect of external variables on IL phonology, I suggest introducing the Ontogeny Phylogeny Model (OPM; Major, 2001), an updated version of the Ontogeny Model (OM; Major, 1987). The OPM is based on the premise that developing interlanguages are comprised of both L1 and L2 features, which are mediated by universal (developmental) phenomena. The OPM maintains that the IL develops *chronologically* such that features from the L2 increase, L1 patterns decrease, and developmental phenomena increase and then decrease in the course of L2 development. Likewise, the OPM claims that IL varies *stylistically* such that in more formal styles, L2 structures increase, L1 features decrease, and developmental phenomena increase and then decrease. Graphic representations of the OPM predictions are illustrated in Figure 2.1.

[8] For example, in slow formal speech, Japanese speakers often insert an epenthetic vowel between initial consonant clusters, as a result of L1 transfer: /skaj/ → [sukaj]; in normal running speech, however, the nativelike form [skaj] is usually produced, following an L1 Japanese rule of vowel devoicing and subsequent deletion.

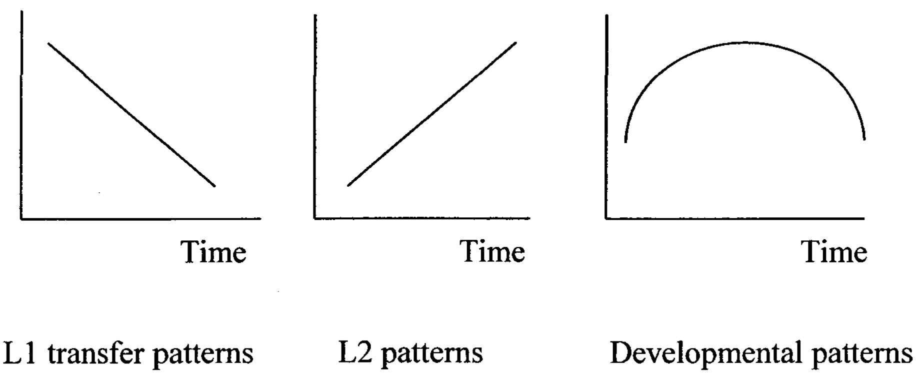

Figure 2.1. The Ontogeny Phylogeny Model of L2 acquisition.

As is the case with style, the development of proficiency has also been shown to influence L2 phonology. Abrahamsson's (1999) study is a case in point. The main aim of the study was to confirm and extend the results reported in Carlisle's (1997) research (in which *only* a formal type of speech was used) to conversational speech data. Despite Abrahamsson's prediction (based on a chronological corollary of the OPM discussed above) that the proportion of e-epenthesis (i.e., L1 transfer) would decline with increased L2 proficiency, the results showed an altogether different pattern. His results revealed a low proportion of e-epenthesis at the beginning of data collection (recording time 1), a relatively increasing rate of the phenomenon during the first year (recording times 1-9) and a decreasing frequency of vowel insertion during the second year (recording time 10). To elucidate this rather unexpected pattern – namely, the 'low-high-low' pattern of e-epenthesis – Abrahamsson suggested the possibility of a nonlinear development of the L2 structures analyzed in his study. In particular, he ascribed the pattern of development from low to high frequencies of epenthesis during the first year to increased speech proficiency; during that period, learners may have focused more on content than on form, thereby producing more erroneous forms in the process. On the other hand, he attributed the decline in error rates during the second year to real learning. That is, over time when L2 fluency has increased, errors begin to disappear. Assuming that e-epenthesis is a transfer phenomenon in the case of L1 Farsi speakers (e.g., Yarmohammadi, 1995), in the current study I predict that the initial state will strictly correspond to the phonology of Farsi, in which sC clusters will syllabify via e-epenthesis (just like in the L1). At more advanced stages, however, the frequency of e-epenthesis will decrease, as predicted by the OPM.

Let us once again revisit Escartin's (2005) study which (as noted earlier) investigated the variable speech of L1 Spanish ESL learners, using a variationist approach for data collection and analysis. An interesting pattern that emerged in her research is related to style. Although Escartin predicted that e-epenthesis before sC onsets – a typical transfer Spanish phenomenon – would decrease in more formal stylistic environments, the GoldVarb statistical results revealed an insignificant difference between informal and formal styles. As was suggested by the researcher, however, these unexpected results might be associated with the insufficient number of sC cluster tokens obtained in the informal interview, possibly due to participants' avoidance of the relevant forms. To avoid smaller proportions of tokens in more casual situations, the present study uses a picture-based interview in the informal task. The pictures included in the interview are believed to provide enough (visual) cues for the participants to produce a considerable number of relevant tokens. With these 'remedial' measures in mind, I predict that the Farsi speakers in my study will show higher accuracy rates of sC cluster production in more formal styles.

Finally, another study which has adopted a holistic approach to investigate L2 phonological phenomena was conducted by Cardoso (2007). In that study, the researcher examined the variable acquisition of word-final stops by 6 adult native Brazilian Portuguese speakers learning English as a foreign language in a classroom context. As hypothesized, the results of the study indicated that the target-like production of English codas is more likely to occur in the speech of more *proficient* speakers and in more formal *stylistic* environments, which conforms to the predictions of Major's (2001) Ontogeny Phylogeny Model for L2 acquisition discussed earlier. More important, the findings in Cardoso's study bolster the idea that L2 development is a complex process whose understanding entails not only a detailed examination of linguistic variables but also a wide appeal to (and investigation of) extra-linguistic constraints. Along the lines of Cardoso (2007), the current investigation adopts an integrated approach to analyze the Farsi-English data, because this approach (as the discussion above suggests) allows us to develop a more thorough perspective on the acquisition of L2 phenomena (i.e., e-epenthesis).

2.2.3 *Research questions and hypotheses*

To better analyze the phenomenon under investigation and address some of the shortcomings observed in previous studies, the present study sets out to examine the variable acquisition of the homorganic /sn/, /sl/, /st/ onset clusters using a multidimensional approach (which combines methodological tools from sociolinguistics and theoretical insights from generative phonology and first and second language acquisition). The current study also aims to extend the findings of previous studies about the acquisition of L2 sC clusters to a new research population – Farsi speakers learning English as a Second Language.

What essentially emerges from the studies reviewed above is that the development of sC clusters (and its associated phenomenon of e-epenthesis) in IL is determined by preceding phonological environment, the sonority profile of the sC cluster, L2 proficiency, and style. More precisely, the survey of previous research leads us to formulate the following research questions:

1. Does sonority markedness have an impact on the acquisition of sC onset clusters by Farsi speakers learning ESL? In particular, does the acquisition of these sC sequences proceed from the less marked sonority-following sequences (i.e., /sl/ and /sn/) to the more marked sonority-violating onset clusters (i.e., /st/)?
2. Is the phenomenon of e-epenthesis sensitive to *preceding phonological environment* (i.e., consonant, pause, vowel)?
3. How is e-epenthesis patterned across the three proficiency groups (beginner, intermediate, advanced)?
4. To what extent is e-epenthesis determined by stylistic factors?

The set of hypotheses stemming from the above questions are:

1. Based on the sonority profile of the cluster and markedness, the development of sC onset clusters will follow the following sequence: /sl/ > /sn/ > /st/.

2. Epenthesis will occur more frequently after word-final consonants and pauses than after word-final vowels.
3. There will be a decline in the amount of e-epenthesis as L2 proficiency rises.
4. The frequency of e-epenthesis will be higher in less formal tasks.

In the next chapter, I will present and discuss the methodological framework used to address the research questions and hypotheses stated above.

CHAPTER 3: RESEARCH DESIGN

This chapter provides a detailed account of the research design of the study. In particular, the chapter discusses the participants recruited for the study (section 3.1) as well as the materials used for data collection (section 3.2). It also describes the situational – temporal, spatial, and procedural – context in which the data collection was undertaken (section 3.3). The chapter then provides the different steps involved in the recording and transcription of the corpus (section 3.4), and it concludes by describing the coding scheme adopted for the statistical analysis of the data (section 3.5).

3.1 Participants and proficiency

The participants were 30 native speakers of Farsi (15 male and 15 female), with an age range between 19 and 42 (average age = 26).[9] All participants were living in the Montreal area at the time of the data collection, and were selected from a representative educated population. Each of the informants was enrolled in a degree program, with the exception of one informant who, while not pursuing a university education in Canada at the time of the experiment, had already completed a university degree in her home country - Iran. In addition to being well-educated, the participants had formally studied English for several years, especially in middle- and/or high-school (3 years was the

[9] To control for the possibly confounding variable *gender*, it was decided to include in this study a sample of *equal* number of men and women (15 in each category). This decision to set aside a difference in gender confound is in line with findings from several variation studies which have reported a differential effect of gender on IL phonology (e.g., Adamson & Regan, 1991; Frey, 1995; Major, 2004; Weiss, 1970).

baseline, as had been attested in the participants' responses to a bio-data questionnaire). Based on this academic measure of English proficiency, it was assumed that all participants would be able to carry out the interviews without difficulty.

Participants who had previously taken a pronunciation class were excluded from the investigation, the assumption being that any prior pronunciation instruction might have alerted them to the problem of e-epenthesis (and to possible ways of remediating it). Once this basic criterion had been met, a preliminary (i.e., pre-experimental) conversation between the researcher and the informants (through the phone or even face-to-face) took place, allowing the researcher to get a sense of the global speaking proficiency of the participants. Besides taking part in this informal oral exchange, participants were also requested to rate their English speaking ability, according to a scale from 0 (very poor) to 5 (very good) (see background questionnaire in Appendix A).

Because the current study examines a specific aspect of L2 pronunciation – namely, the acquisition of English sC clusters – a *more* specialized proficiency measure, aside from the two general procedures mentioned above (i.e., self-assessment and global proficiency), was needed. The measure, which was incorporated as part of the data collection process, allowed the *overall* frequency of correct production of the target sC onset clusters (i.e., /st/, /sn/, and /sl/) to be calculated for each participant, consistent with a principle widely used in L2 phonological research (e.g., Andersen, 1978; Carlisle, 1997; Eckman, 1991; John, 2006).[10] Based on the three selection criteria suggested above

[10] Unlike previous research which has used the (20 - 80%) interval of correct production as the criterion level to define and investigate intermediate proficiency *only* (e.g., Carlisle, 1997; Eckman, 1991), the present study includes a more comprehensive range (0 -100%), from which three proficiency groups (beginner, intermediate, and advanced) are sampled.

– *cumulative sC production, self-assessment, global proficiency* – three distinct proficiency groups of 10 participants each were *ultimately* established. These proficiency groups (see Figure 3.1) were categorized as follows: beginner group – represents the ten lowest percentages on the ultimate proficiency scale (range: 11.62 - 48.06%); intermediate group – designates the ten intermediate (%) scores of ultimate proficiency (range: 48.14 - 72.26%); and advanced group – comprises the ten highest percentages on the ultimate proficiency index (range: 73.33 - 88.31%).

Ultimate proficiency (%) and participants

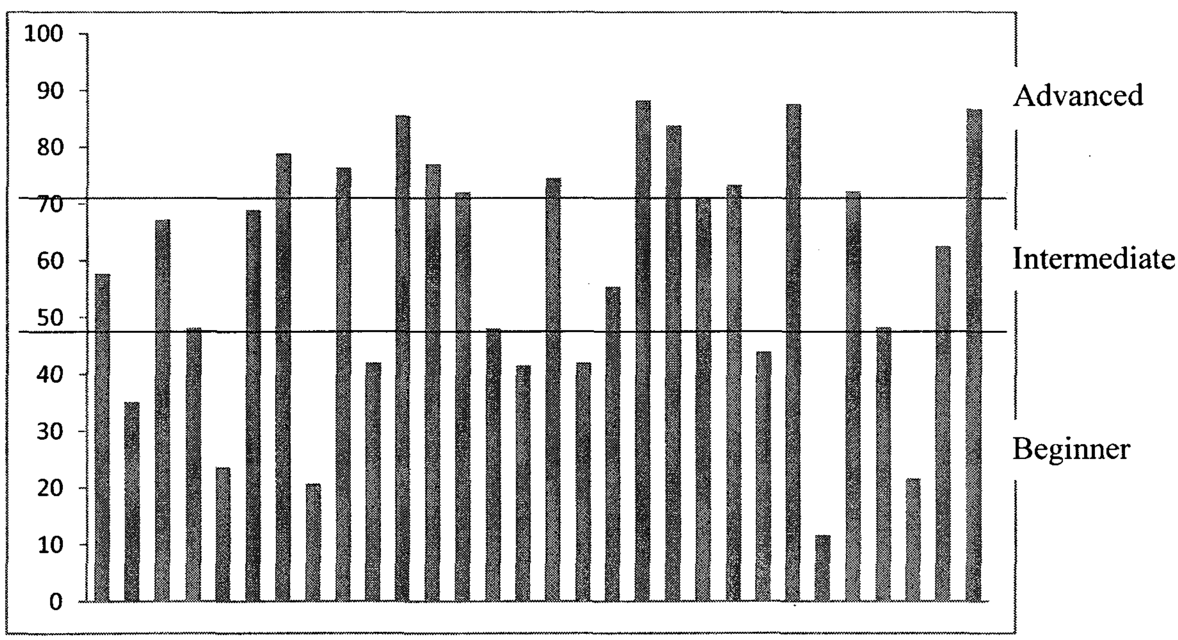

Figure 3.1. Ultimate proficiency in English following three criteria: cumulative sC production, self-assessment, and global proficiency.

3.2 Materials

The materials used for the data collection in this study consisted of a questionnaire, a formal reading task, and an informal interview.[11] I will start with a detailed discussion of the background questionnaire.

3.2.1 Bio-data form (background questionnaire)

As a first step in the data collection process, participants had to fill out a bio-data form, parts of which were adapted from Gass and Mackey (2005). This form is intended to report on the informants' basic demographic characteristics (e.g., age, gender, ethnicity) as well as other information deemed necessary for a better understanding of the sample under investigation – e.g., the participants' overall amount of exposure to English, their self-assessment of L2 proficiency, their attitudes to L2 learning, their familiarity with other languages, and the amount and nature of exposure to English outside the classroom (see Appendix A).

As is always the case with second language research, reporting relevant background information about the participants is useful in interpreting the results, especially if the results cannot be satisfactorily explained in light of the experimental variables alone. In the context of this study, for instance, if a participant has a good command of a third language (e.g., German) which allows onset consonant clusters (just like English), then this might have an impact on the participant's production of the

[11] The adoption of two stylistic environments (i.e., one formal, the other informal), instead of a three-level formality hierarchy (i.e., very formal, formal, and informal), appears to be defendable: Several variation studies (e.g., Cardoso, 2005, 2007; Escartin, 2005; John, 2006) have found no significant differences between the two formal subcategories *very formal* (e.g., reading of word lists / minimal pairs) and *formal* (e.g., sentence and passage reading tasks).

English sC clusters, irrespective of whether or not the participant is proficient in English. As this example situation suggests, thus, it is advisable to include as many relevant participant details as possible when designing questionnaires; this will help the researcher to disentangle the effects of background knowledge (i.e., extra-experimental factors) from the actual influence of the independent variable(s) on the linguistic marker being investigated. The administration of the questionnaire, as detailed above, lasted approximately10 minutes.

3.2.2 Formal task

The formal task involved reading a list of 59 topically unrelated sentences containing the three onset clusters /st/, /sn/, /sl/,[12] *equally* distributed among the three different preceding environments included in this study – vowel, pause, consonant (see (9) below).[13] More specifically, each of the three target sC clusters /st/, /sn/, /sl/ appeared 20 times – 6 times before vowels, 6 times before pauses, and 8 times before consonants (see Appendix C). The decision to include a relatively even number of vowels, pauses, and consonants before each of the target sC clusters is motivated by findings from a number of IL studies which have established that phonological phenomena are largely determined by preceding phonological environment (e.g., Cardoso, 2005, 2007; Carlisle, 1991a, 1991b, 1997; Escartin, 2005; John, 2006). Overall, the results of these studies

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[12] Although the reading instrument contains 59 sentences in all, the target clusters /st/, /sn/, /sl/ actually occur 60 times; one sentence, exceptionally, contains two occurrences of these target clusters (see Appendix B).

[13] For illustrative purposes, the target sC items shown in forthcoming (9) are bolded and the preceding environments underlined; these typographical modifications, of course, do not appear on the version presented to the participants.

have demonstrated that preceding vowels tend to facilitate the development of sC clusters, unlike preceding consonants, which generally hinder the acquisition of such clusters. The results of previous research have also shown that pauses behave just like consonants in a variety of phonological phenomena (e.g., Cardoso, 1999; Escartin, 2005; Winford, 1992; cf. Abrahamsson, 1999). The reading task lasted from 5 to 10 minutes to complete.

(9) Reading task: Sample sentences

Grandma **st**uffed the chicken.

ø **Sn**eakers are very cheap in this shop.

A webcam **st**ood on top of his monitor.

3.2.1 Informal interview

Participants also took part in an informal, picture-based interview which was administered by the researcher in English (see Appendix I). The purpose of the interview was to obtain as 'natural' data as possible and to minimize the effect of the observer's paradox (Labov, 1972) – a situation in which the participants' performance becomes affected because of their awareness that they are being watched or audio-recorded. To avoid such a situation and make certain that less careful speech is obtained, the informal interview used pictures (of relatively frequent words such as 'cat', 'airplane', and 'snake') as cues to engage 'friendly' conversations between the researcher and the respondents (see (10) below for a sample of the questions asked during the picture-based interview). In addition to utilizing images that contained the target sC cluster words, the interview task also included picture distractors, to reduce the likelihood of participants guessing the exact nature of what was being elicited from the pictures and, therefore, minimize any threats to internal validity. The task lasted approximately 25 minutes.

(10) Picture-based (Informal) interview: Sample questions

What do you see in this picture?

Have you ever seen (owned, touched, experienced) one in real life?

Do you use it regularly?

Do you like what you see in the picture? Why?

3.3 Procedure

The participants (originally 31) were individually tested between April and September, 2007, in an office at Concordia University, or at some other location (e.g., in offices at other institutions), depending on room availability and other factors.[14] Each session started with a presentation of the general goals of the study, with no revelation of the precise focus or true nature of the investigation – participants were merely told they were being tested on the acquisition of English. After officially consenting to participate in the study, each participant was handed out a written questionnaire which (s)he had to fill out. Following this, and in order to minimize any potential test effects, it was decided to counterbalance the ordering of both the formal and informal tasks. That is, some

[14] It was decided to eliminate the data from one participant (among the 31 original participants); exceptionally, this participant does not hold a university-level degree (only a high school diploma), nor was she in the process of completing one at the time of the data collection.

respondents started with the formal task before engaging in the informal interview, while others did just the opposite.

3.4 Data recording and transcription

Both the formal and informal tasks were recorded via a CD recorder (Marantz CDR300) and an audio-Technica lavaliere microphone (AT831b). The recorded data were then transcribed by the researcher via Transcriber (version 1.5.1), an application for labeling, segmenting, and transcribing speech. In particular, preceding environments, type of onset clusters, and presence or absence of e-epenthetic were transcribed. Figure 3.2, which represents an actual transcription file, is shown below to illustrate the interface and some of the main functions of Transcriber.

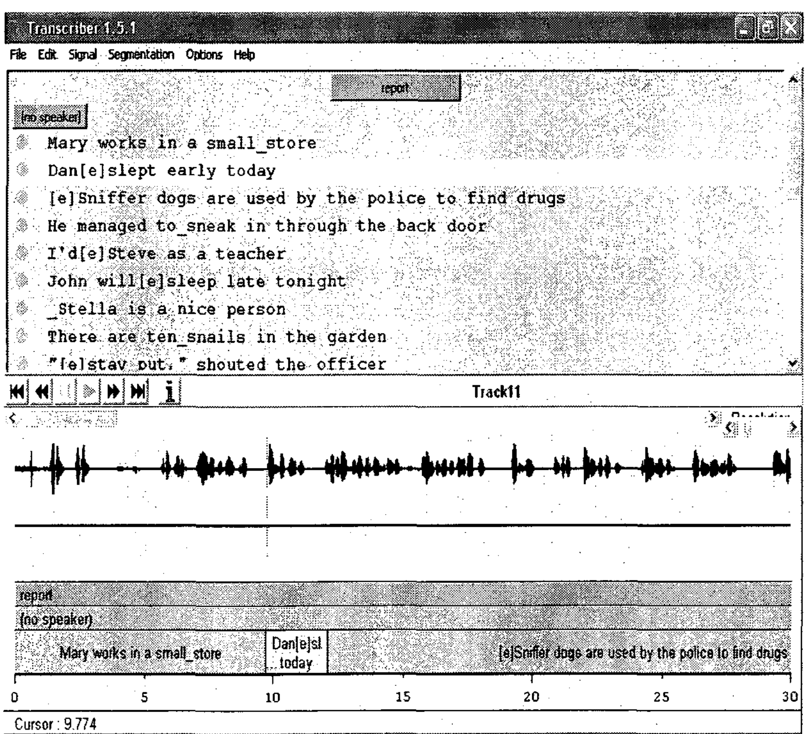

Figure 3.2. Transcriber interface.

