UNIVERSITY OF CALIFORNIA, SAN DIEGO

Learning to Share: Interaction in Spanish-English bilinguals' acquisition of syllable structure and positional phonotactics

A dissertation submitted in partial satisfaction of the requirements for the degree Doctor of Philosophy

in

Linguistics

by

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The Dissertation of Bethany J. Keffala is approved, and it is acceptable in quality and form for publication on microfilm and electronically:

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DEDICATION

This dissertation is dedicated to my mother,
Dr. Valerie J. Keffala.

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* * *

Chapter 2 contains material that is currently being prepared for submission for publication [Keffala, Barlow, & Rose (in prep.) "Markedness, Frequency, and the Positional Acquisition of Liquids in Spanish and English"]. The dissertation author

was the primary investigator and author of this paper. This work was also presented at the 2012 International Child Phonology Conference.

Chapter 3 is a revised version of Keffala, Barlow, & Rose (in press) [Interaction in Spanish-English bilinguals' acquisition of syllable structure. *International Journal of Bilingualism*. Advance online publication. doi:10.1177/1367006916644687]. The dissertation author was the primary investigator and author of this paper. Earlier versions of this work were also presented at the 88th Annual Meeting of the Linguistic Society of America and at the 2013 International Child Phonology Conference.

Chapter 4 is a revised version of a paper that is currently being prepared for submission for publication [Keffala, Barlow, & Rose (in prep.) "Interaction in bilingual phonological acquisition: Spanish-English bilinguals' acquisition of English coda clusters"]. The dissertation author was the primary investigator and author of this paper.

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ABSTRACT OF THE DISSERTATION

Learning to Share:
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by

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Doctor of Philosophy in Linguistics

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Professor Jessica A. Barlow, Co-Chair
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Though the majority of the world's population is bilingual, most of the existing research on child language acquisition has focused on monolinguals. Increasingly, research has begun to investigate language acquisition in bilingual contexts, and has found evidence of both similarity to and difference from patterns found in monolingual language acquisition. One evident source of difference in bilingual language acquisition is interaction, where bilinguals' acquisition of each language affects their acquisition of the other language. Interaction has been shown to occur at multiple levels of linguistic structure (syntactic, phonological, phonetic), and manifests in three different patterns: acceleration, deceleration, and transfer. Acceleration and deceleration refer to the rate at which bilinguals acquire some property relative to monolinguals in the same language. Acceleration occurs when bilinguals acquire some property faster or earlier compared to monolingual peers, whereas deceleration occurs when bilinguals acquire some property later or more slowly than monolingual peers. Transfer refers to bilinguals' use of a property specific to one language in their other language. While the occurrence of each of these patterns has been demonstrated in bilinguals' language acquisition, it is not well understood what causes interaction to occur where and how it does. In this dissertation, I propose that frequency of occurrence and linguistic complexity, features of the input known to affect the course of monolinguals' acquisition, also direct the appearance of interaction in bilinguals' acquisition of language. I present findings from a series of studies demonstrating that differences between languages in frequency of occurrence and complexity of phonological properties influence bilinguals' acquisition of aspects of Spanish and English phonotactics in predictable ways. Specifically, greater frequency of occurrence and greater complexity of phonological properties in one language are shown to promote bilinguals' acquisition of related phonological properties in their other language.

Chapter 1

Introduction

Children acquiring their first language must acquire the various subsystems that make up that language, including the phonological system. Acquiring a phonological system in turn entails acquiring, among other properties, the set of sounds the language uses, how these sounds relate to each other within the phonological system, and how the system allows sounds to co-occur and to organize into larger units, such as syllables. Bilingual children accomplish these tasks for two languages in the amount of time monolinguals take to acquire a single phonological system. This suggests efficiency on the part of bilingual learners, and raises questions regarding the strategies bilinguals might employ as they are learning their languages. Multiple studies have suggested that while bilinguals acquire two separate linguistic systems, these systems are interdependent and interact during the acquisition process (Almeida, Rose, & Freitas, 2012; Barlow, Branson, & Nip, 2013; Fabiano-Smith & Goldstein, 2010; Gawlitzek-Maiwald & Tracy, 1996; Gildersleeve-Neumann, Kester, Davis, & Peña, 2008; Kehoe, 2001; Lleó, 2002; Lleó, Kuchenbrandt, Kehoe, & Trujillo, 2003; Paradis & Genesee, 1996; Weinreich, 1953, among others). In other words, though bilingual children acquire two distinct systems, the acquisition of each system can affect the acquisition of the other.

Research on bilingual language acquisition has demonstrated the existence of three general patterns of interaction: deceleration[1], acceleration, and transfer (Paradis & Genesee, 1996). Deceleration and acceleration refer to the rate of aspects of bilinguals' language acquisition relative to monolinguals' acquisition. Acquisition is decelerated in bilinguals when it is slower relative to monolinguals' acquisition, and is accelerated when it is faster relative to monolinguals' acquisition. Transfer occurs when a bilingual uses a property belonging to one of their languages in their other language. Previous research on bilinguals' phonological productions during language development has shown that bilinguals exhibit a variety of learning patterns that diverge from monolinguals' acquisition along these lines. Examples of deceleration include lower consonant production accuracy in bilinguals compared to monolinguals (Fabiano-Smith & Goldstein, 2010; Gildersleeve-Neumann et al., 2008). Examples of acceleration include higher likelihood of inclusion of consonants in positional phonetic inventories compared to monolinguals, and higher production accuracy for syllable types (ignoring segmental accuracy) compared to monolinguals (Lleó et al., 2003). Finally, examples of transfer include higher production accuracy for shared sounds compared to unshared sounds (Fabiano-Smith & Goldstein, 2010), and transfer in phonetic inventories (Gildersleeve-Neumann et al., 2008; Fabiano-Smith & Barlow, 2010; Fabiano-Smith & Goldstein, 2010).

[1] Though Paradis and Genesee (1996) use the term 'delay,' I follow Fabiano-Smith and Goldstein (2010) in adopting the term 'deceleration' in order to avoid incorrect clinical implications associated with the word 'delay'.

Research investigating the process of bilingual phonological acquisition is still at an early point in its development. While studies have provided evidence of the occurrence of each of these patterns, researchers still lack a thorough understanding of what causes different manifestations of interaction to occur when and where they do. Some research has suggested that the degree of overlap or similarity between systems influences interaction such that greater overlap results in bilinguals' accelerated acquisition while a lesser degree or lack of overlap leads to decelerated acquisition (Barlow, Branson, & Nip, 2013; Mayr, Howells, & Lewis, 2014; Mayr, Jones, & Mennen, 2014; Goldstein & Bunta, 2012; Almeida, Rose, & Freitas, 2012; Kehoe, 2002; Fabiano-Smith & Goldstein, 2010). Related to the notion of degree of overlap is the existence of differences between languages in frequency of occurrence or complexity of linguistic properties. Acceleration has been found in Spanish-German bilinguals' acquisition of Spanish singleton codas (Lleó, Kuchenbrandt, Kehoe, & Trujillo, 2003) and was attributed to the greater frequency of occurrence of singleton codas in German compared to Spanish. In other words, bilinguals' acquisition of Spanish singleton codas was accelerated because they were exposed to this syllable type with greater frequency compared to Spanish monolinguals.

However, the same bilinguals did not exhibit decelerated acquisition of German singleton codas, despite their exposure to the less frequent occurrence of singleton codas in Spanish. Deceleration has been found, though, in Spanish-German bilinguals' acquisition of the German vowel length contrast (Kehoe, 2002). While the German vowel system uses vowel length contrastively, the Spanish vowel system does not. Bilinguals are therefore exposed to contrastive vowel length across their input with less frequency compared to German monolinguals. This difference in frequency, however, could also be considered a lack of overlap between systems or a difference between systems in phonological complexity (where the use of a length contrast is more linguistically complex). Recent research has begun to investigate the influence of complexity on interaction in bilingual language acquisition, where greater linguistic complexity of some property in one language has been associated with accelerated acquisition of the same property in bilinguals' other language (Hsin, 2012; Tamburelli, Sanoudaki, Jones, & Sowinska, 2015). However, in the case of Spanish-German bilinguals' acquisition of vowels described above, bilinguals did not exhibit accelerated acquisition of the Spanish vowel system, despite their exposure to the more complex vowel system of German (Kehoe, 2002).

Still other research has suggested that acceleration can occur as the result of a more general bilingual advantage (Grech and Dodd, 2008; Mayr, et al. 2014a;b), but this approach does not address instances of transfer or deceleration that occur during bilingual phonological acquisition, nor is it clear why acceleration sometimes occurs only in one language and not both, if the underlying mechanism behind interaction is increased awareness of linguistic structure or some similar advantage. More research is needed to determine what features of the input promote interaction, as well as how these features influence the different patterns of interaction that can occur in the developing systems of bilinguals.