As can be seen, three major components are associated with the Transcriber interface. The first component, which represents a text editor located in the upper part of the interface, involves the orthographic transcription of the utterances containing the sC clusters. Each of the transcribed utterances constitutes a single speech segment, which is usually preceded by a dot. For example, in the second speech segment (i.e., line 2), where the sentence 'Dan [e]slept early today' appears, an epenthetic [e] is transcribed to indicate that the recorded speaker inserted an [e] before the sC-initial word (i.e., [e]slept); in the fourth line, where the utterance 'he managed to_sneak in through the back door' is displayed, a '_'sign is transcribed, which indicates that a target-like variant of the sC cluster (i.e., sneak) was heard from the recorded participant.

In the second part of the Transcriber interface, a series of waveforms are displayed that designate specific parts within the larger recording. Each of these waveforms, it should be noted, can be viewed at the same time that the corresponding transcriptions and segmentations are heard. The segmented transcriptions are displayed in the third (i.e., the bottom) component of the Transcriber screen.

In situations where it was not easy to determine whether or not an epenthetic [e] occurred, the problematic data were fed into Praat (version 4.6.21; Boersma & Weenink, 2007), a program which analyzes, synthesizes, and manipulates speech. The waveforms in Figures 3.3 and 3.4 illustrate two words containing an sC cluster – '[e]slept' and 'slept', respectively – as they were analyzed via Praat.

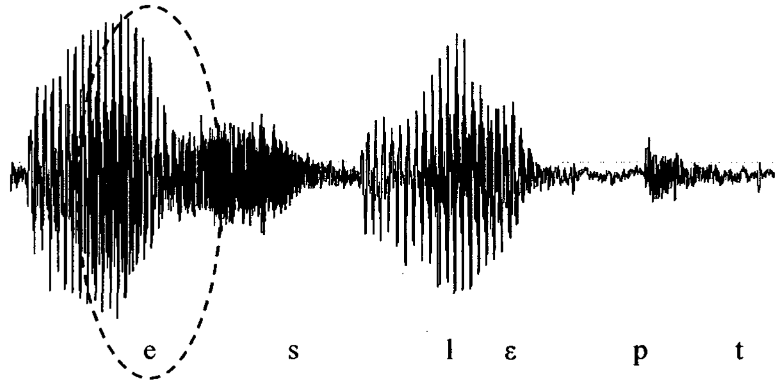

Figure 3.3. Waveform for '[e]slept'.

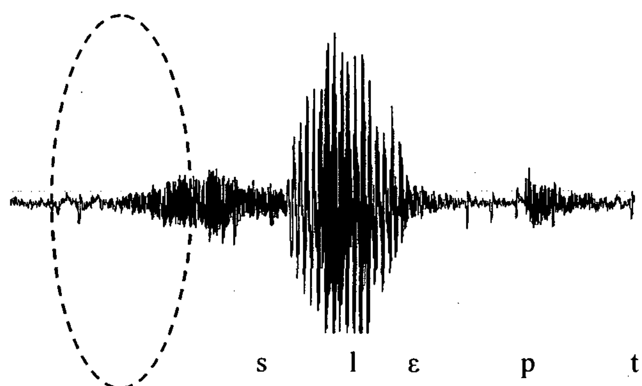

Figure 3.4. Waveform for 'slept'.

Figure 3.3, for instance, displays a high-sonority signal at the beginning of the word 'slept', which testifies to the presence of an epenthetic [e]; by contrast, Figure 3.4 shows no speech signal at the beginning of the same word (i.e., 'slept'), which suggests the absence of an epenthetic [e] in that signal (i.e., the target word 'slept' is pronounced as is, starting with the original fricative /s/). For illustrative purposes, the relevant waveform representations are indicated by a dotted circle. On the rare occasions when the troublesome tokens could not be settled via the previously mentioned software packages (i.e., Transcriber and Praat), the tokens were further examined with the help of my thesis supervisor, Dr. Cardoso.

Finally, mention should be made of the items that were discarded from the data. In total, five items were eliminated from our study, for one reason mainly: Participants misread the words containing the sC onset cluster. To illustrate, one participant substituted the word 'attempts' for 'stamps' in the reading aloud of the sentence 'I need five stamps'. Similarly, another participant misread the word 'sneak' as 'seek', when pronouncing the sentence, 'he managed to sneak in through the back door'. Items involved in another type of speech modification – the modification of consonant environments into pauses – were not eliminated from the data. The decision to keep these items for further analysis is in harmony with the original prediction of this study, namely, that pause and consonant environments (unlike vowel environments) should behave similarly in inducing higher proportions of e-epenthesis.

3.5 Data coding and analysis

For the statistical analysis of the Farsi learners' data, the current investigation adopted GoldVarb X (Sankoff et al., 2005). This statistical package, which was built on earlier programs such as VARBRUL (Pintzuk, 1988, for DOS computers) and GoldVarb (Rand & Sankoff, 1990, for Macintosh computers), has for several years now been an invaluable tool to analyze variable data in variationist linguistics. One major reason is that, unlike statistical procedures such as ANOVA, which are only capable of handling controlled and balanced data, Goldvarb X is conceived primarily 'to account for the extreme distributional imbalances' inherent to natural human language (Tagliamonte, 2006, p. 133). Another, secondary reason is that the program provides a handy tool that allows for a flexible treatment of the data, for it enables the researcher to revise his/her hypotheses and reanalyze the data more easily (Young & Bayley, 1996).

As is often the case with variationist studies, a number of hypotheses need to be generated prior to the Goldvarb analysis of the data. Typically, these hypotheses are formulated as a function of a set of linguistic and extra-linguistic variables, often referred to as factor groups. The factor groups that were initially included in the statistical analyses of the Farsi-English data are listed in Table 3.1, where the parenthetical information indicates the coding system utilized.

Table 3.1. *Factor Groups and Coding Scheme for GoldVarb X Analysis*

Factor	Factor groups		
Dependent variable	Epenthesis (x)	Target form (y)	
sC sonority	s + liquid (L)	s + nasal (N)	s + stop (S)
Preceding environment	Consonant (c)	Vowel (v)	Pause (p)
Proficiency	Beginner (b)	Intermediate (i)	Advanced (a)
Style	Formal (F)	Informal (I)	
Participants	#1 (a)	#2 (b)	#3 (c), etc.

Following transcription of the data, the collected 4,149 tokens were coded according to the coding protocol shown in Table 3.1. For instance, in the reading aloud of the sentence 'Dan [e].slept early today' by participant 5, the sC sequence in [es].lept' was coded as *xLciFe* (where *x* signals an epenthetic [e]; *L* indicates the second segment of the sC cluster is a liquid; *c* means that the preceding environment is a consonant; *i* informs us that the participant is intermediate; *F* indicates that the style is formal; and, finally, *e* designates the code assigned to participant number five).

The coded tokens were then submitted for a series of Goldvarb statistical analyses, to determine the probabilistic contribution of each of the linguistic and extra-linguistic factor included in the study (for a detailed account of the Goldvarb analyses, see chapter 4). Based on these probabilistic results, the Farsi-English data were further analyzed using a stochastic version of the framework of Optimality Theory that includes a Gradual Learning Algorithm (Boersma, 1998; Boersma & Hayes, 2001), as will be shown in chapter 5.

In this chapter, I have presented the methodology used in my study. In chapter 4, I will provide the statistical analysis of the Farsi-English variable data, and then discuss the results of this analysis in terms of the internal and external variable constraints included in the study.

CHAPTER 4: STATISTICAL RESULTS AND DISCUSSION

This study was carried out to find out which factors – linguistic and extra-linguistic – condition the variable application of e-epenthesis in the English IL patterns of Farsi speakers. With this goal in mind, the collected data (which yielded 4,149 tokens of word-initial sC clusters) were coded using the coding protocol illustrated in chapter 3. The generated tokens were fed into GoldVarb X (Sankoff et al., 2005), which performed *multivariate analyses* – i.e., a series of statistical procedures which allows the researcher to figure out the complex set of factors underlying the systematic variation observed in the corpus under investigation. A detailed explanation of these procedures, along with the various steps involved in the Goldvarb analysis of the data, is presented in sections 4.1 and 4.2. A presentation and discussion of the final results are provided in the remaining sections of this chapter.

4.1 Exploring Goldvarb X

As suggested earlier, the current investigation adopted Goldvarb X, a statistical program suitable to manage the type of imbalanced data collected and analyzed in this study. Assuming this body of data to be reasonably large (there are 4,149 tokens in all), the results of a typical Goldvarb analysis should apply to the entire corpus under study. In so far as this is a representative sample of the population under investigation, the analysis should, by the same token, extend to all similar speakers and linguistic and extra-linguistic contexts.

For the statistical analysis, after the data are coded, they are input as a text file into Goldvarb. The factor values are then specified for the program, and the number of factor groups as well as the legal values for each group are entered into the program. Goldvarb initially performs a raw analysis of the data, subject to the fact that the preliminary analysis will involve no recoding. This preliminary procedure, which yields a conditions file, essentially instructs Goldvarb to include all factors and factor groups. The next step is to create a cell file from the existing tokens and condition files. The creation of a cell file also involves selection of the application value (i.e., the value related to the application of the phenomenon under investigation: e-epenthesis). For the purposes of this study, and throughout the statistical analyses of the Farsi speakers' data, e-epenthesis is selected as the application value. Consequently, all results will be reported from the perspective of epenthesis, not target-like production of sC.

After creating the cell file, Goldvarb provides the raw results obtained from the *distributional* analysis of the data, that is, the distribution of each dependent variable with regards to each factor among the independent variables.

However, providing merely raw numbers and percentages is not the best way to ascertain the contribution of each factor, independently of the others. The next step, thus, is to carry out a binomial one-level statistical analysis (see discussion below). Before engaging in any multivariate procedure, it is nonetheless advisable to check the data for interaction and categorical results (i.e., knockouts and singletons). Perhaps the most common way to test for interaction is via a cross-tabulation between the factor groups (e.g., examination of the proportion of e-epenthesis by proficiency and participant – for a detailed explanation, see discussion in section 4.2). Let us now look at the two main procedures involved in conducting a multivariate analysis: the binomial one-level analysis, and the step-up/step-down runs.

The binomial one-level analysis displays a number of probabilistic values. It provides the input probability of each independent factor, which is the overall tendency of a phenomenon to occur (i.e., the likelihood of e-epenthesis application), irrespective of conditioning effects of any specific factor. In addition, this statistical procedure displays the factor weight (*p*), a value that measures the contribution of each factor to the phenomenon under study, namely, e-epenthesis in the IL of Farsi-English speakers. Finally, this type of operation shows the probabilistic results, which represent the most accurate picture of the likelihood of variant occurrence.

The factor weight (*p*) is a key statistical measure, one which is associated with each factor independently of other factors in the same factor group. The further away a factor weight is from 0.50, the greater its effect on the resulting probability. Because the sC sequences investigated in this study involve two variants – i.e., e-epenthesis (e.g., [esn]ake) versus target-like sC (e.g., [sn]ake) –, the factor weight of .50 was identified as the dividing line between the values that favor the occurrence of a specific variant and those that disfavor its presence. On either end of the weight continuum there is, on the one hand, the weight value of 1.00, which designates the maximum contribution a factor can have on the variable phenomenon (i.e., the variant will *always* be selected in the output); on the other hand, the probability value of 0.00, which indicates the weakest effect a factor can have on the observed variation (i.e., the variant will *never* be selected in the output). It should be noted that these types of categorical results are rarely documented in studies of language variation, including the present study whose main focus is on variability.

Because the one-step analysis discussed above does not show statistical significance or relative strength of the factor groups, it is recommended to perform the step-up/step-down regression analyses – otherwise known as the binomial up and down analyses. In essence, the binomial up and down analyses allow the researcher to check whether or not the factor groups included in the investigation contribute significantly to the variable phenomenon under study. In this type of operation, GoldVarb X performs a series of calculations among the factor groups in a stepwise fashion (i.e., the regression analysis first proceeds step-up and then step-down). At the end of the analysis, an ideal model of the output should select and discard the same factor groups during both the step-up and step-down procedures; otherwise, if the selected groups are different during these two types of analyses, this should constitute a good reason for the researcher to re-consider the significance level of the factor groups: It may be that the variables in question are either nonsignificant (at above the $p < .05$ level) or interacting. More specifically, the binomial up and down analysis ultimately selects the factor groups which significantly contribute to the application of e-epenthesis (see forthcoming section).

In this section, I have presented a broad overview of the procedures involved in the Goldvarb analysis of variable data in general. In the following section, I will provide a more detailed account of these procedures, with direct illustrations from the Farsi-English data from my study. In addition, I will also raise the issue of interactive factors/factor groups in the data and propose ways of resolving it. Typical solutions to these troublesome factors/factor groups, as we will see, usually involve some kind of recoding (i.e., either by excluding the variables from the analysis or by combining them).

4.2 Goldvarb analyses

Not surprisingly, the initial Goldvarb analysis, in which all the factors were included as per the hypotheses in section 2.2.3, yielded a model of variation with interactive (and nonsignificant) factors. The probabilistic results from the binomial 1-level analysis are illustrated in Figure 4.1.[15] As can be inferred from the printout, the results pertaining to *sC sonority*, for instance, show that both /st/ and /sn/ onset clusters promote the application of e-epenthesis (.61 and .51, respectively), while clusters of the sonority type /sl/ disfavor the application of the same phenomenon (.34). Also illustrated in the binomial one-step figure are some features characterizing each cell (i.e., a combination of factors and factor groups) in the data. Of these, the most important are: the application values – 'app'ns', the 'Expected' values, and the difference between these two values, the 'Error' value. An examination of the results indicates that for some cells, the 'Errors' are quite high, suggesting that there is interaction between the factor groups (according to Young and Bayley (1996), error values below 2.0 are generally good, as they indicate a good fit of the model to the data).

[15] For the sake of brevity, only the first two independent variables (i.e., sC sonority, preceding phonological environment) and the first five cells are shown. Also, for convenience, these data are displayed in tabular form.

• BINOMIAL VARBRUL, 1 step • 11/13/2007 6:45:35 PM ••••••••••••••••••••••••••••

Name of cell file: condition.cel_first run

Averaging by weighting factors.
One-level binomial analysis...

Run # 1, 538 cells:
Convergence at Iteration 8
Input 0.328

Group Factor	Weight	App/Total	Input&Weight
1: S	0.612	0.44	0.44
L	0.340	0.31	0.20
N	0.513	0.41	0.34
2: c	0.762	0.57	0.61
p	0.584	0.43	0.41
v	0.157	0.15	0.08

Cell	Total	App'ns	Expected	Error
Svilz	11	2	1.313	0.408
Svilu	28	4	3.208	0.221
Svilr	15	3	4.211	0.485
Svilm	12	1	1.533	0.212
Svilf	13	5	1.749	6.983

Figure 4.1. Binomial 1-step output for the first Goldvarb run.

In addition to the binomial 1-level analysis explained above, the fit of the model to the data can also be represented graphically through a scattergram, such as the one illustrated in Figure 4.2. As can be seen, the scattergram has a diagonal line on (and around) which a number of data points are displayed. The size of each data point on the graph corresponds to the number of tokens in the related cell. Points near the line have a good fit, while those away from it represent a bad fit. Based on these criteria, and judging from the many points that stand far from the diagonal, it is clear that the model is a bad fit, and that there is interaction among the factors (e.g., Rand & Sankoff, 1990).

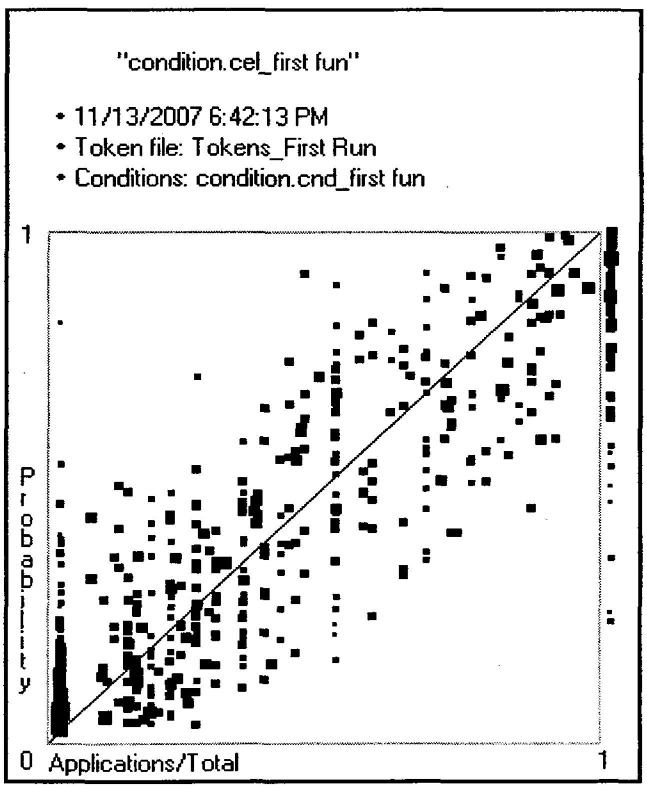

Figure 4.2. Binomial 1-step scattergram for the first Goldvarb run: A bad fit.

I will now proceed to the second procedure relating to the initial Goldvarb run – the binomial up and down statistical analysis. Recall that a binomial up and down analysis essentially brings out the significant factor groups conditioning the variable phenomenon. The output of this analysis (see Appendix J) reveals that both the stepping up and stepping down runs selected the same factor groups 1, 2, 4, and 5 (i.e., *sC sonority*, *preceding environment*, *level of formality*, and *participants*, respectively) as the most significant variables responsible for the observed variation. Moreover, both runs excluded the factor group 3 (i.e., *proficiency*), as it did not seem to have a significant effect.

Based on the initial analysis above (e.g., Figure 4.2), it is clear that there are some distributional issues in the corpus analyzed – e.g., interaction and/or non-orthogonality (Guy, 1988).[16] To address these problematic overlaps, and thus obtain more reliable results, a cross tabulation between the factor groups *proficiency* and *participants* was performed (i.e., the proportion of e-epenthesis by proficiency and participant was examined). Overall, the cross-tabulation (see Appendix K) indicates a number of 'gaps' in the data, most prominent of which are empty cells (which are typically represented by three zeros and two sets of dashes).

These problematic cells, in particular, suggest that there is a redundancy between proficiency and participants. Evidently, the best way to resolve redundancies is by excluding one of the two factor groups altogether – e.g., participants. Exclusion of the

[16] According to Guy (1988), and as restated by Tagliamonte (2006), orthogonality essentially refers to the independence of factor groups among each other. That is, in order for factor groups to be orthogonal, they should not be subgroups or subcategories of each other.

participants variable from the analysis may be justified by the fact that every participant *inherently* belongs to a proficiency group (e.g., Cardoso, 2008). Elimination of the factor group *participants* can also find elucidation in the common sociolinguistic view that language is part of a community's heritage and (that) 'the individual doesn't exist as a unit' (Labov's answer to an interview question – as cited in Gordon, 2006, p. 341). This is also in agreement with Cardoso's (2008) claim that proficiencies represent distinct speech communities and, thus, that the variable patterns within the individual (i.e., the participant) are akin to those observed within the group (i.e., proficiency) (for similar views, see Bayley, 1991; Regan, 1996; Young, 1991). Having removed the *participants* variable from the analysis, I now proceed to the second run of the data.

In the second Goldvarb run, a binomial one-level analysis (see Appendix L) was performed, which displayed the individual probabilistic influence of each factor on the application of e-epenthesis. Interestingly, the results of this analysis indicate that both factors *preceding consonants* (c: 0.75) and *preceding pauses* (p: 0.59) favor the application of e-epenthesis. In addition, although the corresponding scattergram in Figure 4.3 indicates a far better fit to the data, it still shows a considerable number of outliers, which suggests some degree of interaction between the factors *consonant* and *pause*.