This dissertation has two overarching goals. The first is to contribute new data regarding Spanish-English bilinguals' acquisition of phonotactic properties in each of their languages, focusing on acquisition of syllable structure and segments in different syllabic positions. To address this goal, I use new and previously collected data to examine Spanish-English bilinguals' acquisition of liquids in different syllabic positions, and of complex syllable structures including singleton codas, onset clusters, and coda clusters. Despite the fact that most of the world speaks more than one language (Harris & McGhee-Nelson, 1992), the vast majority of language acquisition research is based on monolingual children. Consequently, relatively little is known about bilinguals' phonological development, and there is a need for research that identifies and characterizes acquisition patterns that occur in different bilingual populations. The work presented in this dissertation adds to the field's knowledge of patterns that occur in Spanish-English bilinguals' acquisition of phonotactic properties in each language.

Beyond identifying patterns that occur in bilinguals' acquisition of each phonological system, there is also a need for research investigating how features of the input in each language influence bilinguals' acquisition. While interaction is known to occur during the acquisition process, it is not yet well understood what factors promote interaction, or how linguistic features of the systems a child is learning might influence how interaction appears in each of their languages. The second goal of this dissertation is to address this need by testing predictions about the influence of two input features that have been shown to affect language acquisition in monolingual children. Specifically, I investigate how differences between languages in frequency of occurrence and linguistic complexity of syllable types affect the appearance of interaction in Spanish-English bilinguals' acquisition of syllable structure in each language. Research on language acquisition in monolinguals has shown that greater frequency of occurrence of an element in the ambient language is correlated with earlier acquisition of that element, and that increased complexity in the ambient language similarly promotes acquisition (Levelt, Schiller, & Levelt, 1999/2000; Zamuner, 2003; Gierut, 2007, among others). I predict that differences between bilinguals' languages in complexity or frequency of occurrence of syllable types will promote the occurrence of interaction, and influence bilinguals' acquisition of syllable structure in each language. A brief outline of the chapters of the dissertation presenting this research is given below.

This dissertation is organized into five chapters. Chapter 2 presents the findings of a study evaluating the occurrence of liquids in the positional phonetic inventories of monolingual and bilingual children acquiring American English and Mexican Spanish. This study compared semi-complete phonetic inventories attested in cross-sectional data across three syllabic positions to inventories predicted by two theoretical approaches. The first approach hypothesizes that structural markedness and distributional statistics guide acquisition, and predicts that children learning one or both languages will acquire liquids in singleton onset first, followed by singleton coda, and in the second position of onset clusters last. The second approach hypothesizes that structural markedness and sonority guide acquisition, and predicts that children will not acquire a liquid in the second position of an onset cluster before having acquired that liquid in singleton coda. The results of the study suggest that, for monolinguals and bilinguals, liquid acquisition was guided by structural and sonority based markedness, and also by syllable type frequency in the language. Bilinguals' acquisition was furthermore influenced by their exposure to differences between languages in syllable type frequency. Bilinguals' positional order of acquisition of English /l/ was also influenced by their earlier expertise with Spanish /l/.

Interaction at the level of syllable structure is further explored in Chapter 3, which presents an investigation of bilinguals' and monolinguals' acquisition of onset clusters and singleton codas in Spanish and English. Analyses of single-word production data from Spanish and English mono- and bi-lingual preschoolers show that bilinguals exhibit higher accuracy in their productions of Spanish singleton codas compared to Spanish monolinguals, as well as higher accuracy in their productions of complex onsets in both languages compared to English and Spanish monolinguals. These results support the hypothesis that exposure to syllabic complexity in one language promotes acceleration in bilinguals' acquisition of related types in the other language. Further research is needed to determine whether and how frequency of occurrence of syllable types in one language affects the rate of bilinguals' acquisition of syllable structure in the other language.

Chapter 4 presents a study investigating monolinguals' and Spanish-English bilinguals' acquisition of English coda clusters. Analyses of single-word production data from bilingual and monolingual preschoolers show that they produce English coda clusters with comparable accuracy. This finding suggests that even very low frequency of occurrence of a syllable type in one of a bilingual's languages (e.g. coda clusters in Spanish) will not necessarily result in decelerated acquisition of that syllable structure in the language that uses that syllable type with greater frequency (e.g. coda clusters in English). However, though bilinguals' acquisition of English coda clusters was not decelerated, it was still affected by their exposure to Spanish. While monolingual participants produced English coda clusters and onset clusters at similar rates of accuracy, bilingual participants' onset cluster productions were more accurate than their productions of coda clusters. These accuracy scores suggest that bilinguals and monolinguals proceed differently in their relative development of these structures in English. The results of this study support the hypothesis that overlap between systems promotes accelerated acquisition in bilingual learners. Finally, chapter 5 summarizes the findings of the dissertation, and suggests directions for future research.

Chapter 2

Frequency and Markedness Effects in the Positional Acquisition of Liquids

2.1 Introduction

In the acquisition of syllable types, research has shown that structural complexity builds incrementally according to implicational markedness relationships. For instance, syllables with singleton codas are acquired before syllables with complex codas (Levelt, Schiller, & Levelt, 1999/2000).

(1) CVC > CVCC

However, it is less clear what guides the order of acquisition of syllable types when structural markedness comparisons are indeterminate. For example, consider syllables with singleton codas (Figure 2.1) and complex onsets (Figure 2.2).

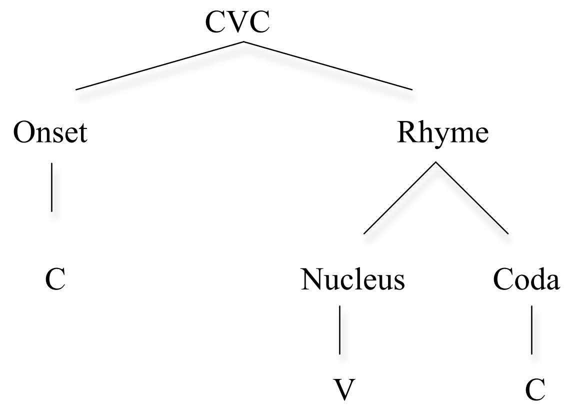

Figure 2.1 Syllable with singleton coda

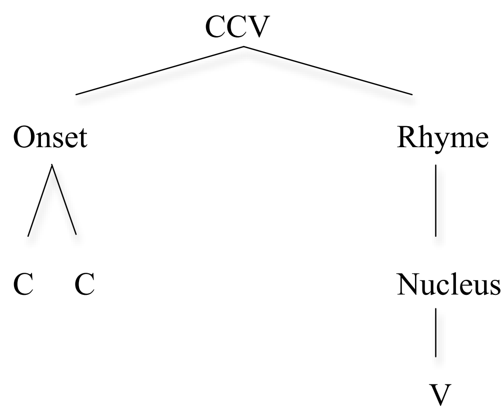

Figure 2.2 Syllable with complex onset

Each position adds structural complexity to the syllable, by creating either a branching rhyme or a branching onset. Furthermore, typological evidence (Blevins, 1995) reveals that language systems can exhibit increased complexity using either structure, allowing CVC syllables but not CCV syllables, and vice versa. A question arises, however, regarding the appearance of these two structures in developing grammars. Do children learning a language with both of these structures tend to acquire one before the other during their linguistic development? And if so, what guides this preference? Research suggests that, beyond markedness, frequency influences the acquisition order of syllable structure (Levelt, Schiller, & Levelt, 1999/2000; Kirk & Demuth, 2003; Jarosz, 2010), such that more frequent syllable types are acquired earlier than less frequent types. We should therefore expect children to show a tendency to acquire singleton codas before branching onsets if they are learning a language where singleton codas occur more frequently, and to acquire branching onsets before singleton codas for languages where onset clusters are more common than singleton codas.

The question of acquisition order is further complicated, however, when we consider the segmental content of syllabic positions. There is evidence that for different segments, different positional orders of acquisition are possible. For instance, children tend to acquire stops in singleton onset before acquiring them in singleton coda, but may produce more sonorous sounds such as fricatives or liquids in singleton coda before singleton onset (Stoel-Gammon, 1985; Fikkert, 1994; Dinnsen, 1996). Children also often produce velar stops in coda before producing them in onset (Stoel-Gammon, 1985; Bernhardt & Stemberger, 1998), and before producing them word-medially (Bernhardt & Stemberger, 2002). Bernhardt & Stemberger (1998) argue that such positional tendencies in acquisition result from a preference for vowel-like features in syllable rhymes. There is additionally evidence that children may produce liquids in the second position of onset clusters, a syllabic position that exhibits cross-linguistic preference for high sonority segments, before producing them in singleton onsets (Fikkert, 1994). When considering the positional acquisition of segments, we must ask what orders of acquisition are attested typologically, and what general or input-specific factors determine these orders.