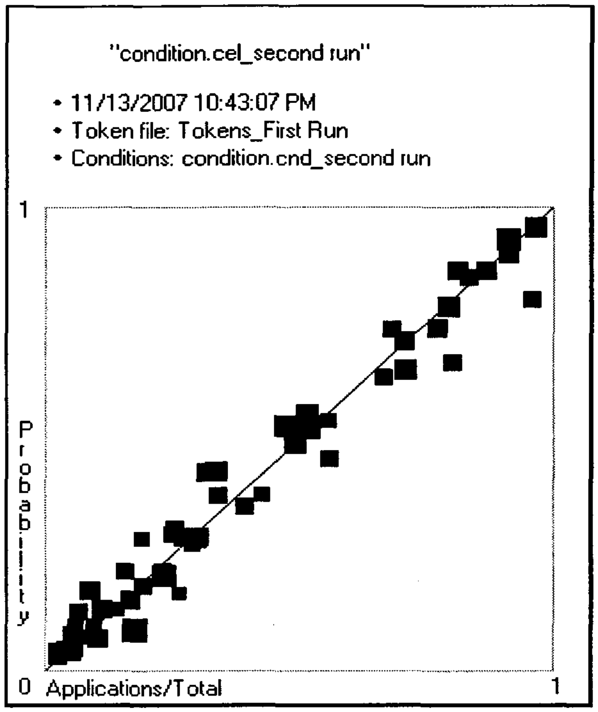

Figure 4.3. Binomial 1-step scattergram for the second Goldvarb run: A still not good enough fit.

Because of the interaction suggested above, a third and final Goldvarb run involving a recoding of the factors preceding pause (p) and preceding consonant (c) into a single factor *consonant/pause* (P) was performed (see section 4.3.1 for a rationale behind combining the two environments *preceding pause* and *preceding consonant*). The first procedure in the final run consisted of a factor by factor distributional analysis. The output of this analysis (see Appendix M) displayed the numbers and percentages of each variant of the dependent variable as a function of each of the independent factors. Because, as noted earlier, this distributional type of analysis does not provide the effect of each factor independently of the others, a binomial one-step analysis was conducted. The results of the binomial one-step analysis, shown in Figure 4.4, give the weight that each factor has on the observed variation, with the linguistic factor pause/consonant P (0.68) having a significant effect on the variable phenomenon. The resulting scattergram, shown in Figure 4.5, indicates that the model, although far from being perfect, is 'the best' fit to the data. For convenience, only the results for *sC sonority* and *preceding phonological environment* are shown.

• BINOMIAL VARBRUL, 1 step • 11/14/2007 11:17:48 PM ••••••••••••••••••••••••••

Name of cell file: condition.cel_third run

Run # 1, 36 cells:
Convergence at Iteration 8
Input 0.335

Group	Factor	Weight	App/Total	Input&Weight
1:	**S**	**0.607**	0.45	0.44
	L	0.351	0.31	0.21
	N	**0.508**	0.41	0.34
2:	**P**	**0.683**	0.51	0.52
	v	0.168	0.15	0.09

Figure 4.4. Binomial 1-step output: Final Goldvarb run, with consonant and pause recoded as P.

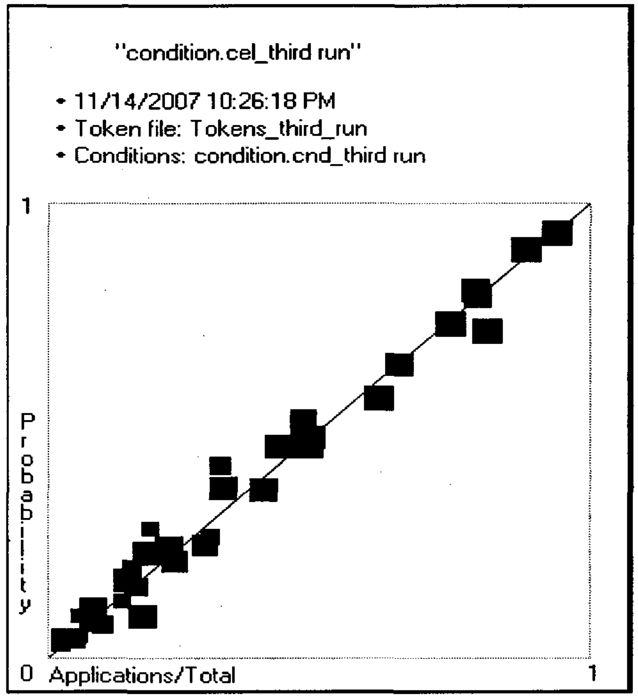

Figure 4.5. Binomial 1-step scattergram for the final Goldvarb run: A good fit.

Finally, to ascertain which factor groups ultimately determine the variable application of e-epenthesis, a binomial up and down analysis for the third (and final) Goldvarb run was carried out. The output of this analysis, illustrated in Figure 4.6, reveals that both runs considered the same factor groups – 1, 2 and 3, and 4 – as having the most significant effect on the pattern of variation (i.e., sC sonority, preceding environment, proficiency, and level of formality, respectively). Moreover, both runs did *not* exclude any single factor group, as each factor was statistically significant at above the $p < .05$ level. In short, the pattern of variation observed in the IL of Farsi speakers is motivated by the internal variables *sC sonority* and *preceding environment*, as well as the external variables *proficiency* and *formality.*

BINOMIAL VARBRUL • 11/14/2007 11:49:31 PM ••••••••••••••••••••••••••••••••••

Name of cell file: condition.cel_third run

Averaging by weighting factors.
Threshold, step-up/down: 0.050001
All remaining groups significant

Groups eliminated while stepping down: None
Best stepping up run: #**11**
Best stepping down run: #**12**

Run # 11, 36 cells:
Convergence at Iteration 8
Input 0.335
Group # 1 -- S: 0.607, L: 0.351, N: 0.508
Group # 2 -- P: 0.683, v: 0.168
Group # 3 -- b: 0.793, i: 0.472, a: 0.227
Group # 4 -- F: 0.351, I: 0.626
Log likelihood = -1957.475 Significance = 0.000

Run # 12, 36 cells:
Convergence at Iteration 8
Input 0.335
Group # 1 -- S: 0.607, L: 0.351, N: 0.508
Group # 2 -- P: 0.683, v: 0.168
Group # 3 -- b: 0.793, i: 0.472, a: 0.227
Group # 4 -- F: 0.351, I: 0.626
Log likelihood = -1957.475 Log likelihood = -1925.978

Figure 4.6. Best stepping up and stepping down runs for the Farsi-English data. The factor groups 1, 2, 3, and 4 (sC sonority, preceding phonological environment, proficiency, and formality) were selected as the most significant variables in the analysis ($p < .05$).

Because (as mentioned earlier) the binomial up and down analysis cannot inform us which individual factors in each group significantly contribute to the phenomenon of e-epenthesis, it was necessary to re-examine the results obtained from the binomial 1-level analysis discussed earlier in this section. These results, it should be emphasized, are those that will be considered in the analyses and discussions in section 4.3.

4.2.1 Final GoldvarbX results: A summary

The final probabilistic results from the Goldvarb statistical analysis, illustrated in Table 4.1 below, indicate that the application of e-epenthesis is favored in the speech of less advanced learners (e.g., beginners: .79), when the type of speech is less formal (e.g., informal: .62), when the sC cluster is /st/ or /sn/ (.60 and .51, respectively), and when the cluster is preceded by a consonant or pause (.68).

Table 4.1. *Significant Goldvarb Results (weight): Probability of e-epenthesis* ($p < .05$)

Factor Groups	**Factors**		
Preceding environment	Consonant/pause **0.68**		Vowel 0.17
sC sonority	s + nasal **0.51**	s + liquid 0.35	s + stop **0.60**
Style	Formal 0.35		Informal **0.62**
Proficiency level	Beginning **0.79**	Intermediate 0.47	Advanced 0.23

Having presented the Goldvarb statistical results, I will now discuss the results in terms of the linguistic factors.

4.3 Interpreting the results

4.3.1 Linguistic factors

The first hypothesis, based on the effects of sonority on IL, posited that the acquisition of the sC onset clusters would follow the sequence /sl/ > /sn/ > /st/ (where '>' indicates 'more easily articulated and thus acquired earlier than'). That is, the original prediction was that L2 learners should acquire the less marked and sonority-abiding clusters (i.e., /s/ + liquid and /s/ + nasal onset clusters) before the more marked and sonority-violating clusters (i.e., /s/ + stop onset clusters), based on Clements' (1990) Sonority Sequencing Principle (SSP). The expectation was also that the least marked clusters /sl/ would surface before the relatively more marked /sn/ clusters, following Clements' (1990) Minimal Sonority Distance (MSD) discussed in chapter 2. The results from the current study indicate that, contrary to expectation, /s/ + nasal onset clusters induce nearly as much error (i.e., e-epenthesis) as /s/ + stop sequences do (.51 and .60, respectively). In addition, and as expected, the findings also show that /s/ + liquid onset sequences do not exhibit a significant effect on the occurrence of e-epenthesis. Table 4.2 (which is a partial reproduction of Table 4.1) illustrates these results.

Table 4.2. *Significant Goldvarb Results for the Factor Group sC Sonority*

Factor group	Factors	e-epenthesis
sC sonority	s + liquid	.35
	s + nasal	**.51**
	s + stop	**.60**

The above results invite the question: Why do the Farsi learners pattern the SSP-abiding /s/ + nasal onset clusters together with the SSP-violating /s/ + stop onset clusters, instead of grouping the former together with the (equally) sonority-abiding /s/ + liquid clusters, as hypothesized in section 2.2.3.?

Clearly, a sonority-based account, which predicts a development pattern of less marked SSP-following versus more marked SSP-violating onset sequences (i.e., /sl/, /sn/ > /st/), cannot adequately account for the sC acquisition hierarchy observed in this study (i.e., /sl/ > /sn/, st). Instead, the answer seems to lie in a phonetically-based approach to phonology (e.g., Hayes, Kirchner, & Steriade, 2004), which can capture complex phonological phenomena by appealing to their underlying phonetic conditions. A phonetically-based account of the acquisition of sC onset clusters, in particular, draws on core phonetic principles which explore the relationship between the relative markedness of the sC clusters and the degree of *gestural effort* involved in their articulation (e.g., Kirchner, 1998).[17]

[17] The term 'gesture' is adopted here to refer to 'any voluntary displacement or tension of any organ in the vocal tract' (Krichner, 1998, p. 41); it is not used in the task dynamic

In other words, this phonetically-oriented view of markedness permits us to establish an acquisition hierarchy that takes into account the degree of articulatory effort made in producing each of the three onset clusters involved in our study: /st/, /sn/, and /sl/. In particular, this alternative view of markedness, which is based on the articulatory feature *continuancy* (i.e., the freedom of airflow through the oral cavity), allows us to advance the following argument: Given that the production of /st/ and /sn/ onset clusters entails more gestural effort (i.e., a transition from [+continuant] to [-continuant] – see forthcoming discussion) than the articulation of /sl/ (in which continuancy remains constant), the latter sequence is considered less marked and is therefore expected to be acquired earlier in the learning process. The markedness hierarchy observed across the three target sC onset clusters /sl, st, sn/ is illustrated in (11), following the continuancy-based analysis just outlined.

(11) Markedness on continuancy & acquisition order of English sC onsets by Farsi speakers:

[+continuant] [+continuant]	>	[+continuant] [-continuant]
sl		**sn, st**

Before getting into the specifics of how markedness on continuancy is able to capture the sC development (and hence the e-epenthesis) patterns obtained in this study, I

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sense, as promoted by proponents of Articulatory Phonology (e.g., Browman & Goldstein, 1989).

propose a more elaborate definition of the concept of *continuancy*, one which closely relates to the articulation of each segment in the target cluster sets (/sn/, /st/, /sl/).

For example, in articulating the sound /s/, both the tip of the tongue and the alveolar ridge are brought very closely together, resulting in air being forced out of the mouth through a very narrow passageway. This close contact creates a relatively high pressure, aside from the friction noise. Because air can still flow through the vocal tract when /s/ is articulated, this sound is referred to as [+continuant]. Also included in the [+continuant] category is the liquid /l/ – a sound which is made with the *central* part of the articulators (the tip of the tongue and the alveolar ridge) touching each other, and the sides of the tongue being pulled down slightly from the roof of the mouth. This articulation of the liquid /l/ results in air being expelled along the sides of the tongue, hence the term *lateral.* That the lateral liquid /l/ is categorized as [+continuant] is based on a more liberal definition of continuancy, one which states that a continuant sound is made whenever air can flow through *any* part – not necessarily the middle – of the mouth unobstructed (e.g., Ladefoged, 1993; Spencer, 1991). Let us now look at how stop sounds are articulated with respect to continuancy.

In making stop sounds, as in the case of the anterior coronals /t/ and /n/, the air is completely blocked from passing through the mouth. For example, in making the oral sound /t/, the alveolar ridge comes into close contact with the tip of the tongue, preventing the air from escaping through the mouth and creating pressure (which results in the production of a *[-continuant]* segment). Similarly, in making the sound /n/, the alveolar ridge and the tongue tip are brought together and the soft palate is lowered, blocking the passage of air from the oral cavity and allowing it instead through the nasal opening (which also yields *a [-continuant]* sound).

Now that I have described the articulation of each individual segment involved in my study, the next step is to examine how the segments are realized *in coordination* within their respective sC cluster groups and, more importantly, with regard to continuancy. To use simple terminology, [st], [sn] are articulated by making a [+continuant] sound for [s] and then *halting* it during the production of the [-continuant] [n] and [t]. In making the [sl] sequence, however, the [+continuant] feature remains unchanged across the articulation of the two sounds. Comparing the two previous articulation patterns, one could fairly claim that, because of the obstruction process that follows the articulation of the [+continuant] sound /s/ when pronouncing /st/ and /sn/, a relatively higher effort cost (due to higher articulatory pressure) is involved. In terms of language acquisition, this means that when language users attempt to pronounce clusters that are [+continuant +continuant], they normally need not deploy as much articulatory effort as when they produce [+continuant –continuant] onsets – the articulation involved in the latter set requiring an abrupt reversal of continuancy.

Let us now see how the results pertaining to the continuancy feature elaborated above fit within the general findings of the literature on L2 speech. An inspection of the literature, particularly that which concerns the effects of sonority markedness on the nonnative acquisition of sC clusters, reveals a mixed bag of results. While some studies have turned up results consistent with the predictions of the Sonority Sequencing Principle (SSP) (e.g., Cardoso, 2008; Carlisle, 1988, 2006; Eckman, 1991; Eckman &

Iverson, 1993; Hancin-Bhatt & Bhatt, 1997; Tropf, 1987),[1] other studies have reported sC production patterns in the form of more marked s + liquid/s + stop versus less marked /s/ + nasal onset clusters (e.g., Abrahamsson, 1999; Escartin, 2005). To my knowledge, the present investigation is the first *L2 adult* acquisition study to establish the rather unorthodox markedness hierarchy in the form of more marked s + nasal/s + stop onsets (i.e., s + [-continuant]) versus less marked /s/ + liquid onsets. Evidence for such a grouping, however, can be found in data from studies of L1 acquisition (e.g., Ben-David, 2006; Gierut, 1999; Grunwell, 1981; Ingram, 1989; Smit, 1993; Yavas & Beaubrun, 2006; Yavas & Someillan, 2005).[2]

For example, in her investigation of the acquisition of sC clusters by 11 small children (age 3:2 to 7:8) exhibiting functional phonological delays, Gierut (1999) reported some of her participants grouping together consonant clusters whose member segments had a sonority distance of 2 or less. Consistent with my results, Gierut found a consonant cluster patterning of the type s + stop/s + nasal versus s + liquid/s + glide. Likewise, Smit (1993) reported a relatively similar sC grouping arrangement – i.e., s + stop/s + nasal clusters versus other sC sequence types – among the children (age 2 to 9 years old) she investigated in her study. Finally, and strikingly similar to my findings, Yavas and Someillan (2005), who investigated the production of English sC onset sequences by 15 Spanish-English bilingual children (age 3:3 to 3:7), found a binary

[1] Recall from chapter 2 that the markedness hierarchy according to the SSP predicts the following path of acquisition for sC: *sl* > *sn* > *st*.

[2] Although Gierut (1999) found a similar sC cluster grouping of s + nasal/s + stop onsets (i.e., s + [-continuant]) versus /s/ + liquid onsets (i.e., s + [+continuant]), she nonetheless reported *a reversed* path of acquisition for the two types of onsets. That is, unlike the data from my study, Gierut's data showed evidence of earlier acquisition of s + nasal/s + stop onsets before /s/ + liquid onsets.

grouping of problematic s + stop/s + nasal clusters versus less problematic s + liquid/glide sequences. As was the case with the L1 studies reviewed above, the observed sC acquisition pattern in the latter study was also attributed to a binary split between s + [-continuant] versus s + [+continuant].

Having accounted for the study's results in terms of the linguistic factor sC sonority, I will now discuss the results in relation to the second linguistic factor – *preceding phonological environment*. Recall that the second hypothesis in my study predicted that e-epenthesis would occur more frequently after word-final consonants and pauses than after word-final vowels. The findings of the present study (see Table 4.3 below) corroborate my initial hypothesis, as confirmed by the results for the preceding consonant/pause set (0.68)). The results with respect to preceding vowels (0.17) also support the original prediction that vocalic environments should have a facilitating effect, incurring the lowest amount of epenthesis.

Table 4.3. *Significant Probabilistic Results for the Factor Group Preceding Environment*

Factor groups	Factors	e-epenthesis
Preceding environment	Consonant/Pause	**0.68**
	Vowel	0.17

It is important to underscore at this point that the general findings of this study vis-à-vis preceding phonological environment – namely that consonants as much as pauses favor the occurrence of errors – is not in any way a revelation: A number of other variation studies have reached the same conclusion (e.g., Cardoso, 1999; Escartin, 2005; Winford, 1992). A possible explanation why preceding pauses and consonants promote the application of e-epenthesis has to do with the linguistic process of prosodic resyllabification (e.g., Harris, 1983): I suggest, based on assumptions made from earlier studies (e.g., Broselow, 1983; Carlisle, 1997; Karimi, 1987), that the Farsi speakers in the current study will transfer the L1-based process of prosodic resyllabification into the IL. Accordingly, when a word-initial sC cluster occurs after a word-final vowel /V/ (i.e., /V#sCV/, as in /h[i#slæ]ps/ 'he slaps'), the Farsi speakers will resyllabify the /s/ in the sC cluster as the coda of the preceding vowel-final syllable, as follows: [Vs.CV] (e.g., h[is.læps]) – which eliminates the need for e-epenthesis. If, on the other hand, an onset consonant cluster is preceded by a word-final consonant or pause (e.g., /C#sC/: /dea[d#sn]ake/), the Farsi speakers will use e-epenthesis to create the conditions for prosodic resyllabification to occur (i.e., [Ces.C], as in /dea[des.n]ake/).

In this section, I have offered an explanation of the probabilistic results in terms of the linguistic factors included in my investigation, i.e., sC sonority and preceding phonological environment. In the following section, I will discuss the results obtained in light of the two extra-linguistic factors deemed significant by the analysis: proficiency and formality.

4.3.2 Extra-linguistic factors

The third hypothesis of our research predicted a decline in the rate of e-epenthesis with increased L2 proficiency. In accordance with this hypothesis, the Goldvarb results indicate that the amount of e-epenthesis is inversely proportional to the level of proficiency. More specifically, these results reveal a decrease in e-epenthesis application from 0.79 in the beginner group to 0.22 in the advanced group. This decreasing pattern in error production across the higher proficiencies should, however, come as no surprise: With increased exposure to L2 speech, one would normally expect an improvement in pronunciation.

Interestingly, this observed pattern of L2 improvement (and the corresponding decline in error production) is exactly what is foreseen by the developmental corollary of the Ontogeny Phylogeny Model (Major, 2001). As mentioned in chapter 2, the Ontogeny Phylogeny Model (OPM) predicts that over time (hence with increased proficiency) and as style becomes more formal, L1 features (e.g., e-epenthesis) decrease while L2 features (e.g., sC production) increase. To illustrate how the OPM captures the Farsi-English data in my study, two graphs are juxtaposed in Figure 4.7: While the darker line shows a decrease in L1-based e-epenthesis patterns across the three levels of proficiency, the shaded line indicates a rise in target sC production patterns across the same proficiency groups.