To address these questions, we investigate the positional acquisition of liquids in American English and Mexican Spanish. Both languages permit liquids in singleton onset, and because liquids are relatively sonorous, both languages also permit them in singleton coda and in the second position of onset clusters. This distribution allows us to examine possible orders of acquisition of liquids between these three syllabic positions. In this retrospective study, we examine 46 cross-sectional phonetic inventories to determine what orders of acquisition are attested for liquids between these three positions. We compare these inventories to possible inventories predicted by two theoretical approaches to the positional order of acquisition of segments. One approach addresses potential effects of frequency (Jusczyk, Cutler & Rendanz, 1999; Roark & Demuth, 2000; Levelt, Schiller & Levelt, 1999/2000; Kirk & Demuth, 2003) and structural markedness (Demuth, 1995; Gnanadesikan, 2004; Levelt, Schiller & Levelt, 1999/2000), while the other addresses potential effects of structural and sonority-based markedness (Stoel-Gammon, 1985; Gnanadesikan, 2004; Pater, 1997; Baertsch, 2002).

A further dimension of this investigation compares the inventories of monolingual and bilingual learners. Research has shown that interaction can occur in bilingual phonological acquisition, such that bilinguals' acquisition of each language is affected by their acquisition of the other language (Paradis & Genesee, 1996;

Kehoe, 2002; Lleó, Kuchenbrandt, Kehoe, & Trujillo, 2003; Gildersleeve-Neumann, Kester, Davis, & Peña, 2008; Fabiano-Smith & Goldstein, 2010, Barlow, Branson, & Nip, 2013, among others). Given phonetic and phonological differences between liquid segments and their distributions in Spanish and English, it is unclear precisely how bilinguals' positional acquisition of liquids may differ from that of monolinguals in either language. A goal of this study is therefore to determine whether and how bilinguals' positional acquisition of liquids in each language is influenced by their acquisition of the other language.

Finally, establishing the positional acquisition order of liquids is important from a clinical perspective. Liquid sounds are among the latest acquired sounds in English (Bleile, 2004), while in Spanish, /l/ is acquired relatively early and rhotic sounds are acquired relatively late (Jiménez, 1987; Cataño, Barlow, & Moyna, 2009). Similarly, aside from being acquired later in typically developing children, liquids in English (Ingram, 1989; Shriberg & Kwiatkowski, 1994) and Spanish (Meza, 1983; Goldstein & Iglesias, 1996) are often implicated in speech sound disorders. Knowledge of implicational relationships in the positional order of acquisition of liquids, or simply of what patterns are attested, could inform treatment design. Specifically, the complexity approach to treatment of speech sound disorders suggests that selection of targets for treatment may be of central importance to treatment outcome (see Gierut, 2001; 2007 for review), and has shown that treatment employing more complex targets results in greater learning and generalization. Consequently, implicational relationships in the acquisition of liquids should be considered when designing a treatment plan for speech sound disorders involving liquids.

In the following sections, we present two hypotheses regarding the positional acquisition order of liquids. These hypotheses stem from considerations of the structural markedness of complex syllables, the frequency with which liquids occur in each syllabic position, and sonority preferences associated with different syllabic positions. While we consider order of acquisition of liquids between different positions (e.g. LV > CVL), we do not extend the scope of the article to consider acquisition order of different liquid segments relative to each other within each position.

2.1.1 The Influence of Structural Markedness

As children acquire language, their productions increase in complexity over time. For instance, children produce CV syllables before producing more structurally complex syllables, such as CVC or CCV (Jakobson, 1941/68; Vihman, Macken, Simmons, & Miller, 1985; Gnanadesikan, 2004; Levelt, Schiller, & Levelt 1999/2000). In other words, children acquire marked syllable structures (Clements & Keyser, 1983; Clements, 1990; Blevins, 1995) only after they have acquired implicationally less marked structures (Levelt, Schiller, & Levelt, 1999/2000).

This ordering can be demonstrated using the Optimality Theory framework[2] (Prince & Smolensky, 1993). In Optimality Theory, violable constraints represent competing pressures to i) avoid producing marked linguistic elements, and ii) faithfully produce linguistic elements in the input form (underlying representations). These constraints apply to candidate output forms for a given input form. Constraints are ranked with respect to each other such that the optimal output form incurs the fewest violations of the highest ranked constraints. Constraints are universal, and are ranked differently in different languages to allow different patterns of linguistic output. For example, in a language that does not allow syllables to end in a coda (a marked structure), the markedness constraint NOCODA (which penalizes codas) must outrank opposing faithfulness constraints that preserve features of the input form (such as MAX and DEP, which penalize deletion and epenthesis, respectively). Here we employ a generalized faithfulness constraint, FAITH, which penalizes changes between input and output forms.

(2)

Input: /CVC/	NOCODA	FAITH
a. ☞ CV		*
b. CVC	*!	

Input: /CVC/	FAITH	NOCODA
a. CV	*!	
b. ☞ CVC		*

[2] For the reader's convenience, see the Chapter Appendix for a table outlining terms and concepts from Optimality Theory used here.

Output candidates (possible realizations of the underlying form) are listed below the input form. The symbol '*!' indicates a fatal violation, while ☞ indicates the optimal output candidate. The tableau in (2) shows that when NOCODA is ranked above FAITH in the grammar, the optimal output for any input syllable will lack a coda, since a coda incurs a violation of the higher-ranked constraint, NOCODA. By contrast, languages that permit codas must rank relevant faithfulness constraints above NOCODA, since changes to syllabic structure violate higher-ranked faithfulness constraints.

In the earliest stages of acquisition, a child's grammar is hypothesized initially to rank all markedness constraints over all faithfulness constraints (Smolensky, 1996). Evidence for marked elements in linguistic input to the child motivates demotion of relevant markedness constraints below opposing faithfulness constraints, such that optimal output forms may contain the marked elements. This reflects the general trend in linguistic development of less complex output preceding more complex output. For example, a child learning a language that permits codas must demote NOCODA below structure-preserving faithfulness constraints. Similarly, a child learning a language with onset clusters must demote *COMPLEX (which penalizes tautosyllabic consonant clusters), below opposing faithfulness constraints to match the adult grammar. Since singleton onsets are structurally unmarked, the CV syllable type will be acquired first, whereas acquisition of more structurally complex singleton codas and onset clusters requires the demotion of markedness constraints below FAITH. If liquid acquisition across different syllabic positions is guided by structural markedness pressures, then we would expect these segments to be acquired first as onsets, simply because other syllabic positions are more structurally marked, as shown below (where “L” is a liquid):

(3)	Order	Initial constraint ranking
	a. LV > CVL	NOCODA >> FAITH
	b. LV > CLV	*COMPLEX >> FAITH

For languages that allow both codas and onset clusters, children must eventually demote both NOCODA and *COMPLEX below faithfulness constraints to acquire these marked structures. This suggests that children’s inventories should contain liquids in singleton onset first, followed by liquids in coda or in C2. Under this approach, liquids in singleton coda or in C2 would imply the existence in the same inventory of liquids in singleton onset during acquisition of a language that allows liquids in all three positions.

However, it is not clear how structural markedness might determine where liquids appear next between singleton codas and onset clusters. Since each structure is acquired after the demotion of a separate constraint (NOCODA below FAITH for singleton coda acquisition and *COMPLEX below FAITH for onset cluster acquisition), either structure could be acquired second. Levelt et al. (2000) suggest that in such circumstances where implicational markedness relationships are indeterminate, frequency guides acquisition order. They showed that children learning Dutch acquired the more frequent complex coda syllable type before acquiring the less frequent complex onset, similar to Kirk and Demuth's (2003) findings for children learning English. In contrast, Jarosz (2010) found that children learning Polish tended to acquire the more frequent complex onset before acquiring the less frequent complex coda. If structural markedness does not govern the positional acquisition of liquids between singleton coda and C2, then frequency is predicted to step in.