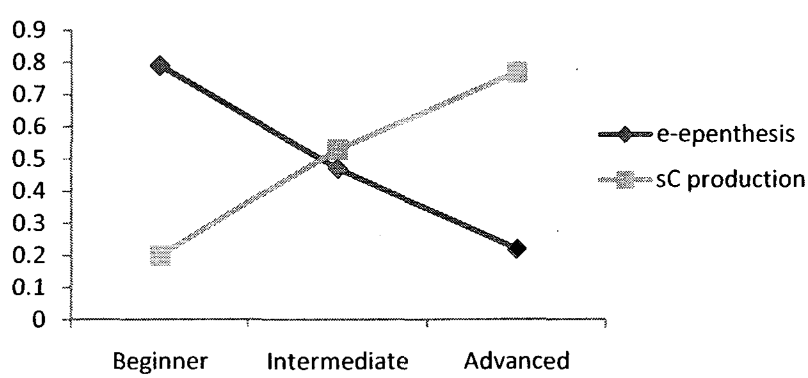

Figure 4.7. Rise in sC cluster production vs. a decline in e-epenthesis across proficiencies.

Taken together, the findings above suggest that with increased proficiency, there is a decrease in transfer (i.e., e-epenthesis), which corresponds to an increase in target-like production of sC clusters. These findings confirm the results from several other studies of IL variation (e.g. Bunta & Major, 2004; Cardoso, 2005, 2007; Escartin, 2005; Major, 2001, 2004).

In addition to proficiency, the external variable *level of formality* was also shown to have a conditioning effect on the variable application of e-epenthesis. The factor weights for the two stylistic factors considered in this study are illustrated in Table 4.4.

Table 4.4. *Significant Probabilistic Results for the Factor Group Formality Level*

Factor group	Factors	e-epenthesis
Formality level	Formal	0.35
	Informal	**0.62**

What the statistical results in Table 4.4 above tell us is that e-epenthesis is more likely to occur in more informal stylistic environments (.62) and, consequently, that sC onset clusters are more likely to surface as such in more formal stylistic environments. This pattern is in agreement with the fourth hypothesis of my study, namely: that the frequency of e-epenthesis will be higher in less formal tasks. What the probabilistic results in Table 4.4 cannot tell us, however, is how the formality and proficiency variables interact in their contribution to the observed patterns of variation. For a better understanding of how e-epenthesis is distributed across proficiencies and the two stylistic levels considered in this study, I explored the intersection between the external variables *level of formality* and *proficiency* via cross-tabulations.

Before I discuss the results from the cross-tabulations, however, some general assumptions about the analysis of variability in my study are in order. I assume, based on a view on the definition and nature of grammar, that proficiency groups represent distinct interlanguages and, by extension, distinct grammars mediated by developmental (i.e., transitional) systems (e.g., Adamson, 1988; Cardoso, 2005, 2007; Escartin, 2005; John, 2006; Preston, 1996; Selinker, 1972; White, 1989); and that formality levels designate distinct grammars (Boersma, 2001; Cardoso, 2001, 2003, 2007; Chomsky, 1988; Morris, 1998; Oostendorp, 1997, 2005; Selkirk, 1972). Based on these assumptions, I propose that the Farsi-English data in my study be stratified over six different grammars: (1) two variable grammars for proficiency group 1 (i.e., beginners), in which both formal and informal environments are characterized by variable e-epenthesis; (2) two variable grammars (split along the formal/ informal lines) for proficiency group 2 (i.e., intermediate); and (3) two variable grammars (formal/informal) for proficiency group 3 (i.e., advanced). The cross-tabulation results in the form of chart columns (corresponding to the six distinct grammars just mentioned) are illustrated in Figure 4.8.

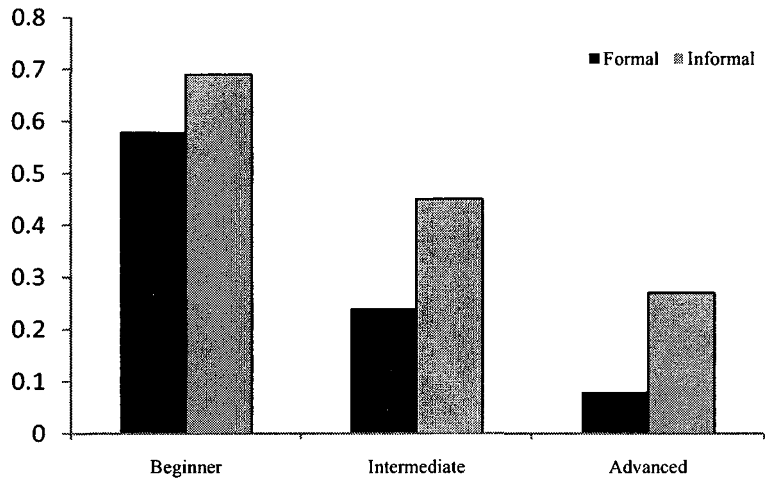

Figure 4.8. Distribution of e-epenthesis by proficiency and style (%).

It is clear from Figure 4.8 that the application of e-epenthesis by the Farsi participants decreases as proficiency increases, and increases in informal tasks. The higher proportion of target-like structures in more formal stylistic settings confirms a similar pattern observed in the variationist literature (e.g., Cardoso, 2005, 2007; Gatbonton, 1975, 1978; Major, 2004; Schmidt, 1977; Tarone, 1988; cf. Beebe, 1980; Lin, 2001; Major, 1994, 1996; Weinberger, 1987). It also supports the common sociolinguistic view that more target-like or 'prestigious' forms are often correlated with more formal registers (e.g., Cardoso, 2001, 2003, 2007; Dickerson & Dickerson, 1977; Labov, 1966; Oostendorp, 1997; cf. John, 2006).

Another generalization that can be made, based on Figure 4.8 above, is that while intermediate and advanced learners show significant stylistic differences, beginning learners exhibit relatively fewer such distinctions. This smaller stylistic difference (observed in the beginner group) should not, however, be taken as evidence that beginning learners display a single (near-) categorical grammar (cf. Cardoso, 2007).[20] Indeed, the bars in Figure 4.8 attest to the variable character of the two IL Beginner grammars considered in my study: There is 70% likelihood of e-epenthesis occurrence for the Beginner informal grammar, against 60% probability for the Beginner formal grammar. Finally, the cross-tabulation results from Figure 4.8, especially those concerning the lower frequency of e-epenthesis (i.e., L1 transfer) in more formal styles (and, conversely, the higher proportion of sC cluster production in more formal styles), provide further evidence for the robustness of Major's (2001) OPM model for L2 acquisition, as discussed earlier in this section.

4.4 Summary to chapter 4

This study has established that the variable application of e-epenthesis in the English IL speech of Farsi speakers is determined by a combination of linguistic (i.e., markedness on continuancy and preceding phonological environment) and extra-linguistic factors (i.e., proficiency and formality). In particular, this research has demonstrated that e-epenthesis is more likely to occur in the speech of less proficient speakers, in less formal styles, in s + stop/s + nasal clusters, and in sC clusters preceded by a consonant or pause.

In the following chapter, I present a formal phonological analysis of the patterns of e-epenthesis observed in the Farsi-English corpus, drawing in particular on the Framework of Optimality Theory (OT) (Prince & Smolensky, 1993).

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[20] Contrary to the current study, Cardoso's (2005, 2007) studies found that the grammar of beginner learners is characterized by *monostylism*, a situation in which style distinctions are almost inexistent in the speech of early L2 (and even L1) learners.

CHAPTER 5: FORMAL ANALYSIS VIA OPTIMALITY THEORY

5.1 Optimality Theory: An Overview

First proposed by Prince and Smolensky (1993), Optimality Theory (OT) refers to a model of generative linguistics which essentially claims that language systems stem from the interactions of a set of conflicting constraints. The constraints, which are used by OT to model linguistic well-formedness, are in principle assumed to be *universal* and *violable*.[21] They are universal in the sense that they designate and formalize universal properties of language; they are violable in that every conceivable output of a specific grammar entails an automatic violation of at least some constraint. Violation of a constraint, however, is allowed only to the extent that it satisfies another higher-order constraint.

Importantly, this new conception of language (as a way of resolving the demands of competing constraints) has signaled a shift from earlier linguistic frameworks, generally grouped together under the umbrella of *rule-based* approaches. Perhaps a good way to ascertain the foundational differences between these so-called rule-based approaches and the OT model would be to explore, by way of comparison, some of the insights by Kager (1999).

Kager (1999) observes that, aside from very basic assumptions which OT and its generative ancestor share (especially the common goal to formalize universal principles of language), OT departs markedly from earlier generative models in several respects: (1) rather than positing a resetting of 'parameters' to account for cross-linguistic (and

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[21] Though generally conceived in universal terms, some constraints are also considered context- and language-dependent (e.g., Cardoso, 2003; Boersma, Dekkers, & Weijer, 2000).

language-internal) variation, OT presupposes an inevitable violation of universal constraints; (2) instead of imposing well-formedness restrictions on the input forms, OT allows the structural conditions to apply *solely* at the output level – a feature which makes the model output-based (i.e., surface-based); and (3) as an alternative to serial derivations, OT adopts the principle of parallel evaluation (i.e., all relevant constraints are evaluated within a single hierarchy).[22] Because this concept of parallel evaluation implies an inherent conflict within OT constraints, I propose in the following discussion a description of this conflict in terms of two major underlying forces: *markedness* and *faithfulness*.

Constraints under OT are generally subsumed under two categories: markedness constraints and faithfulness constraints. While markedness constraints designate universal preferences for certain types of structure (e.g., simple syllable margins versus complex syllable margins), faithfulness constraints strive to make surface forms similar to specific properties of other forms (e.g., output correspondence; McCarthy & Prince, 1995). Before illustrating how the two types of constraints (markedness and faithfulness) work in actual language data, I will introduce some of the fundamental tenets of OT.

Understanding OT obviously requires basic knowledge regarding the operation of its major functions – Input-Output relations, Generator (GEN), Evaluator (EVAL), and Constraint (CON). The input (i.e., Underlying Representation in rule-based traditions) is usually fed into the function GEN, which creates a potentially infinite number of surface representations or output candidates. The function EVAL evaluates these candidates

[22] In rule-based derivational models, unlike constraint-based approaches, single underlying representations typically undergo a *series* of phonological and morphological rules (i.e., intermediate representations) before they finally surface as output forms.

against a specific ranking of constraints CON, which designate a set of properties presumed to be part of Universal Grammar (UG). During evaluation, the candidate incurring the least costly violation is selected as the optimal output (i.e., the surface form).

In OT, evaluation of an optimal candidate by a set of constraints can be schematically represented by a Tableau. Tableau 1, for instance, features a hypothetical situation in which the well-formedness of three competing output candidates ($Form_1$, $Form_2$, $Form_3$) is determined by three ranked constraints (Con_1, Con_2, Con_3). The three output candidates are randomly listed in the leftmost vertical column, while the three constraints are displayed in the uppermost horizontal row. Observe that these constraints are usually ordered in a descending fashion from left to right in such a way that Con_1 outranks Con_2, Con_2 outranks $Cons_3$, and (presupposing the transitive nature of the ranking relation), Con_1 outranks Con_3. This ranking hierarchy is expressed as follows: $Con_1 >> Con_2 >> Con_3$.

Tableau 1. *Hypothetical Hierarchy: $Con_1 >> Con_2 >> Con_3$*

	Con_1	Con_2	Con_3
☞ a. $Form_1$			*
b. $Form_2$		*!	
c. $Form_3$	*!		

An asterisk (*) often signals violation of a constraint for the relevant candidate. An exclamation mark (*!) to the right of an asterisk indicates that the relevant candidate incurs a fatal (i.e., crucial) violation, leaving it with no chance to surface. Because columns to the right of the exclamation point are deemed irrelevant for evaluation, they are usually shaded. The pointing finger (☞) marks the optimal candidate, i.e., the best candidate which is selected by the constraint ranking. To illustrate from the hypothetical example above, $Form_1$ is considered the optimal (i.e., the most harmonious) output, as it has only a minimal violation of the lowest ordered constraint Con_3. As is shown in Tableau 1, the solid line separating Con_2 and Con_3 indicates a strict (i.e., total) ordering of the constraints with respect to each other. In cases where the ranking between two constraints is indeterminate – e.g., crucial nonraking of constraints – dotted lines are used, instead of a solid line.

I will now illustrate how the interaction between markedness and faithfulness constraints is able to generate distinct (cross-linguistic) constraint hierarchies, and how these hierarchies translate into different surface structures (syllable structures, in our case). To this end, I will analyze e-epenthesis in both Farsi and English. Prior to that, however, I provide a definition for the set of constraints relevant to my study: (1) MAX-IO stipulates that every input segment has a correspondent in the output (i.e., no deletion) (McCarthy & Prince, 1995); (2) DEP-IO presupposes that every output segment has a correspondent in the input (i.e., no epenthesis) (McCarthy & Prince, 1995); (3) *sC states that /s/ + consonant clusters are banned in onset position (Cardoso, in press).

Recall from section 2.2 that the syllable structure in Farsi is generally formulated as (C) V (C) (C). This means that even though Farsi permits complex consonants at the coda position, it allows no consonant clustering at the onset position. Remember also that Farsi speakers tend to break the illicit nonnative onset clusters by initiating them with an epenthetic [e]. An interesting question which might be raised at this point is, 'How can the attested patterns of e-epenthesis be formalized under OT?' Or, to put it more simply: 'To what extent is the Farsi-based e-epenthesis a reflection of the inherent conflict between the well-formedness (i.e., *sC) and the faithfulness constraints (i.e., MAX-IO and DEP-IO)?' A good place to start is Tableau 2, which illustrates the constraint ranking and candidate evaluation related to the selection of e-epenthesis in Farsi.

As Tableau 2 shows, the well-formedness/faithfulness conflict is typically settled in Farsi by having MAX-IO and *sC over-rank DEP-IO. As a result of this specific ordering, the output form [es.lim] surfaces as the winning candidate despite a violation of lowly ranked DEP-IO. This suggests that, in Farsi, it is less costly to insert a new segment (i.e., a vowel) than it is to preserve the syllable structure intact, which explains why in this language the number and types of syllables allowed are limited. This typological restriction, as we shall see in the following discussion, does not apply in the case of English.

Tableau 2. *Farsi Constraint Ranking and Evaluation*

MAX-IO, *sC » * DEP-IO

slim	MAX-IO	*sC	DEP-IO
☞ a. [es.lim]			*
b. [slim]		*!	
c. [lim]	*!		

Recall from section 2.3 that syllables in North American English (NAE) are typically structured as (C) (C) (C) V (C) (C) (C) (C). This means that NAE allows up to three consonant segments at the onset position. As was the case with Farsi, I will examine the degree to which the syllable structure in NAE represents a conflict between markedness and faithfulness constraints. As illustrated in Tableau 3, English ranks the markedness constraint *sC lower than the faithfulness constraints MAX-IO and DEP-IO, which results in the selection of an sC-initial structure: [slim] (represented by candidate (b)).

Tableau 3. *English Constraint Ranking and Evaluation*

*MAX-IO, DEP-IO » *sC

slim	MAX-IO	DEP-IO	*sC
a. [es.lim]		*!	
☞ b. [slim]			*
c. [lim]	*!		

In the following section, we will see how the OT framework, under its different strands, handles the type of variation observed in the corpus analyzed in this study.

5.2 OT and linguistic variation

In standard OT (Prince & Smolensky, 1993), constraints are assumed to be strictly ranked with respect to each other (e.g., *sC >> DEP-IO) such that, for a given input, only one candidate can be selected as an optimal output. However, actual language data (e.g., Auger, 2001; Cardoso, 2001, 2003, 2005; Coetzee, 2006; Reynolds, 1994) presents situations where there is a selection of more than one optimal candidate per input, sparking the question, 'How can variation be handled by OT?' In an attempt to address this question, several researchers suggested the notion of crucial nonranking of constraints (e.g., Anttila, 1997; Reynolds & Nagy, 1997), rejecting thus the principle of strict ordering typical of standard OT.[23] Dissatisfied with the mainstream view associating variation with different grammars, other researchers also proposed the concept of a critical cut off point to promote the idea of variation emanating from non-optimal candidates (Coetzee, 2006). Still, other researchers, eschewing the notion of discrete nonranked constraints, put forward the possibility of continuous ranking (Boersma & Hayes, 2001).

The aim of this section is to briefly assess these different views of variation in OT, and to introduce a stochastic version of OT, that of Boersma & Hayes (2001), the approach that I adopted to analyze variation in interlanguage.

The first of these views, the *multiple grammars* approach (Kiparsky, 1993), essentially claims that language variation originates from the coexistence of multiple grammars in the individual. More specifically, the model suggests that variation is the result of competing linguistic systems which are, in turn, a consequence of distinct

[23] Despite their insistence on the total ordering of constraints, Prince and Smolensky (1993) nonetheless envisage the possibility of crucial nonranking: 'We assume that the basic ranking hypothesis is that there is some total ranking which works; there could be (and typically will be) several, because a total ranking will often impose noncrucial dominance relations … *this opens up the possibility of crucial nonranking … for which we have not found evidence* [italics added]. Given present understanding, we accept the hypothesis that there is a total order of domination on the constraint set; that is, that all nonrankings are noncrucial.' (p. 51).

constraint hierarchies. A corollary to this approach is that each time a speaker produces an utterance, (s)he has access to a variety of parallel grammars from which (s)he can select a specific ranking pattern (or grammar). For instance, in the case of the variable Farsi-English data analyzed in my study, the Farsi speakers are supposed to alternate between two distinct IL grammars: one in which an sC structure (e.g., [sn]ore) is selected, and another in which e-epenthesis is generated (e.g., [esn]ore).

A major problem with the multiple grammars approach is that it presupposes that a language learner is able to internalize all the grammars which account for the variable patterns of a given language (or across languages), a situation which is neither probable nor practical from a language acquisition standpoint. Another caveat of Kiparsky's (1993) model is that it remains silent on the question of frequency of variant occurrence, i.e., it offers no account as to how likely an output is to surface during candidate evaluation. In short, the proposed model lacks parsimony as well as predictive power, which makes it far from being an ideal choice for the analysis of my data.

This brings us to another set of approaches – the *floating constraint* approach and the *partial grammars* approach. The two approaches are deemed conceptually similar because, rather than assume multiple grammars to account for variation, they both adopt the notion of crucial nonranking of constraints.

The first of these proposals, put forth by Reynolds (1994) and later by Nagy and Reynolds (1997), posits the notion of floating constraints, whence the *floating constraint* approach. Briefly, this approach attempts to capture the idea that a grammar can have one or more constraints that may float (i.e., whose ranking is indeterminate) in relation to another constraint *or* group of constraints. For example, in the grammar shown in (12a), constraints A and B may float with respect to each other (as signaled by the comma between them), unlike constraints C and D which are strictly ranked (as indicated by the '>>' sign). In addition, the two constraint sets (designated by the labels S_1 and S_2 and delimited each by a pair of curly brackets) may also float with respect to each other, as the hierarchy in (12a) predicts.

(12a) Reynolds' floating constraints:

$\{A,B\}_{S1},\{C >> D\}_{S2}$

Based on the indeterminate ordering which characterizes the set of constraints in (12a), a variety of constraint rankings and surface candidates can potentially be generated. In particular, the indefinite (hence variable) ranking involving the sets S_1 and S_2 yields four distinct rankings (as shown in (12b)) and consequently different outputs.

(12b) Different rankings following a set of floating constraints:

A >> B >> C >> D
B >> A >> C >> D
C >> D >> A >> B
C >> D >> B >> A

Building on Reynolds' (1994) floating constraint approach just discussed, Anttila (1997) proposed a more restrictive model of variation in OT: *the partial grammars* approach. According to this approach, sets (i.e., groups) of constraints are not allowed to float; *only* individual constraints can float with respect to each other. That is, partial nonranking of constraints involves the *same* set of unranked constraints only and, therefore, cannot be carried over to other strictly ranked (set of) constraints. For example, given four constraints (A, B, C, D) and the partially unranked grammar in (13a) below, variation is possible due to the crucial nonranking of constraints A and B *only* (as indicated by the semicolon ';' between them); the other (strictly ordered) constraints – C and D – do not enter into the interaction, which restricts the possibilities of ranking within the grammar (cf. the grammar in (12b)). As a result of this restriction, only two ordering hierarchies are generated to account for variation in the grammar, as shown in (13b).