2.1.2 The Split Margin Approach

Aside from structural markedness, another potential factor to consider is markedness due to sonority. Research shows that different syllabic positions prefer segments with higher or lower sonority (Selkirk, 1982; Clements, 1990; Blevins, 1995; Zec, 1995). Cross-linguistically, singleton onsets with lower sonority are less marked than those with higher sonority, while higher sonority segments are less marked than lower sonority segments in singleton coda and in C2. Typological examples of this asymmetry can be found in Yakut, where the sonorous segments /r/ and /j/ are allowed in singleton coda but not in singleton onset, and in Campidanian Sardinian, where [r] occurs only in singleton coda or in C2, but not as a singleton onset (Davis & Baertsch, 2005). Similarly, Gujarati allows sonorous /w/ to surface faithfully in singleton coda and in C2, but not in word-initial singleton onsets where it instead surfaces as less sonorous [v] (de Lacy, 2001). Cross-linguistically, languages tend to place more restrictions on what can appear in coda or C2, often restricted to only more sonorous segments, whereas onsets tend to allow a greater variety of segments, but sometimes exclude very sonorous segments.

Research also suggests that segmental acquisition within or across syllabic positions is affected by positional sonority preferences. For instance, Stites, Demuth, and Kirk (2004) found that children acquiring English used either of two strategies in their acquisition of coda segments. They argued that children who acquired nasals or fricatives before stops in coda were attending to sonority-based markedness, since nasals and fricatives are more sonorous and therefore less marked than stops in coda. By contrast, children who acquired stops in singleton coda before nasals or fricatives were attending to frequency, since stops, while marked in coda generally due to their low sonority, are actually the most frequent coda segment type in English. Additionally, Stoel-Gammon (1985) showed that English monolingual infants between 15-24 months old often produced sonorous consonants in singleton coda before producing them in singleton onset, reflecting cross-linguistic positional sonority preferences.

Within the Optimality Theory framework, Baertsch (2002) proposed the existence of a Split Margin Hierarchy to account for cross-linguistic positional asymmetries in sonority preference. This approach makes predictions about both segmental distribution across languages and positional order of segment acquisition in child language acquisition. The Split Margin Hierarchy is an expansion of the Margin Hierarchy (Prince & Smolensky, 1993/2002), which addressed the observation that syllable onsets optimally have low sonority while syllable peaks optimally have high sonority. Prince and Smolensky proposed that syllable Margins, M, are governed by a hierarchy of sonority constraints whereby less sonorous segments are preferred to more sonorous segments. Syllable Peaks, P, are governed by a hierarchy of sonority constraints whereby sonorous segments are preferred. Prince and Smolensky's approach does not distinguish between codas and onsets in the treatment of Margins, although these positions do have different sonority preferences. Furthermore, in order to predict consonant clusters allowed by a language, researchers must appeal to sonority scales or sonority distance information external to the phonological grammar's constraint set (Baertsch, 2002). Finally, the Margin Hierarchy alone does not account for distributional similarities between segments allowed in singleton codas and those allowed in C2, where segments allowed in C2 are often a subset of segments allowed in singleton coda. Consequently, Baertsch (2002) argued in favor of splitting the Margin Hierarchy into M_1 and M_2 hierarchies to account for sonority-based distributional tendencies.

In the Split Margin Hierarchy, consonants are assigned to M_1 or M_2 positions. M_1 positions are singleton onsets, the first position of a complex onset, or the second position of a complex coda. M_2 positions are the second position of a complex onset (C2), singleton codas, or the first position of a complex coda, as shown in (4-5).

(4) p æ n
| | |
M_1 P M_2

(5) p l æ n t
| | | | |
M_1 M_2 P M_2 M_1

Consonants in M_1 and M_2 are governed by constraint hierarchies (6-7) that are organized by sonority.

(6) M_1 Margin Hierarchy
$*M_1/[+lo] >> *M_1/[+hi] >> *M_1/[r] >> *M_1/[l] >> *M_1/Nas >> M_1/Obs$

(7) M_2 Margin Hierarchy
$*M_2/Obs >> *M_2/Nas >> *M_2/[l] >> *M_2/[r] >> *M_2/[+hi] >> *M_2/[+lo]$

These constraints are ordered such that M_1 positions prefer segments with lower sonority, whereas M_2 positions prefer segments with higher sonority. The M_1 and M_2 hierarchies are segment-specific and separable, meaning that any particular segment can be acquired first as either a singleton onset (M_1) or a singleton coda (M_2).