(13) Anttila's partial nonranking of constraints:

a. A partially unranked grammar	$\{A; B\}_{S3} \gg C \gg D$
b. Possible rankings	$A \gg B \gg C \gg D$
	$B \gg A \gg C \gg D$

The important thing to retain about the floating constraint model of Reynolds (1994) and Anttila's (1997) partial grammars approach is that the former approach is more permissive in the ranking possibilities allowed within the grammar (e.g., Auger, 2001; Cardoso, 2001, in press). For instance, observe in (12a) that, even though C and D are crucially ranked with respect to each other (just like in (13a) in Anttila's model), these constraints can still float as a group (S_1) with respect to the adjacent set of constraints S_2. Thus, in the Reynolds-based example above, the variable grammar can yield two *additional* rankings, which are not predicted by Anttila's model. In sum, because of its less restrictive nature, Reynolds' proposal seems a less appealing choice for the analysis of variation in general.

I will now examine how Anttila's (1997) partial nonranking approach is implemented into an actual grammar, the Farsi-English (FE) grammar investigated in my study. Suppose that, aside from the strictly ranked MAX-IO constraint, the two adjacent constraints *sC and DEP-IO are crucially unranked with respect to each other, as is indicated by the semicolon in (14a) below. Based on this assumption, two potentially variable rankings (and outputs) are yielded, as can be seen in (14b) and Tableaux 4a-b.

(14) Antilla's partial nonranking and the FE grammar

a. A variably ranked grammar: MAX-IO » *sC; DEP-IO

b. Ranking possibilities: MAX-IO » *sC » DEP-IO

MAX-IO » DEP-IO » *sC

Tableau (4a). *Variation in FE Speech: Ranking 1 – (Target-like) sC Onset Clusters*

MAX-IO » *sC » DEP-IO

/snejk/	MAX-IO	DEP-IO	*sC
a. [es.nejk]		*!	
☞ b. [snejk]			*
c. [nejk]	*!		

Tableau (4b). *Variation in FE Speech: Ranking 2 – e-epenthesis*

MAX-IO » *sC » DEP-IO

/snejk/	MAX-IO	*sC	DEP-IO
☞ a. [es.nejk]			*
b. [snejk]		*!	
c. [nejk]	*!		

In the first ranking pattern in Tableau 4a, the markedness constraint *sC is ranked lower than the faithfulness constraints MAX-IO and DEP-IO, resulting in the optimal syllabification of the input [snejk]. In the second ranking illustrated in Tableau 4b, the markedness constraint *sC is ranked higher than the faithfulness constraint DEP-IO, thus making the candidate [es.nejk] the optimal choice.

Having demonstrated how Anttila's (1997) partial nonranking model can analyze variable outputs, I will now examine whether the proposal can actually predict the output frequencies observed in the FE corpus. According to Anttila, the probabilistic distribution of a specific variant (e.g., f) is equal to the ratio of the number of hierarchies which select that variant as optimal (n) to the total number of hierarchies (t) (i.e., $f = n/t$).[24] To illustrate this point, I will use the FE grammar from my study as an example (see Tableaux 4a-b above). Recall that this grammar generates two ranking options and, consequently, two surface outputs. Applying Anttila's formula to the FE data, we obtain a 50% probability of use for each of the two variants observed in the study. A comparison

[24] The operator (f) is included here for illustrative purposes only; it was not originally used by Anttila (1997).

of this even distribution of variant occurrence with the probabilistic results obtained for beginners in this study reveals a clear mismatch. For example, rather than exhibiting the 50-50 ratio, as predicted by Anttila's model, the statistical results pertaining to the group of beginners indicated a .79 (79%) likelihood of e-epenthesis application, and a corresponding .21 (21%) probability of sC cluster production.

A more recent OT model of variation, *the Rank-ordering Model of EVAL* (ROE), has been proposed by Coetzee (2006). According to this model, the harmonic rank-ordering imposed by the function *EVAL* applies *not* only to one optimal candidate (as is the case in Standard OT), but rather to the whole set of candidates. That is, whereas in Standard OT a different output is often selected as optimal at different (evaluation) times, the output of an ROE grammar is usually assumed to be constant – the same set of candidates is generated every time. Accordingly, as Coetzee argues, the source of variation in ROE is not the grammar (i.e., ranking) itself, but rather it lies in the way the language user handles the invariant set of outputs: While on some occasions the language user accesses a ranking that yields a given (e.g., more faithful) candidate, on other occasions s/he may also access a ranking that generates another (e.g., a less faithful) candidate.

To better explain his view on variation, Coetzee proposes the notion of *critical cut-off*, an imaginary position on the constraint continuum that separates higher-order constraints from lower-order constraints. In particular, the researcher claims that variation occurs when there is more than one candidate being disqualified *only* by constraints on the lower side (i.e., to the right) of the cut-off, as illustrated in Tableau 5.

Tableau 5. *Variation: More than one output disqualified only by constraints below the cut off*

Con_1 » Con_2 » Con_3» Con_4

	Con_1	Con_2	Con_3	Con_4
☞ a. $Cand_1$				*
☞ b. $Cand_2$			*	
c. $Cand_3$		*!		
d. $Cand_4$	*!			

As can be seen in Tableau 5, candidates $Cand_1$ and $Cand_2$ violate constraints Con_4 and Con_3, respectively. To the extent that these violations involve *below the cut-off* (i.e., lower-order) constraints, they (i.e., the violations) are not considered serious enough to prevent $Cand_1$ and $Cand_2$ from surfacing as optimal outputs; hence, variation between these two optimal candidates is likely to occur.

There are two problems with Coetzee's (2006) proposal. First, the approach is premised on the idea of a critical cut-off that divides the constraint set into low-ordered versus high-ranked constraints – an idea that has yet to be tested empirically. That is, whether or not to include a critical cut-off in the analysis of variable and categorical phenomena is, by the researcher's own admission, a question that deserves further empirical investigation. Second, and more important, Coetzee's approach to variation, like that of Kiparsky's discussed earlier, does not provide for absolute frequency predictions; it only presupposes that a more well-formed output will surface more frequently than a less well-formed output. Due to these limitations, the ROE approach does not seem suited for the analysis of our data.

To summarize, none of the approaches reviewed here (i.e., the multiple grammars, the crucial nonranking of constraints, the rank-ordering model of EVAL) is adequate to analyze the types of variation that characterize the variable phenomenon described in this study. By restricting its scope to partial nonranking, Anttila's (1997) proposal is able to account for both categorical and variable phenomena via a more constrained analysis. However, his approach as well as the other models surveyed so far cannot actually capture the probabilistic distribution (i.e., the likelihood of variant occurrence) observed in this study.

In the next section, I will introduce an approach that I believe is better suited for the analysis of variation in OT: Stochastic Optimality Theory.

5.3 Stochastic OT (SOT)

5.3.1 SOT: Basics

For the formal analysis of the variable patterns discussed in chapter 4, I adopt Boersma's (1998, 2000) and Boersma and Hayes' (2001) version of Optimality Theory: Stochastic OT (SOT). At the heart of SOT is a constraint-ranking algorithm for optimality-theoretic grammars called Gradual Learning Algorithm (GLA). Under SOT, each constraint is assigned a fixed value on a ranking *continuum*, with higher values corresponding to higher-ranked constraints. During *evaluation time* (i.e., during actual speaking), a random noise value is added to the discrete ranking location of each constraint, yielding interval values called *selection points*. The centre of the range covered by each selection point is commonly referred to as the *ranking value*. That is, selection points for constraints (e.g., CON_1 and CON_2) are normally distributed, with the ranking value representing the mean of the distribution (typically, all constraint distributions have a uniform standard deviation of 2.0).

Variation in SOT is determined by the distance between constraints on the numerical scale as well as the amount of evaluation noise added to the numerical values. As a general rule, a distance of 10 or more units between two constraints will yield a categorical grammar. To illustrate, Figure 5.1 shows a hypothetical grammar in which CON_1 and CON_2 are distant, whereas Figure 5.2 depicts a variable grammar in which the crucially ordered constraints overlap.

Figure 5.1 reveals that CON_1 is ranked 10 points higher than CON_2, a difference large enough to ensure that CON_1 will always be ranked higher within the hierarchy, thereby yielding only one categorical output. Figure 5.2, on the other hand, shows that CON_1 is ranked less than 10 points higher than CON_2, a difference too small to secure a single output. Given that the distribution of crucially ranked constraints includes an area of overlap between constraint CON_1 and CON_2, it follows that the grammar can potentially select any point within this overlapping area, yielding two main possibilities: a more frequent ranking, in which CON_1 outranks CON_2; and a less likely ranking, where CON_2 outranks CON_1, resulting in a different candidate being selected. Note that in the latter case, in particular, the selection points are located somewhere in the range covered by the upper part of CON_2 and the lower part of CON_1 (the overlapping area is indicated by an arrow below).

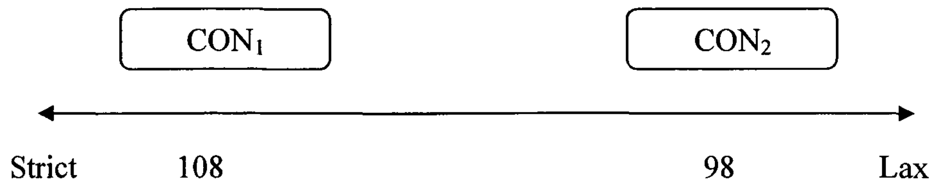


Figure 5.1. Categorical (non-variable) ranking along a continuous scale.

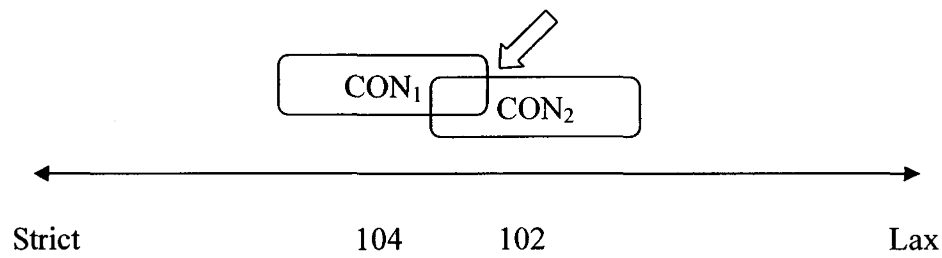


Figure 5.2. Variable ranking along a continuous scale.

As indicated at the outset of this section, the current study adopts a stochastic version of OT for the formal analysis of the FE data. Two main reasons justify this choice: (1) to account for both categorical and variable data, SOT makes use of one single grammar; (2) it can account for variable phenomena by appealing to fewer constraints (Cardoso, 2007); (3) unlike other OT approaches to variation (e.g., Reynolds' (1994) floating constraints and Anttila's (1997) partial nonranking of constraints), which predict variation frequencies in terms of small integer fractions (e.g., 1/2, 1/3), SOT is able to render the probability distributions more faithfully. In other words, Boersma and Hayes' (2001) approach is more likely to capture with precision the observed variation patterns, as will be demonstrated in the following section.

5.3.2 SOT Analyses

For a stochastic optimality theoretic analysis of the variable FE data, I adopt the following three OT constraints:

(15) OT constraints

MAX-IO	every input segment has a correspondent in the output (i.e., no deletion) (McCarthy & Prince, 1995)
DEP-IO	every output segment has a correspondent in the input (i.e., no epenthesis) (McCarthy & Prince, 1995)
*sC	/s/ + consonant clusters are banned in onset position (Cardoso, in press)

These constraints (together with a set of inputs, outputs and their probabilistic values, erroneous rival candidates, and constraint violations) were entered into OTSoft (Hayes, Tesar, & Zurow, 2003), a software package with a set of automated functions (e.g., a Gradual Learning Algorithm) that allow for a stochastic analysis of OT grammars. In particular, the GLA was utilized to conduct a series of computer simulations in order to 'learn' each of the six grammars it was presented with (i.e., Beginner Formal, Beginner Informal; Intermediate Formal, Intermediate Informal; Advanced Formal, and Advanced Informal; see section 4.3.2 for a rationale behind the adoption of the six grammars). The learning simulation was made possible by having the GLA exposed to 1,000,000 input forms (standard deviation or evaluation noise: 2.00; initial/final plasticity: 2/00.2; original arbitrary ranking for each constraint: 100). By the end of the simulation cycle (which is typically set to 2,000 times),[25] the learning algorithm reached a final grammar that is a close match to the learning set (see forthcoming section). That is, after multiple runs, the GLA was able to mimic the output frequencies observed in the data, by generating a ranking value for each of the constraints.

In the following section, I examine in detail how the GLA arrived at the ranking values that characterize the six grammars analyzed in this investigation.

5.3.2.1 The Farsi-English interlanguage (IL) grammars

Let us start by presenting the stochastic results for the Beginner Informal grammar. The Goldvarb results for the Beginner Informal grammar (which can be inferred from the cross-tabulation results between *proficiency* and *formality*) reveal that the probability of e-epenthesis was 69%, which corresponds to 31% likelihood of target-like sC production. These probabilistic weights were fed into the GLA application for further learning, which generated an empirically appropriate value for each constraint. Table 5.1 and Figure 5.3 illustrate these ranking values in two different ways (for the complete results of this GLA analysis, see Appendix N).

[25] This value indicates the number of times the GLA will repeat the process of stochastic evaluation and compare the results to the relative frequencies that were observed in the data (i.e., the Goldvarb X results).

Table 5.1. *GLA-generated Ranking Values: Beginner Informal Grammar*

Constraint	Ranking value
MAX-IO	106
*sC	97.7
DEP-IO	96.2

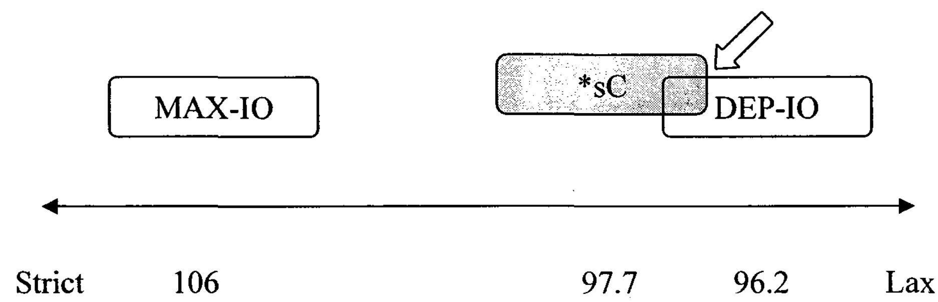


Figure 5.3. Beginner informal grammar ranking.

Figure 5.3 shows that the distance between MAX-IO and the closest of the two other constraints (i.e., *sC) is 8.3 units, a difference large enough to ensure that the grammar will very likely rank *sC and DEP-IO lower than MAX-IO on the hierarchy scale, thereby preventing any /s/ deletion in the process. Also shown in Figure 5.3 is an area covering the two overlapping constraints *sC and DEP-IO. This specific area (highlighted by an arrow) indicates an overlap in the distribution of the constraints along the ranking continuum, which suggests some degree of variation. More precisely, due to the high value assigned to *sC, this constraint will overrank DEP-IO 68.8% of the time, and thus predict e-epenthesis at a 68.8% rate. The relatively higher frequency of e-epenthesis, as anticipated in the Beginner Informal grammar of the Farsi speakers, is illustrated in Tableau 6.

Tableau 6. *Ranking Values for Beginner Informal Grammar: e-epenthesis*

MAX-IO » *sC » DEP-IO

/snejk/	MAX-IO	*sC	DEP-IO
☞ a. [es.nejk]			*
b. [snejk]		*!	
c. [nejk]	*!		

Although less likely (i.e. 31.2% of the time, as estimated by the GLA), the grammar will sometimes select a point that is part of the overlap of *both* the higher ranked area of DEP-IO and the lower ranked area of *sC. In such a case, DEP-IO will outrank *sC, resulting in the selection of a target-like sC onset cluster (e.g., [snejk]) as the winning candidate, as shown in Tableau 7.

Tableau 7. *Ranking Values for Beginning Informal Grammar: sC Clusters*

MAX-IO » DEP-IO » *sC

/snejk/	MAX-IO	DEP-IO	*sC
a. [es.nejk]		*!	
☞ b. [snejk]			*
c. [nejk]	*!		

Table 5.2 summarizes the results obtained for the beginner informal grammar. Note that, in this grammar, *sC is expected to outrank DEP-IO 68.8% of the time and, accordingly, e-epenthesis is predicted to occur 68.8% of the time. Target-like sC production, on the other hand, is the result when the ranking is reversed, which is expected to occur 31.2% of the time. A comparison of the GLA-generated values (under GLA) with the Goldvarb probabilistic results (under observed) reveals a striking match between what is predicted by the GLA and what is observed in the data under investigation: the grammar learned by the GLA is able to mimic the frequencies obtained in the FE corpus.

Table 5.2. *Output Selection for the Beginner Informal Grammar*

	Output type		Frequency (%)	
Constraint ordering	sC	e-epenthesis	GLA	observed
a. MAX-IO » ***sC** » DEP-IO		✓	**68.8**	**69**
b. MAX-IO » DEP-IO » ***sC**	✓		**31.2**	**31**

The SOT analyses for the other five grammars followed the same procedures as described above for the beginner Informal Grammar. Due to space limitations and to avoid repetitive discussions, I summarize in Table 5.3 the analyses for each of the six variable grammars analyzed in my study (represented by the shaded cells). For comparison's sake, I complement the summary with two *categorical* grammars at each end of the IL spectrum: one grammar representing L1 Farsi, which is characterized by categorical e-epenthesis, and the other illustrating target English, a language in which sC sequences can freely occur. The resulting summary below allows us to visualize not only the differences in constraint ranking for each IL grammar, but also the degree to which the GLA-generated frequencies and the observed frequencies match.

Table 5.3. *Summary of Grammars by Proficiency and Style*

IL Grammars by Proficiency & Style	**e-epenthesis (%)**	
	GLA-Generated	**Actual (observed)**
L1: Farsi MAX-IO$_{104}$ >> *sC$_{104}$ >> DEP-IO$_{92}$	100	N/A
IL1: Beginner Informal MAX-IO$_{106}$ >> *sC$_{97.7}$ >> DEP-IO$_{96.2}$	68.8	69
IL2: Beginner Formal MAX-IO$_{106}$ >> *sC$_{97.3}$ >> DEP-IO$_{96.6}$	58.4	58
IL3: Intermediate Informal MAX-IO$_{106}$ >> DEP-IO$_{97.2}$ >> *sC$_{96.8}$	44	45
IL4: Intermediate Formal MAX-IO$_{106}$ >> DEP-IO$_{98}$ >> *sC$_{96}$	24.2	24
IL5: Advanced Informal MAX-IO$_{106}$ >> DEP-IO$_{97.8}$ >> *sC$_{96.1}$	28	27
IL6: Advanced Formal MAX-IO$_{106}$ >> DEP-IO$_{98.9}$ >> *sC$_{95.1}$	8	8
Target English MAX-IO$_{104}$ >> DEP-IO$_{104}$ >> *sC$_{92}$	0	N/A

Note. The subscripted numbers in each ranking indicate the ranking value assigned by the GLA - OTSoft.

Observe in Table 5.3 that the variable development of sC sequences in the IL speech of Farsi learners amounts to a relative re-ranking of *sC with regard to DEP-IO. In particular, the ESL learner starts off with a categorical grammar that is typical of native Farsi (i.e., dominated by L1 transfer patterns: e-epenthesis) – a grammar in which *sC is ranked higher than DEP-IO. Over time, and as the learner progresses through the acquisition of L2 English, his/her learning is restructured to the reverse ranking of the constraints *sC and DEP-IO. In the case of the Intermediate Informal grammar, for instance, the learner reaches a point where the overlapping constraints *sC and DEP-IO are re-ordered in the opposite direction (i.e., DEP-IO becomes higher-ranked than*sC), yielding IL forms that are closer (at least quantitatively) to the target sC structure.

To summarize, in this section, I have empirically tested the Gradual Learning Algorithm to analyze the variable Farsi-English data from my study. I have demonstrated that this GLA-based stochastic version of OT is capable of predicting the different variants found in the development of the IL grammars as well as the relative frequencies of each of these variants. This power with which the GLA is endowed – namely, its ability to capture a speaker's knowledge of variation and the probabilistic distribution of variants (via Goldvarb X) – has important theoretical implications. Crucially, the finding that knowledge of surface variants (and their predictability) is embedded in a speaker's linguistic knowledge offers new evidence against many of the earlier generative models which have often advocated a distinction between competence and performance (e.g., Bickerton, 1971; Chomsky, 1965; Gregg, 1989). These traditional models, in particular, claim that the choice of surface variants by a speaker is not the result of grammatical competence, but is instead a characteristic of linguistic performance. However, my results, as well as those found in the sociolinguistic literature (e.g., Auger, 2001; Anttila & Cho, 1998; Cardoso, 2001, 2003; Escartin, 2005), suggest that the process of variant selection in language cannot be ascribed solely to grammatical performance. Rather, the results indicate that language variation in general should be incorporated into a more sophisticated level of organization – grammatical competence (Labov, 1972, p.3).

CHAPTER 6: IMPLICATIONS, APPLICATIONS, AND CONCLUDING REMARKS

In this concluding chapter, I discuss the implications and applications of the results presented and discussed in chapter 4. I will focus on two main areas: second language acquisition and pronunciation teaching. With regard to pronunciation teaching, a set of pedagogical recommendations will be proposed to assist the classroom teacher in her/his teaching of sC onset clusters. Thereafter, a discussion of the limitations of the study will be provided, followed by an exploration of what appears to be promising directions for future research. The chapter then closes with my concluding remarks.

6.1 Research Implications

As discussed in chapter 1, a primary motivation of the current study originates from the absence of research investigating the effects of homorganicity on the production of L2 syllables. While previous research (e.g., Carlisle, 1997, 2006; Greenberg, 1965) has generally acknowledged the assumption that homorganicity is a key factor in determining the degree of ease with which consonant clusters are articulated, that assumption had not yet been tested empirically (but see Cardoso, 2008). In an attempt to fill this gap, the present study has tracked the development of three *homorganic* sC onset clusters – /sn/, /sl/, /st/ – in the IL speech of Farsi speakers. By limiting its scope to these homorganic sC sequences, and thus controlling for the effect of place of articulation on L2 syllable production, the present study aims to make some contribution to L2 phonological research.

Another major contribution of this study relates to the research sample involved: native speakers of Farsi. An examination of the L1 Farsi background not only allows us to broaden the research on nonnative acquisition of sC onset clusters but, more importantly, it enables us to draw parallels between the Farsi-English data from my study and other types of IL data, especially data from structurally similar first languages (e.g., Spanish, Portuguese, and most varieties of Arabic).

Another no less important contribution concerns the methodological and theoretical approaches used to analyze the Farsi-English data. The methodological approach adopted for data collection, for instance, comprised a combination of research measures and/or procedures (i.e., questionnaire, formal reading task, and informal interview), while the theoretical framework employed for data analysis involved insights from a variety of linguistic disciplines (including first and second language acquisition, sociolinguistics, and generative phonology – Optimality Theory). To a large degree, the motivation to use this type of integrative approach stems from the belief that L2 phenomena (e.g., e-epenthesis) are better understood if they are examined not as a function of linguistic or extra-linguistic factors in isolation, but in terms of a synergic interaction between a variety of factors.

A final contribution of this study involves the use of current developments in phonological theory (i.e., Optimality Theory) to explain the variable patterns of e-epenthesis. As has been previously suggested (e.g., Boersma, 1998; Cardoso, 2007; Escartin, 2005), and discussed in chapter 5, the adoption of a constraint-based approach (rather than a rule-based model) to analyze variation has the advantage of accounting for variable phenomena in a more constrained way.

6.2 Classroom applications

The pedagogical significance of the results obtained in this study can be far-reaching. For instance, the results concerning the relative markedness of /st/ and /sn/ clusters with respect to their less marked counterpart /sl/, may point to the need for language teachers and materials designers to put more emphasis on these clusters when designing pronunciation tasks. Accordingly, the findings pertaining to the less problematic (i.e., the least marked) /sl/ clusters, should be perceived by the teacher as a welcome opportunity to spend less time on these clusters when devising pronunciation activities: It is very likely that these clusters will emerge with little or no difficulty in the development of English as a second language speech by Farsi speakers.

In addition, the finding that learners perform differently depending on the level of formality of the task might suggest that the language teacher should be more cautious when assessing pronunciation activities. The learner who says, 'I like that [e]star' in a casual conversation with his peers might well utter the same sentence as, 'I like that _star' in, say, a classroom reading aloud task (where '_' indicates that 'no intrusive vowel is inserted'). Therefore, along the lines of Dickerson (1975), teachers are advised to evaluate the oral performance of a group of students using only one register: A student reading a text aloud, for instance, is expected to do better (at least in the production of sC clusters) than another student speaking in a more colloquial fashion (e.g., role-playing or group discussions).

Finally, because the current study has demonstrated that the production of sC clusters increases with increased exposure to the second language, an implied pedagogical corollary is to suggest that teachers should be particularly patient with lower proficiency learners of ESL when they venture sentences such as 'I bought five [e]stamps.' As indicated in this study, errors of this type are systematic and, more importantly, determined by a set of linguistic and extra-linguistic factors. Errors may in fact be a healthy sign of the learner's progress towards the acquisition of the L2 phonology. At more advanced proficiency levels, the learner will eventually exhibit more target-like accuracy in his/her pronunciation of sC clusters.

6.3 Limitations and future directions for research

There are several limitations to the present study. The first limitation has to do with external validity, that is, generalizability of the findings. In particular, the findings concerning the Farsi learners investigated in this study clearly cannot be generalized to other research contexts: All of the learners were university-educated, learning English in a 'study-abroad' ESL setting. Most were highly motivated to learn and study the L2, and were socioeconomically advantaged (based on their current status as international students in Canada). It would be important to elicit and analyze similar data from other research samples with different constraints; for example, a sample that would involve: (1) a mix of EFL and ESL settings, (2) a balance between educated and less educated people, and (3) a blend of structure-oriented and communicative-based classrooms. This would certainly allow for a tighter control of the contextual factors (e.g., the native language and instructional setting), and therefore lead to a more reliable generalization of the findings.

Another limitation of this study relates to the fact that word frequency and its effects on L2 acquisition of sC clusters were not examined, even though an attempt was made to minimize those effects by selecting words and phrases of relatively high frequency in English. That word frequency (i.e., the frequency with which individual lexical forms occur) has an impact on IL development has been recognized by a growing number of acquisition theorists (e.g., Bybee, 2001, 2006, 2007; Gass, 1997; Gass & Mackay, 2002; Regan, 1996; Trofimovich, Gatbonton, & Segalowitz, 2007). For example, Bybee (2006) argues in favor of the role of frequency in a variety of language aspects, maintaining that 'Language can be viewed as a complex system in which the processes that occur in individual usage events … with *high levels of repetition, not only lead to the establishment of a system within the individual, but also lead to the creation of grammar* [emphasis added], its change, and its maintenance within a speech community.' (p. 730). More recently, Cardoso, John, and French (2008) reported an interesting pattern regarding the conditioning effects of frequency on the structuring of L2 syllables. Specifically, the researchers have established that, unlike nonnative sC cluster production which is *more* receptive to markedness criteria, L2 sC cluster perception appears to be more sensitive to frequency effects.

This brings us yet to another area which the current study did not address: the relationship between production and perception. In general, previous research on L2 development has suggested some degree of interaction between production and perception (e.g., Best, 1995; Fledge, 1995; Hume & Johnson, 2001; Leather, 1999; Strange, 1992; Major, 2001; Zampini, 2008), although the nature of that interaction remains a complex and contentious issue to the present day. In the context of nonnative syllable acquisition, for instance, a number of studies have reported that consonant cluster production is relatively affected by perception, among a variety of other factors (e.g., Davidson, 2006; Hansen, 2004; Kwon, 2006). An example of a perception-based factor that is often thought to have an influence on IL phonotactics is the *Maximal Perceptual Contrast* (MPC) (e.g., Jakobson, 1941). Simply put, the MPC claims that language users have a preference for a sequence of two segments where there is a maximal perceptual contrast, based on the acoustic salience of each segment (e.g., Côté, 2000 – /sl/ > /sn/ > /st/). In order to verify this claim, and thus make more explicit the role of perception in L2 syllable development, future research could, for instance, explore the MPC and test it against a wider range of L2 acquisition data.

Apart from the directions for future research offered above, and based on the current state of L2 phonological knowledge, there are several other aspects that could benefit from future investigations. For example, in addition to the set of independent variables examined in this study (i.e., sonority markedness, preceding phonological environment, proficiency, and style), future studies should consider an even greater range of linguistic and extra-linguistic factors, including: word size (monosyllabic, bi-syllabic, etc.), quantity and quality of following and preceding vowels, and social issues involving identity and gender roles in society. Needless to say, this wider spectrum of linguistic and social constraints would make for an even richer, more reliable and representative dataset and analyses.

In addition, more research ought to be done to extend the investigation of nonnative sC clusters to less studied native language backgrounds, particularly those which disallow sC clusters altogether: Punjabi, Sinhalese, Iraqi Arabic, Armenian, etc. This would allow not only a comparison of the results across a wider variety of languages, but also the possibility to draw more robust insights into the linguistic and social factors affecting the acquisition of nonnative syllables in general.

Another area of L2 phonological research that has not received enough attention concerns a need for longitudinal studies that trace the development of L2 speech production over time, similar to those conducted by Abrahammsson (1999) and Hansen (2006). Such studies will enable us to ascertain not only a more reliable development path of the target sC sequences but also the eventual L2 attainment. In particular, this type of research could help us identify which factors – linguistic and extra-linguistic – tend to favor or hinder L2 ultimate attainment.

Finally, because most studies on acquisition of sC sequences focus on L2 English (e.g., Broselow, 1983; Cardoso, 2008; Carlisle, 1988, 2006; Kim, 2000; Rauber, 2006), it is perhaps time that future research looked into other target sC-initial languages (e.g., Dutch, Hebrew, German, Polish, Czech). Examination of these typologically similar languages (with respect to syllable structure) will not only enrich the L2 syllable research agenda, but it will also allow researchers to test whether the patterns obtained from L2 English data in general can be extrapolated to other less commonly studied L2 contexts.

6.4 Concluding remarks

In this thesis, I have examined the variable phenomenon of vowel insertion [e] in Farsi speakers' production of three homorganic sC onset consonant clusters (/st/, /sl/, and /sn/), using a multidisciplinary perspective that brings together insights from first and second language acquisition, formal phonology, phonetics, as well as methodological tools from variationist sociolinguistics. The overall results suggest that, similar to what is usually observed in natural languages, the phenomenon of e-epenthesis is systematic (i.e., predictable), and more importantly, motivated by a combination of linguistic and extra-linguistic variable constraints. In particular, the results reveal that e-epenthesis in Farsi-based IL is more likely to occur: (1) when the sC sequence is preceded by consonants or pauses, (2) in the IL of less proficient speakers, (3) in less formal stylistic environments, (4) and in /s/ + stop and /s/ + nasal sC clusters.

The results involving *markedness on sonority* – namely that e-epenthesis is more likely to occur in /st/ and /sn/ sequences – were somewhat surprising because they did not conform to the predictions of Clements' (1990) markedness-based Principles of Sonority Sequencing (SSP) and Minimal Sonority Distance (MSD), as hypothesized. These results, in particular, showed that the SSP-abiding /sn/ clusters were almost as difficult to acquire as their SSP-violating counterparts (i.e., the /st/ clusters). Accordingly, it was argued that these idiosyncratic results follow from articulatory factors which make /st/ and /sn/ more marked (and thus more likely to induce epenthesis) than /sl/; that is, both /st/ and /sn/ sequences are considered more difficult to produce because their articulation entails a more effortful gesture from [+continuant] /s/ to [-continuant] /t/ or /n/. Finally, it was noted that whereas the observed sC learning hierarchy (sl > sn, st) had already been reported in L1 acquisition (e.g., Gierut, 1999; Grunwell, 1981; Ingram, 1989; Smit, 1993; Yavas & Beauburn, 2006; Yavas & Someillan, 2005), this hierarchy had *not* yet been documented in L2 acquisition research.

Less surprising were the results relating to the factor *preceding phonological environment*. These results, in general, lend further support to the cross-linguistic observation that preceding pauses and consonants behave similarly in a variety of phonological phenomena (Cardoso, 1999; Escartin, 2005; Winford, 1992).

In addition, the results concerning L2 proficiency and style conform to those of several other studies of IL variation, especially with regard to the predictions of Major's (2001) Ontogeny Phylogeny Model. In particular, the results from the FE data have shown that over time (hence with increased L2 proficiency) and in more formal situations, the amount of L1 transfer (i.e., e-epenthesis) decreases, while the proportion of L2 features (sC onset cluster production) increases.

Finally, for the formal analysis of the variable patterns observed in vowel epenthesis in FE-based interlanguage, I adopted a stochastic version of Optimality Theory via the use of a Gradual Learning Algorithm (Boersma & Hayes, 2001). In this analysis, I argued that the type of IL grammars that characterize the speech production of Farsi speakers can be captured by the relative ranking of the faithfulness constraint DEP-IO with respect to the markedness constraint *sC. More importantly, I have demonstrated that the Gradual Learning Algorithm is able to predict the relative frequency with which e-epenthesis occurs across each of the six grammars in development considered in this study.

References

Abrahamsson, N. (1999). Vowel epenthesis of /sC(C)/ onsets in Spanish/Swedish interphonology: A longitudinal case study. *Language Learning, 49 (3),* 473-508.

Adamson, H. D. (1988). *Variation theory and second language acquisition.* Washington, D.C.: Georgetown University Press.

Adamson, H. D., & Regan, V. M. (1991). The acquisition of speech community norms by Asian immigrants learning English as a second language. *Studies in Second Language Acquisition 33,* 1-22.

Allen, W. S. (1973). *Accent and rhythm: Prosodic features of Latin and Greek: A study in theory and reconstruction.* Cambridge, UK: Cambridge University Press.

Andersen, R. (1978). An implicational model for second language research. *Language Learning, 28,* 221-281.

Anderson, J. I. (1987). The markedness differential hypothesis and syllable structure difficulty. In G. Ioup & S. H. Weinberger (Eds.), *Interlanguage phonology: The acquisition of a second language sound system* (pp. 279-291). Cambridge, MA: Newbury House.

Anttila, A. (1997). Deriving variation from grammar: A study of Finnish genitives. In F. Hinskens, R. Van Hout, & L. Wetzels (Eds.), *Variation, change and phonological theory* (pp. 35-68). Amsterdam: John Benjamins.

Anttila, A., & Cho, Y. Y. (1998). Variation and change in Optimality Theory, *Lingua 104,* 31-56.

Auger, J. (2001). Phonological variation and Optimality Theory: Evidence from word-initial vowel epenthesis in Picard. *Language Variation and Change, 13,* 253-303.

Barlow, J. A. (1997). *A constraint-based account of syllable onsets: Evidence from developing systems.* Unpublished doctoral dissertation, Indiana University.

Battistela, E. (1990). *Markedness: The evaluative superstructure of language.* Albany: The State University of New York Press.

Bayley, R. (1991). *Variation theory and second language learning: Linguistic and social constraints on IL past marking.* Doctoral Dissertation, Stanford University.

Bayley, R. (1996). Competing constraints on variation in the speech of adult Chinese learners of English. In R. Bayley & D. Preston (eds.), *Second language acquisition and linguistic variation* (pp. 97-120). Amsterdam: John Benjamins.

Bayley, R., & Preston, D. (1996). *Second language acquisition and linguistic variation.* Amsterdam: John Benjamins.

Beebe, L. M. (1980). Sociolinguistic variation and style shifting in second language acquisition. *Language Learning, 30,* 433-447.

Bebee, L. M., & Zuengler, J. (1983). Accommodation theory: An explanation for style shifting in second language dialects. In N. Wolfson & E. Judd (Eds.), *Sociolinguistics and second language acquisition* (pp. 195-213). Rowely, MA: Newbury House.

Belvins, J. (1995). The syllable in phonological theory. In J. A. Goldsmith (Ed.), *A handbook of phonological theory* (pp. 206-244). Cambridge, MA: Blackwell Publishers.

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

Best, C. T. (1995). A direct realist perspective on cross-language speech perception. In W. Strange (Ed.), *Speech perception and linguistic experience: Issues in cross-language research* (pp. 171-204). Timonium, MD: York Press.

Bickerton, D. (1971). Inherent variability and variable rules. *Foundations of Language 7,* 457-492.

Bickerton, D. (1973). Quantitative versus dynamic paradigms: The case of Montréal 'que'. In C. J. Bailey & R.W. Shuy (Eds.), *New ways of analyzing variation in English* (pp. 23-43). Washington D.C.: Georgetown University Press.

Boersma, P. (1998). *Functional phonology: Formalizing the interactions between articulatory and perceptual drives.* The Hague, Netherlands: Holland Academic Graphics.

Boersma, P. (2000). Learning a grammar in functional phonology. In J. Dekkers, V. van der Leeuw, & J.van der Weijer (eds.), *Optimality theory: Phonology, syntax and acquisition* (pp. 465–523). Oxford: Oxford University Press.

Boersma, P. (2001). Review of Arto Anttila: Variation in Finnish phonology and morphology. *GLOT International 5*, 31-40.

Boersma, P., & Dekkers, J., & van de Weijer, J. (2000). Introduction. In J. Dekkers, F. van der leeuw, & J. van de Weijer (Eds.), *Optimality theory: Phonology, syntax, and acquisition* (pp. 1-44). New York: Oxford University Press.

Boersma, P., & Hayes, B. (2001). Empirical tests of the gradual learning algorithm. *Linguistic Inquiry, 32,* 45-86.

Boersma, P., & Weenink, D. (2007). Praat, a system for doing phonetics by computer. Retrieved February 20, 2008, from http://www.praat.org

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

Broselow, E. (1983). Non-obvious transfer: On predicting epenthesis errors. In S. M. Gass & L. Selinker (Eds.), *Language transfer in language learning* (pp. 269-280). Rowely, MA: Newbury House.

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

Broselow, E., Chen, S. I., & Wang, C. (1998). The emergence of the unmarked in second language phonology. *Studies in Second Language Acquisition, 20,* 261–280.

Browman. C. P., & Goldstein, L. (1989). Articulatory gestures as phonological units. *Phonology, 6 (2),* 201-251.

Bunta, F., & Major, R. (2004). An Optimality Theoretic account of Hungarian ESL learners acquisition of /e /and/æ/. *IRAL: International Review of Applied Linguistics in Language Teaching, 42 (3),* 277-299.

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

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

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

Cardoso, W. (1999). A quantitative analysis of word-final /r/-deletion in Brazilian Portuguese. *Linguistica Atlantica, 21,* 13-52.

Cardoso, W. (2001). Variation patterns in regressive assimilation in Picard. *Language Variation and Change, 13,* 305-341.

Cardoso, W. (2003). *Topics in the phonology of Picard.* Doctoral Dissertation, McGill University, Montréal. Published by the McGill Working Papers in Linguistics.

Cardoso, W. (2005). The variable acquisition of English word-final stops by Brazilian Portuguese speakers. In L. Dekydtspotter, R. A. Sprouse, & A. Liljestrand (Eds.), *Proceedings of the Generative Approaches to Second Language Acquisition Conference (GASLA 7)* (pp. 38-49). Somerville, MA: Cascadilla Proceedings Project.

Cardoso, W. (2007). The variable development of English word-final stops by Brazilian Portuguese speakers: A stochastic optimality theoretic account. *Language Variation and Change, 19,* 1-32.

Cardoso, W. (2008). The Development of sC Onset Clusters in Interlanguage: Markedness vs. Frequency Effects. In R. Slabakova, J. Rothman, P. kempchinsky, & E. Gavruseva (Eds.), *Proceedings of the Generative Approaches to Second Language Acquisition (GASLA 9)* (pp. 15-29). Somerville, MA: Cascadilla Proceedings Project.

Cardoso, W. (in press). Sociolinguistic variation and Optimality Theory: Regressive assimilation in Vimeu Picard. *Journal of the Brazilian Association of Linguistics* (ABRALIN).

Cardoso, W., John, P., & French, L. (2008). The variable perception of /s/+coronal onset clusters in Brazilian Portuguese English. In A. S. Rauber, M. A. Watkins, & B. O. Baptista (Eds.), *New sounds 2007: Proceedings of the fifth international symposium on the acquisition of second language speech* (pp. 86-106). Florianópolis, Brazil: Federal University of Santa Catarina.

Carlisle, R. (1988). The effects of markedness on epenthesis in Spanish/English interlanguage phonology. *Issues and Developments in English and Applied Linguistics, 3,* 15-23.

Carlisle, R. (1991a). The influence of syllable structure universals on the variability of interlanguage phonology. *Applied Linguistics, 12 (1),* 76-95.

Carlisle, R. (1991b). The influence of environment on vowel epenthesis in Spanish/English interphonology. In A. D. Volpe (Ed.), *The Seventeenth LACUS Forum 1990* (pp.135-145). Lake Bluff, IL: Linguistic Association of Canada & the United States.

Carlisle, R. (1997). The modification of onsets in a markedness relationship: Testing the interlanguage structural conformity hypothesis. *Language Learning, 47*, 327-361.

Carlisle, R. (2001). Syllable structure universals and second language acquisition. *International Journal of English Studies, 1*, 1-19

Carlisle, R. (2006). The sonority cycle and the acquisition of complex onsets. In B. Baptista & M. Watkins (Eds.), *English with a Latin beat: Studies in Portuguese/Spanish English interphonology* (pp. 105-137). Amsterdam: Johns Benjamins

Chomsky, N. (1965). *Aspects of the theory of syntax*. Cambridge, MA: MIT Press.

Chomsky, N. (1988). *Language and problems of knowledge: the Managua lectures*. Cambridge, MA: MIT Press.

Chomsky, N., & Halle, M. (1968). *The sound patterns of English*. Cambridge, MA: MIT Press.

Clements, G. (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 physics of speech* (pp. 282-333). Cambridge, MA: Cambridge University Press.

Clements, G., & Keyser, S. (1983). *CV phonology: A generative theory of the syllable*. Cambridge, MA: MIT Press.

Côté, M. H. (2000). *Consonant cluster phonotactics: A perceptual approach*. Doctoral Dissertation, MIT, Massachusetts.

Coetzee, A. W. (2006). Variation as accessing 'non-optimal' candidates. *Phonology, 23*, 337-385.

Davidson, L. (2003). *The atoms of phonological representation: Gestures, coordination and perceptual features in consonant cluster phonotactics*. Unpublished Doctoral Dissertation, Johns Hopkins University.

Davidson, L. (2006). Phonology, phonetics, or frequency: Influences on the production of nonnative sequences. *Journal of Phonetics, 34,* 104–137.

Dickerson, L. (1975). The learner's interlanguage as a system of variable rules. *TESOL Quarterly, 9,* 401-407.

Dickerson, L.B., & Dickerson, W.B. (1977). Interlanguage phonology: Current research and future directions. In S.P. Corder & E. Roulet (Eds.), *Acte du 5ème colloque de linguistique appliquée* (pp. 18-29). Neuchâtel, Switzerland: Faculté de Lettres.

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

Eckman, F. (1991). The structural conformity hypothesis and the acquisition of consonant clusters in the interlanguage of ESL learners. *Studies in Second Language Acquisition*, 13, 23-41.

Eckman, F. (2008). Typological markedness and second language phonology. In J. G. Hansen & M. L. Zampini (Eds.), *Phonology and second language acquisition* (pp. 95-115). Philadelphia: John Benjamins.

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

Ellis, R. (1994). Variability and the natural order hypothesis. In R. Barasch & C. V. James (Eds.), *Beyond the monitor model* (pp. 139-158). Boston: Heinle and Heinle.

Ellis, N. (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.

Escartin, C. (2005). *The development of sC onset clusters in Spanish English.* Unpublished master's thesis, Concordia University, Montréal.

Evanini, K. (2007). How to formalize variation: Stochastic OT models and /s/ deletion in Spanish. In P. Reich, W. J. Sullivan, A. R. Lommel, & T. Griffen (Eds.), *The thirty-third LACUS* Forum 2006 (pp. 147-158): Toronto, ON: Linguistic Association of Canada and the United States.

Fledge, J. E. (1995). Second language speech learning: Theory, findings, and problems. In W. Strange (Ed.), *Speech perception and linguistic experience: Issues in cross-linguistic speech research* (pp. 233-277). Timonium, MD: York Press.

Fikkert, P. (1994). *On the acquisition of prosodic structure.* Amsterdam: Holland Institute of Generative Linguistics.

Frey, E. (1995). Gender specific characteristics of word syllabification: A new aspect for the conceptualization of pronunciation instruction; Geschlechtsspezifische Merkmale bei der Syllabierung von Worten: ein nueuer Aspekt die Konzeptionierung von Ausspracheschulung. *Zilesprach Duetsch, 26,* 136-142.

Gass, S. (1997). *Input, interaction, and the second language learner.* Mahwah, NJ: Lawrence Erlbaum Associates.

Gass, S. M., & Mackey, A. (2002). Frequency effects and second language acquisition: A complex picture? *Studies in Second Language Acquisition, 24,* 249-260.

Gass, S. M., & Mackey, A. (2005). *Second language research: Methodology and design.* Mahwah, NJ: Lawrence Erlbaum Associates.

Gatbonton, E. (1975). *Systematic variations in second language speech: A sociolinguistic study.* Unpublished Doctoral Dissertation, McGill University, Montréal.

Gatbonton, E. (1978). Patterned phonetic variability in second language speech: A gradual diffusion model. *Canadian Modern Language Review, 34,* 335-347.

Giegerich, H. (1992). *English phonology.* Cambridge, MA: Cambridge University Press.

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

Gnanadesikan, A. E. (2004). Markedness and faithfulness constraints in child phonology. In R. Kager, J. Pater, & W. Zonneveld (Eds.), *Constraints in phonological acquisition* (pp. 73-08). Cambridge, UK: Cambridge University Press.

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, UK: Cambridge University Press.

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

Greenberg, J. (1965). Some generalizations concerning initial and final consonant sequences. *Linguistics, 18,* 5-34.

Gregg, K. (1989). Second language acquisition theory: The case for a generative perspective. In S. Gass & J. Schacter (Eds), *Linguistic perspectives on second language acquisition* (pp. 15-40). Cambridge, MA: Cambridge University Press.

Grunwell, P. (1981). *The nature of phonological disability in children.* New York: Academic Press.

Guy, G. (1988). Advanced VARBRUL analysis. In K. Ferrara, B. Brown, K. Walters, & J. Baugh (Eds.), *Linguistic contact and change* (pp. 124-136). Austin: University of Texas Department of Linguistics.

Hancin-Bhatt, B., & Bhatt, R. M. (1997). Optimal L2 syllables: interactions of transfer and developmental effects. *Studies in Second Language Acquisition, 19,* 331-378.

Hansen, J. G. (2004). Developmental sequences in the acquisition of English L2 syllable codas. *Studies in Second Language Acquisition, 26,* 85–124.

Hansen, J. G. (2006). *Acquiring a non-native phonology: Linguistic constraints and social barriers.* London: Continuum Publishers.

Harris, J. (1983). *Syllable structure and stress in Spanish: A non-linear analysis.* Cambridge, MA: MIT Press.

Hayes, B., Kirchner, R., & Steriade, D. (2004). *Phonetically based phonology.* Cambridge, UK: Cambridge University Press.

Hayes, B., Tesar, B., & Zuraw, K. (2003). OTsoft 2.1 software package. Retrieved on January 18, 2008 from http://www.linguistics.ucla.edu/people/hayes/otsoft

Hogg, R., & McCully, C. B. (1987). *Metrical phonology: A coursebook.* Cambridge, UK: Cambridge University Press.

Hooper, J. B. (1976). *An introduction to natural generative phonology.* New York: Academic Press.

Hume, E., & Johnson, K. (2001). A model of the interplay of speech perception and phonology. In E. Hume, & K. Johnson (Eds.), *The role of perception in phonology* (pp. 3-26). New York: Academic Press.

Ingram, D. (1989). *Phonological disability in children* (2nd ed.). London: Cole & Whurr.

Jakobson, R. (1941). *Child language, aphasia and phonological universals*. The Hague: Mouton.

Jespersen, O. (1922). *Language: Its nature, development, and origin*. London: George Allen & Unwin.

John, P. (2006). *Variable h-epenthesis in the interlanguage of Francophone ESL learners*. Unpublished master's thesis, Concordia University, Montréal.

Karimi, S. (1987). Farsi speakers and the initial consonant clusters in English. In G. Ioup & S. H. Weinberger (Eds.), *Interlanguage phonology: The acquisition of a second language sound system* (pp. 305-318). Cambridge, MA: Newbury House.

Kehoe, M. M., & Lleó, C. (2002). Intervocalic consonants in the acquisition of German: Onsets, codas or something else? *Clinical Linguistics & Phonetics, 16 (3),* 169-182.

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

Kim, H. Y. (2000). *The interlanguage phonology of Korean learners of English: A computational implementation of optimality theoretic constraints*. Doctoral Dissertation, Georgetown University.

Kiparsky, P. (1993). Variable rules. Paper presented at the Rutgers Optimality Workshop. New Brunswick, NJ.

Kirchner, R. M. (1998). *An effort-based approach to consonant lenition*. Doctoral Dissertation, University of California, Los Angeles.

Kwon, B. Y. (2006). *Korean speakers' production of English consonant clusters: Articulatory and perceptual accounts*. Doctoral Dissertation, Michigan State University, Ann Arbor.

Labov, W. (1966). *The social stratification of English in New York City*. Washington, D.C.: Center for Applied Linguistics.

Labov, W. (1969). Contraction, deletion, and inherent variability of the English copula. *Language, 45,* 715-762.

Labov, W. (1972). *Sociolinguistic Patterns.* Philadelphia: University of Pennsylvania Press.

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

Lado, R. (1957). Linguistics across cultures. Ann Arbor: The University of Michigan Press.

Leather, J. (1999). *Phonological issues in language learning.* Malden, MA: Blackwell Publishers.

Levelt, C. C., Schiller, N. O., & Levelt, W. J. M. (1999). A development grammar for syllable structure in the production of child language. *Brain and Language, 68,* 291-299.

Lin, Y. H. (2001). Syllable simplification strategy: A stylistic approach. *Language Learning, 51,* 681-718.

Lin, Y. H. (2003). Interphonology variability: sociolinguistic factors affecting L2 simplification strategies. *Applied Linguistics, 24 (4),* 439-464.

Major. R. C. (1987). A model for interlanguage phonology. In G. Ioup & S. H. Weinberger (Eds.), *Interlanguage phonology: The acquisition of a second language sound system* (pp. 101-125). Cambridge, MA: Newbury House.

Major. R. C. (1994). Chronological and stylistic aspects of second language acquisition of consonant clusters. *Language Learning, 44,* 655-680.

Major, R. C. (1996). Markedness in second language acquisition of consonant clusters. In R. Bayley & D. R. Preston (Eds.), *Second language acquisition and linguistic variation* (pp. 75-96). Amsterdam: John Benjamins.

Major, R. C. (2001). *Foreign accent. The Ontogeny and phylogeny of second language phonology.* New Jersey: Lawrence Erlbaum Associates.

Major, R. C. (2004). Gender and stylistic variation in second language phonology. *Language Variation and Change, 16,* 169-188.

McCarthy, J. J., & Prince, A. (1995). *Faithfulness and reduplicative identity*. In: J. Beckman, L. Walsh Dickey, & S. Urbanczyk (Eds.). *Papers in Optimality Theory* (pp. 249-384). University of Massachusetts Occasional Papers in Linguistics 18, Amherst, MA: GLSA.

Morris, R. E. (1998). *Stylistic variation in Spanish phonology*. Doctoral Dissertation, Ohio State University.

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

Ohala, J. J., & Kawasaki-Fukumuri, H. (1997). Alternatives to the sonority hierarchy for explaining the segmental sequential constraints. In S. Eliasson, & E. H. Jahr (Eds.), *Language and its ecology*, (pp. 343-365). Berlin: Mouton de Gruyter.

Osburne, A. (1996). Final cluster reduction in English L2 speech: A case study of a Vietnamese speaker. *Applied Linguistics, 17(2)*, 164-181.

Oostendorp, M. V. (1997). Style levels in conflict resolution. In F. Hinskens, R. van Hout, & W. Wetzels (Eds.). *Variation, change and phonological theory* (pp. 207-229). Amsterdam: John Benjamins.

Oostendorp, M. V. (2005). Variation in generative grammar. Manuscript, Royal Netherlands Academy of Arts and Sciences, Amsterdam (The Netherlands).

Parker, S. (2002). *Quantifying the Sonority Hierarchy*. Doctoral Dissertation, University of Massachusetts, Amherst.

Parrondo-Rodriguez, A. (1999). *L2 acquisition of syllable structure and stress in Spanish*. Doctoral Dissertation, University of Durham, UK.

Pater, J., & Barlow, J. A. (2003). Constraint conflict in cluster reduction. *Journal of Child Language, 30,* 487-526.

Pintzuk, S. (1988). *VARBRUL programs*. Philadelphia: University of Pennsylvania Department of Linguistics.

Preston, D. (1996). Variationist perspectives on second language acquisition. In R. Bayley & D. R. Preston (Eds.). *Second language acquisition and linguistic variation* (pp. 1-45). Amsterdam: John Benjamins.

Price, P. J. (1980). Sonority and syllabicity: acoustic correlates of perception. *Phonetica, 37,* 327-343.

Prince, A., & Smolensky, P. (1993). *Optimality theory: Constraint interaction in generative grammar.* Cambridge, MA: MIT Press.

Rand, D., & Sankoff, D. (1990). *Goldvarb: A variable rule application for Macintosh* (version 2.0) [computer program]. Montréal: Centre de recherches mathématiques, Université de Montréal.

Rauber, A. S. (2006). Production of English initial /s/-clusters by speakers of Brazilian Portuguese & Argentine Spanish. In B. Baptista and M. Watkins (Eds.), *English with a Latin beat: Studies in Portuguese/Spanish English interphonology* (pp. 155-167). Amsterdam: Johns Benjamins

Regan, V. (1996). Variation in French interlanguage: A longitudinal study of sociolinguistic competence. In R. Bayley & D. R. Preston (Eds.), *Second language acquisition and linguistic variation* (pp. 177–202). Amsterdam: John Benjamins.

Reynold, W. (1994). *Variation and phonological theory.* Doctoral Dissertation, University of Pennsylvania.

Reynold, W., & Nagy, N. (1997). Optimality Theory and variable word-final deletion in Faetar. *Language Variation and Change, 9,* 37–55

Sankoff, D., Tagliomente, S., & Smith, E. (2005). *Goldvarb X: A variable rule application for Macintosh and Windows.* Toronto: University of Toronto Press.

Sato, C., J. (1985). Task variation in IL phonology. In S. M. Gass & C. G. Madden (Eds.), *Input in second language acquisition* (pp. 181-196). Rowley, MA: Newbury House.

Sato, C., J. (1987). Phonological processes in second language acquisition: Another look at interlanguage syllable structure. In G. Ioup & S. Weinberger (Eds.), *Interlanguage phonology: The acquisition of a second language sound system* (pp. 248-260). Cambridge, MA: Newbury House.

Schmidt, W.R. (1977). Sociolinguistic variation and language transfer in phonology. *Working Papers in Bilinguilism, 12,* 79-95.

Selinker, L. (1972). Interlanguage. *International Review of Applied Linguistics, 10,* 209-231.

Selkirk, E. (1972). *The phrase phonology of English and French.* Doctoral Dissertation, MIT, Massachusetts.

Selkirk, E. (1982). The syllable. In H. Van der Hulst & N. Smith (Eds.), *The structure of phonological representations (part III)* (pp. 337-84). Dordrecht: Foris Publications.

Selkirk, E. (1984). On the major class features and syllable theory. In M. Aronoff & R. Oerhle (Eds.), *Language sound structure: Studies in phonology presented to Morris Halle by his teachers and students* (pp. 107-136). Cambridge, MA: MIT Press.

Smit, A. B. (1993). Phonological error distribution in the Iowa-Nebraska Articulation Norms Project: Word-initial consonant clusters. *Journal of Speech and Hearing Research, 36,* 931 – 947.

Spencer, A. (1991). *Phonology.* Oxford, UK: Blackwell Publishers.

Steriade, D. (1982). *Greek prosodies and the nature of syllabification.* Doctoral Dissertation, MIT, Massachusetts.

Strange, W. (1992). Learning non-native phoneme contrasts: Interaction among subjects, stimulus, and task variables. In Y. Tohkura, E. Vatikiotis-Bateson, & Y. Sagisaka (Eds.), *Speech perception, production, and linguistic structure* (pp. 197-219). Tokyo: Ohmasha.

Tagliomonte, S. A. (2006). *Analysing sociolinguistic variation.* New York: Cambridge University Press.

Tarone, E. E. (1976). Some influences in interlanguage phonology. *Working Papers in Bilingualism,* 87-111.

Tarone, E. E. (1979). Interlanguage as a chameleon. *Language Learning, 29,* 181-191.

Tarone, E. E. (1988). *Variation in interlanguage.* London: Edward Arnold.

Taxeira Rebello, J. (1997). The acquisition of English initial /s/ clusters by Brazilian EFL learners. In J. Leather and A. James (Eds.), *New sounds 97* (pp. 286-293). Klagenfurt, Austria: University of Klagenfurt.

Tropf, H. (1987). Sonority as a variability factor in second language phonology. In A. James & J. Leather (Eds.), *Sound patterns in second language acquisition* (pp. 173-191). Providence, RI: Foris Publications.

Trubetzkoy, N. (1939). Grundzuge der phonologie. Göttingen: Vandenhoeck und Ruprecht [Principles of Phonology, translated by C. Baltaxe. Berkeley and Los Angeles: University of California Press, 1969].

Weinberger, S. H. (1987). The influence of linguistic context on syllable simplification. In G. Ioup & S.H. Weinberger (Eds.), *Interlanguage phonology: The acquisition of a second language sound system* (pp. 401-417). Cambridge, MA: Newbury House.

Weiss, L. (1970). Auditory discrimination and pronunciation of French vowel phonemes. *Dissertation Abstracts International, 31,* 4051-A.

Vennemann, T. (1988). The rule dependence of syllable structure. In C. Duncan-Rose & T. Vennemann (Eds.), *On language: Rhetorica, phonologica, syntactica* (pp. 187-283). Beckenham, Kent, UK: Croom Helm.

White, L. (1989). Universal grammar and second language acquisition. Amsterdam: John Benjamins.

Winford, D. (1992). Back to the past: the BEV/Creole connection revisited. *Language Variation and Change, 4(3),* 311-357.

Wright, R. (2004). Perceptual cue robustness and constraints: Rethinking sonority. In B. Hayes, R. Kirchner, & D. Steriade (Eds.), *Phonetically based phonology* (pp. 34-57). Cambridge, UK: Cambridge University Press.

Yarmohammadi, L. (1995). *A contrastive phonological analysis of English and Persian: A coursebook in applied phonological studies.* Shiraz: Shiraz University Press.

Yavaş, M. (2006a). *Applied English phonology.* Malden, MA: Blackwell Publishers.

Yavaş, M. (2006b). Sonority and the acquisition of #sC clusters. *Journal of Multilingual Communication Disorders, 4(3),* 159-168.

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

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

Yildiz, Y. (2005). The structure of initial /s/-clusters: Evidence from L1 and L2 language acquisition. *Developmental Paths in Phonological Acquisition (2)1,* 163-187. Retrieved on September 25, 2008, from http://www.let.leidenuniv.nl/pdf/lucl/lwpl/2.1/yildiz.pdf.

Young, R. (1991). *Variation in interlanguage morphology*. New York: Pater Lang.

Young, R., & Bayley, R. (1996). VARBRUL analysis for second language acquisition research. In R. Bayley and D. Preston (Eds.), *Second language acquisition and linguistic variation* (pp. 253-306). Amsterdam: John Benjamins.

Young-Scholten, M. (1993). *The acquition of prosodic structure in a second language.* Tübingen: Niemeyer.

Young-Scholten, M., & Archibald, J. (2000). Second language syllable structure. In J. Archibald (Ed.), *Second language acquisition and linguistic theory* (pp. 64-101). Oxford, UK: Blackwell Publishers.

Zampini, M. L. (2008). L2 speech production research: findings, issues, and advances. In J. G. Hansen & M. L. Zampini (Eds.), *Phonology and second language acquisition* (pp. 219-249). Philadelphia: John Benjamins.

Zharkova, N. (2005). Strategies in the acquisition of segments and syllables in Russian-speaking children. *Developmental Paths in Phonological Acquisition (2)1,* 189-213. Retrieved on September 25, 2008, from http://www.let.leidenuniv.nl/pdf/lucl/lwpl/2.1/zharkova.pdf.

APPENDIX A

Biodata Form: Researcher's version

Identification (demographic information)

Name: ______________________________ research code _______________

E-mail address (or other contact information): ________________

First language (s) ________________ Gender: male ___female ___

Age: 20 or younger ___ 20-24 ___ 25-29 ___ 30-35 ___ 35 and above ___

Overall exposure to English:

How old were you when you started studying English? ________________

How long have you studied English? (Tick (✓) the option that best describes you)

___ 0-1 year
___ 1-2 year
___ 2-3 year
___ 3-4 year
___ 4 or more years

Frequency and context of L2 use outside the classroom:

How many hours per week you spend using English outside class to do each of the following activities? (Tick (✓) the number of hours for each activity).

	0	1-2	3-4	5-6	6 and more
Do your assignments / homework					
Read for pleasure (on your own)					
Listen to (English) language tapes					
Listen to music					
Watch TV, videos & movies					
Speak to others (e.g., family, friends)					

Amount of travel or experience in countries where the L2 is spoken:

Have you ever been to an English-speaking country other than Canada (e.g., UK, Australia, USA, etc.)?

—— Yes —— No

If yes, how long were you there? _____ What did you do there? __________

Have you ever been to a country (other than Canada) where you used English to communicate (e.g., Thailand, Malaysia, Japan, Qatar, etc.)?

—— Yes —— No

If yes, how long were you there? _____

Learners' self-assessment of L2 speaking proficiency and attitude to L2:

How well do you think you can speak English? Circle the number that best describes you. (0 means that you can hardly speak English; 5 means that you can speak English very well – almost like a native speaker).

0 (none) 1 (very poor) 2 (poor) 3 (average) 4 (good) 5 (very good)

How important is it for you to learn English? (Tick (✓) the statement that best describes you)

___ It is very important for me to learn English

___ It is somewhat important for me to learn English

___ It is not important for me to learn English

Participants' familiarity with other languages:

Do you know any languages *other* than your first language(s) and English?
___ Yes ___No

If yes, what are these languages? ________________________________

How good are you at speaking them? ________________________________

APPENDIX B

Biodata Form: Informants' version

1)

Name: ______________________ research code ___________

E-mail address (or other contact information): ____________

First language (s) ____________ Gender: male ___ female ___

Age: 20 or younger ____ 20-24 ____ 25-29 ____ 30-35 ____ 35 and above ____

2)

How old were you when you started studying English? ____________

How long have you studied English? (Tick (✓) the option that best describes you)

____ 0-1 year
____ 1-2 year
____ 2-3 year
____ 3-4 year
____ 4 or more years

3)

How many hours per week you spend using English outside class to do each of the following activities? (Tick (✓) the number of hours for each activity)

	0	1-2	3-4	5-6	6 and more
Do your assignments / homework					
Read for pleasure (on your own)					
Listen to (English) language tapes					
Listen to music					
Watch TV, videos & movies					
Speak to others (e.g., family, friends)					

4)

Have you ever been to an English-speaking country other than Canada (e.g., UK, Australia, USA, etc.)?

___ Yes ___ No

If yes, how long were you there? _____ What did you do there? __________

Have you ever been to a country (other than Canada) where you used English to communicate (e.g., Thailand, Malaysia, Japan, Qatar, etc.)?

___ Yes ___ No

If yes, how long were you there? _____

5)

How well do you think you can speak English? Circle the number that best describes you. (0 means that you can hardly speak English; 5 means that you can speak English very well – almost like a native speaker)

0 (none) | 1 (very poor) | 2 (poor) | 3 (average) | 4 (good) | 5 (very good)

How important is it for you to learn English? (Tick (✓) the statement that best describes you)

___ It is very important for me to learn English

___ It is somewhat important for me to learn English

___ It is not important for me to learn English

6)

Do you know any languages other than your first language(s) and English?

___ Yes ___ No

If yes, what are these languages? ______________________________

How good are you at speaking them? ______________________________

Thank you for your time!

APPENDIX C

Formal task: researcher's version

sC = onset cluster; S = stop; F = fricative; N = nasal; L = liquid; Ø = pause.

1. Mary works in a small store. (L sC)

2. Dan slept early today. (N sC)

3. Sniffer dogs are used by the police to find drugs. (Ø sC)

4. He managed to sneak in through the back door. (V sC)

5. I had Steve as a teacher. (S sC)

6. John will sleep late tonight. (L sC)

7. Stella is a nice person. (Ø sC)

8. There are ten snails in the garden. (N sC)

9. "Stay put," shouted the officer. (Ø sC)

10. Many slim models are on the covers of fashion magazines. (V sC)

11. Bob snapped his fingers to get his friend's attention. (S sC)

12. He really likes her slender figure. (L sC)

13. Beth still works two jobs. (F sC)

14. "Sleek" was the word he used to describe her hair. (Ø sC)

15. The law states that you have the right to an attorney. (V sC)

16. Slippery roads are dangerous. (Ø sC)

17. The car is too slow. (V sC)

18. The outlaw sniper was finally arrested. (V sC)

19. She survived the terrible snow storm. (L sC; V sC)

20. Slammer means prison. (Ø sC)

21. Every day I eat three snacks. (V sC)

22. Slide the keys under the door after you lock it. (Ø sC)

23. Grandma stuffed the chicken. (V sC)

24. Sneakers are very cheap in this shop. (Ø sC)

25. A webcam stood right on top of his monitor. (NsC)

26. Keep slicing these tomatoes please. (S sC)

27. He ran into a snag, but he managed to finish on time. (V sC)

28. Snares are still used to catch wild animals in some areas. (Ø sC)

29. I wonder if slums still exist in that city. (F sC)

30. "You can draw slippers," said the teacher. (VsC)

31. Sniffing repeatedly can be a symptom of a bad cold. (Ø sC)

32. The captain began steering left. (N sC)

33. This is a slip of paper. (V sC)

34. Stage directors are part of the movie team. (Ø sC)

35. The time slot was very convenient. (N sC)

36. There were five snobs in my grade 6 class. (F sC)

37. Story one has a happier ending, but it was very long. (Ø sC)

38. He took Slavic Literature last semester. (S sC)

39. I need five stamps. (F sC)

40. Raise your toe slightly. (V sC)

41. Slavery was abolished a long time ago. (Ø sC)

42. "Draw snooker tables," said the teacher. (V sC)

43. Dave snuggled up to his mother. (F sC)

44. Sneezing could be caused by an allergy. (Ø sC)

45. The blue sticker in her car indicated that she has a disability. (V sC)

46. Slant the picture to the right. (Ø sC)

47. Three stems were broken by the wind. (V sC)

48. She is not stupid. (S sC)

49. There is a stove in the kitchen. (V sC)

50. Snakes are eaten in some parts of the world. (Ø sC)

51. Grandpa slapped Tom for being rude. (V sC)

52. More students have graduated this year. (L sC)

53. Steamed fish is my favourite meal. (Ø sC)

54. There were twelve slabs of cheese on the table. (F sC)

55. Greg snores loudly. (S sC)

56. A snorkel allows a swimmer to breather underwater. (V sC)

57. I heard Jeff sneer at his employees. (F sC)

58. Start reading the book now. (Ø sC)

59. Tim snatched her purse and ran away. (N sC)

APPENDIX D

Formal task: Informants' version

Name: ____

Instructions: Read aloud the following sentences, please.

1. Mary works in a small store.
2. Dan slept early today.
3. Sniffer dogs are used by the police to find drugs.
4. He managed to sneak in through the back door.
5. I had Steve as a teacher.
6. John will sleep late tonight.
7. Stella is a nice person.
8. There are ten snails in the garden.
9. 'Stay put,' shouted the officer.
10. Many slim models are on the covers of fashion magazines.
11. Bob snapped his fingers to get his friend's attention.
12. He really likes her slender figure.
13. Beth still works two jobs.
14. 'Sleek' is the word he used to describe her hair.
15. The law states that you have the right to an attorney.
16. Slippery roads are dangerous.
17. The car is too slow.
18. The outlaw sniper was finally arrested.

19. She survived the terrible snow storm.

20. Slammer means prison.

21. Every day I eat three snacks.

22. Slide the keys under the door after you lock it.

23. Grandma stuffed the chicken.

24. Sneakers are very cheap in this shop.

25. A webcam stood right on top of his monitor.

26. Keep slicing these tomatoes please.

27. He ran into a snag, but he managed to finish on time.

28. Snares are still used to catch wild animals in some areas.

29. I wonder if slums still exist in that city.

30. "You can draw slippers," said the teacher.

31. Sniffing repeatedly can be a symptom of a bad cold.

32. The captain began steering left.

33. This is a slip of paper.

34. Stage directors are part of the movie team.

35. The time slot was very convenient.

36. There were five snobs in my grade 6 class.

37. Story one has a happier ending, but it was very long.

38. He took Slavic Literature last semester.

39. I need five stamps.

40. Raise your toe slightly.

41. Slavery was abolished a long time ago.

42. "Draw snooker tables," said the teacher.

43. Dave snuggled up to his mother.

44. Sneezing could be caused by an allergy.

45. The blue sticker in her car indicated that she has a disability.

46. Slant the picture to the right.

47. Three stems were broken by the wind.

48. She is not stupid.

49. There is a stove in the kitchen.

50. Snakes are eaten in some parts of the world.

51. Pa slapped Tom for being rude.

52. More students have graduated this year.

53. Steamed fish is my favourite meal.

54. There were twelve slabs of cheese on the table.

55. Greg snores loudly.

56. A snorkel allows a swimmer to breathe underwater.

57. I heard Jeff sneer at his employees.

58. Start reading the book now.

59. Tim snatched her purse and ran away.

APPENDIX E

Target Words with Onset Clusters

Cluster	words	Total
/st/	store, Steve, Stella, stay, stick, states, storm, stuffed, stood, steering, stage, story, stamps, sticker, stems, stupid, stove, students, steamed, start	20
/sl/	slept, sleep, slim, slender, sleek, slippery, slow, slammer, slide, slicing, slums, slippers, slip, slot, Slavic, slightly, slavery, slant, slapped, slabs	20
/sn/	sniffer, sneak, snakes, snapped, sniper, snow, snacks, sneakers, snag, snares, sniffing, snobs, snooker, snuggled, sneezing, snails, snores, snorkel, sneering, snatched	20

APPENDIX F

Onset Clusters and Preceding Consonantal Environments

Cluster	Preceding consonant	Sentence #	Total
/st/	/l/	1	8
	/d/	5	
	/z/	13	
	/v/	39	
	/r/	52	
	/t/	48	
	/n/	32	
	/m/	35	
/sl/	/n/	2	8
	/l/	6	
	/r/	12	
	/p/	26	
	/z/	29	
	/m/	35	
	/k/	38	
	/v/	54	
/sn/	/n/	8	8
	/b/	11	
	/l/	19	
	/v/	36	
	/g/	55	
	/z/	57	
	/v/	43	
	/m/	59	

APPENDIX G

Onset Clusters and Preceding Vocalic Environments

Cluster	Preceding vowel	Sentence #	Total
/st/	/ɔ/ /ow/ /ɑ/ /uw/ /iy/ /ə/	15 19 23 45 47 49	6
/sl/	/iy/ /uw/ /ɔ/ /ə/ /ow/ /ɑ/)	10 17 30 33 40 51	6
/sn/	/uw/ /ɔ/ /iy/ /ə/ /ɔ/ /ə/	4 18 21 27 42 56	6

APPENDIX H

Onset Clusters and Preceding Environments (Pauses)

Cluster	Sentence #	Total
/st/	7 9 34 37 53 58	6
/sl/	14 16 20 22 41 46	6
/sn/	3 24 28 31 44 50	6

APPENDIX I

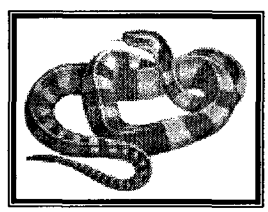
Informal task: Picture-based interview

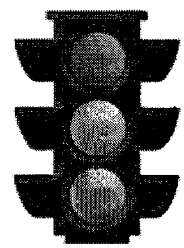
1. Sample questions:

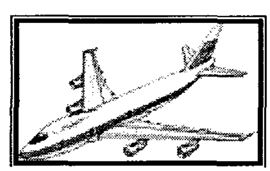
- What do you see in this picture?
- Have you ever seen one?
- Do you use it regularly?
- Do you like what you see in the picture? Why?
- Etc…

List of Interview Pictures

Picture #	Referent
1	Snake
2	Ball*
3	Stadium
4	Snail
5	Dog*
6	Sleeve
7	Sneeze
8	Cat*
9	Sleep
10	Student
11	Airplane*
12	Slap
13	Slippers
14	Stop
15	Snow
16	Hat*
17	Star







Note: * indicates distractors

APPENDIX J

BINOMIAL VARBRUL • 11/13/2007 7:54:58 PM ••••••••••••••••••••••••••••••••••

Name of cell file: condition.cel_first run

Averaging by weighting factors.
Threshold, step-up/down: 0.050001
Stepping up...

Groups selected while stepping up: 5 2 4 1
All remaining groups significant
Groups eliminated while stepping down: 3

Best stepping up run: #**14**
Best stepping down run: #**20**

Run # **14**, 538 cells:
Convergence at Iteration 9
Input 0.328
Group # 1 -- S: 0.612, L: 0.340, N: 0.513
Group # 2 -- c: 0.762, p: 0.584, v: 0.157
Group # 4 -- F: 0.343, I: 0.635
Group # 5 -- a: 0.586, b: 0.820, c: 0.382, d: 0.687, e: 0.869, f: 0.383, g: 0.304, h: 0.901, i: 0.270, j: 0.761, k: 0.197, l: 0.252, m: 0.369, n: 0.662, o: 0.757, p: 0.321, q: 0.648, r: 0.609, s: 0.107, t: 0.207, u: 0.340, v: 0.332, w: 0.752, x: 0.102, y: 0.922, z: 0.351, A: 0.609, B: 0.877, C: 0.516, D: 0.130
Log likelihood = -1885.809 Significance = 0.000

Run # **20**, 538 cells:
Convergence at Iteration 9
Input 0.328
Group # 1 -- S: 0.612, L: 0.340, N: 0.513
Group # 2 -- c: 0.762, p: 0.584, v: 0.157
Group # 4 -- F: 0.343, I: 0.635
Group # 5 -- a: 0.586, b: 0.820, c: 0.382, d: 0.687, e: 0.869, f: 0.383, g: 0.304, h: 0.901, i: 0.270, j: 0.761, k: 0.197, l: 0.252, m: 0.369, n: 0.662, o: 0.757, p: 0.321, q: 0.648, r: 0.609, s: 0.107, t: 0.207, u: 0.340, v: 0.332, w: 0.752, x: 0.102, y: 0.922, z: 0.351, A: 0.609, B: 0.877, C: 0.516, D: 0.130
*** Warning, negative change in likelihood (-0.00123372) replaced by 0.0.
Log likelihood = -1885.809 Significance = 1.000

Best stepping up and stepping down runs for the initial Goldvarb run of the Farsi-English data.

APPENDIX K

```
• CROSS TABULATION • 11/15/2007 2:00:27 PM
•••••••••••••••••••••••••••••••••••••
• Cell file:  condition.cel_first fun
• 11/15/2007 1:36:46 PM
• Token file: Tokens_First Run
• Conditions: condition.cnd_first fun

Group #3 -- horizontally.
Group #5 -- vertically.

        i    %     b    %     a    %     ∑    %
   + - - - - + - - - - + - - - - + - - - -
a x:    41  40:     0  --:     0  --|   41  40
  -:    61  60:     0  --:     0  --|   61  60
  ∑:   102    :     0    :     0    |  102
   + - - - - + - - - - + - - - - + - - - -
b x:     0  --:    96  63:     0  --|   96  63
  -:     0  --:    56  37:     0  --|   56  37
  ∑:     0    :   152    :     0    |  152
   + - - - - + - - - - + - - - - + - - - -
c x:    56  32:     0  --:     0  --|   56  32
  -:   118  68:     0  --:     0  --|  118  68
  ∑:   174    :     0    :     0    |  174
   + - - - - + - - - - + - - - - + - - - -
d x:    56  46:     0  --:     0  --|   56  46
  -:    65  54:     0  --:     0  --|   65  54
  ∑:   121    :     0    :     0    |  121
   + - - - - + - - - - + - - - - + - - - -
e x:     0  --:    83  69:     0  --|   83  69
  -:     0  --:    37  31:     0  --|   37  31
  ∑:     0    :   120    :     0    |  120
   + - - - - + - - - - + - - - - + - - - -
```

Cross-tabulation between the factors proficiency and participants. Empty cells are shown to illustrate interaction between the 2 factors. (For convenience, only a portion of the cross-tabulation output is displayed.)

APPENDIX L

• BINOMIAL VARBRUL, 1 step • 11/12/2007 12:23:46 PM ••••••••••••••••••••••••••
Name of cell file: condition.cel_second run
Averaging by weighting factors.
One-level binomial analysis...

Run # 1, 54 cells:
Convergence at Iteration 8
Input 0.334

Group	Factor	Weight	App/Total	Input&Weight
1:	S	0.607	0.45	0.44
	L	0.350	0.31	0.21
	N	0.509	0.41	0.34
2:	c	0.749	0.57	0.60
	p	0.589	0.43	0.42
	v	0.167	0.15	0.09
3:	b	0.803	0.64	0.67
	i	0.471	0.36	0.31
	a	0.218	0.19	0.12
4:	F	0.361	0.31	0.22
	I	0.617	0.47	0.45

Cell	Total	App'ns	Expected	Error
SviI	126	27	22.984	0.858
SviF	55	2	3.987	1.068
SvbI	123	56	62.046	1.189
SvbF	61	17	16.034	0.079
...				
LcbF	64	50	41.459	4.996
LcaI	81	23	21.400	0.163
LcaF	78	7	8.715	0.380

Total Chi-square = 79.0268
Chi-square/cell = 1.4635
Log likelihood = -1925.978

Binomial one-step analysis for the second Goldvarb run.

APPENDIX M

```
• CELL CREATION • 11/7/2007 10:46:10 AM
••••••••••••••••••••••••••••
     Name of token file: Tokens_First Run
Name of condition file: condition.cnd_first run
(
; Identity recode:  All groups included as is.
(1)
(2)
(3)
(4)
(5)
(6)
)
       Number of cells:  538
  Application value(s):  x
  Total no. of factors:  41

                   Non-
 Group      Apps   apps   Total     %
--------------------------------------
 1 (2)
   S   N     704    885    1589  38.3
       %    44.3   55.7

   L   N     369    830    1199  28.9
       %    30.8   69.2

   N   N     560    801    1361  32.8
       %    41.1   58.9

 Total N    1633   2516    4149
       %    39.4   60.6
------------------------------------
```

Factor by factor distributional analysis during the third and last Goldvarb run. For convenience, only the independent factor group *sC sonority* is included.

APPENDIX N

Result of Applying Gradual Learning Algorithm to Tableau Begin Informal.xls
7-02-2008, 11:58 p.m.
OTSoft 2.1, release date 4/17/03

1. Ranking Values Found

106.000	MAX-IO
97.732	*sC
96.268	DEP-IO

2. Matchup to Input Frequencies

/snake/	Input Fr.	Gen Fr.	Gen. #
es.nake	0.690	**0.688**	1375
snake	0.310	**0.312**	625
nake	0.000	0.000	

3. Testing the Grammar: Details

The grammar was tested for 2000 cycles.
Average error per candidate: 0.167 percent
Learning time: 0.013 minutes

4. Parameter Values Used by the GLA

Initial Rankings

All constraints started out at the default value of 100.

Schedule for GLA Parameters

Stage	Trials	PlastMark	PlastFaith	NoiseMark	NoiseFaith
1	12500	2.000	2.000	2.000	2.000
2	12500	0.200	0.200	2.000	2.000
3	12500	0.020	0.020	2.000	2.000
4	12500	0.002	0.002	2.000	2.000

There were a total of 50000 learning trials.

A screenshot of the GLA analysis: Beginner Informal grammar.