To account for language-specific phonotactics on the occurrence of consonant clusters, the Split Margin approach employs a hierarchy of conjoined M_1 and M_2 constraints in addition to the two Margin Hierarchies. Conjoined constraints are complex constraints of the form *A&*B that are made up of the individual constraints *A and *B (Smolensky, 1997). For example, the conjoined constraint $*M_1/Nas\&*M_2/Obs$ is violated when M_1 contains a nasal and M_2 an obstruent (i.e. a nasal-obstruent onset cluster such as /nt-/ incurs a violation). M_1 and M_2 constraint hierarchies interact with these conjoined $*M_1/\alpha\&*M_2/\beta$ constraints, other markedness constraints such as ONSET (a syllable must have a margin, M_1), and faithfulness constraints. Together, these constraints result in a preference for low sonority M_1 segments (singleton onsets and the first members of onset clusters) and higher sonority M_2 segments (codas and C2).

Baertsch and Davis (2003) further suggest that the Split Margin approach's constraint hierarchies and their interaction obviate the necessity of the constraints *COMPLEX (which penalizes onset and coda clusters) and NOCODA (which penalizes codas). Placement of conjoined constraints from the Margin hierarchies dictates which onset clusters, if any, are allowed in a language. In order for a language to allow onset clusters, some of the conjoined $*M_1/\alpha\&*M_2/\beta$ constraints must be ranked below faithfulness constraints (FAITH >> $*M_1/\alpha\&*M_2/\beta$). Because conjoined constraints are universally ranked higher than their component constraints (Smolensky, 1997), it follows that those component constraints $*M_1/\alpha$ and $*M_2/\beta$ must also be outranked by faithfulness constraints. This means that segments dispreferred by $*M_2/\beta$ are necessarily allowed in singleton coda position, since faithfulness constraints that outrank $*M_1/\alpha\&*M_2/\beta$, will also outrank $*M_2/\beta$ ($*M_1/\alpha\&*M_2/\beta$ >> $*M_2/\beta$), as shown in (8).

(8)

Input: /tɹi/ 'tree'	$*M_1$/t&$*M_2$/ɹ	FAITH	$*M_2$/ɹ
a. ☞ [ti]		*	
b. [tɹi]	*!		*

Input: /tiɹ/ 'tier'	$*M_1$/t&$*M_2$/ɹ	FAITH	$*M_2$/ɹ
a. [ti]		*!	
b. ☞ [tiɹ]			*

Input: /tɹi/ 'tree'	FAITH	$*M_1$/t&$*M_2$/ɹ	$*M_2$/ɹ
a. [ti]	*!		
b. ☞ [tɹi]		*	*

Input: /tiɹ/ 'tier'	FAITH	$*M_1$/t&$*M_2$/ɹ	$*M_2$/ɹ
a. [ti]	*!		
b. ☞ [tiɹ]			*

Consequently, the Split Margin approach predicts that if a language allows onset clusters, that language must also allow codas (Baertsch & Davis, 2003). More specifically, any system that allows a segment in C2 necessarily also allows that same segment in singleton coda.

Framed in terms of acquisition, the Split Margin approach makes the prediction that acquisition of a segment in C2 cannot precede acquisition of that same segment in singleton coda (*CXV > CVX). However, no such implicational relationships are drawn between singleton onsets and either i) singleton codas or ii) C2. Singleton onsets are determined by the ranking of M_1, constraints, while allowable onset cluster and singleton coda segments are determined by the ranking of M_2 and conjoined constraints. Consequently, a segment may be acquired as a singleton onset before, after, or at the same time as it is acquired in C2 or in singleton coda. The Split Margin approach allows the following orders of acquisition for liquid segments (L) for the three positions we consider:

(9) Acquisition pathways allowed by the Split Margin approach

a. LV > CVL > CLV
b. CVL > LV > CLV
c. CVL > CLV > LV

In any order, acquisition of a liquid in C2 may not precede acquisition of a liquid in singleton coda. Two predicted orders allow liquids to be acquired first in singleton coda while one allows liquids to be acquired first in singleton onset.

Barlow and Gierut (2008) tested the prediction made by the Split Margin approach that for a given inventory the existence of a segment in C2 implies the existence of the same segment in singleton coda. They investigated the inventories of 16 children (14 acquiring American English and 2 acquiring Mexican Spanish) who produced liquids in word-initial C2, and determined if they also produced liquids in word-final coda position. Although the data were longitudinal, inventories from the same children acquired at different points in time were treated as different grammars, meaning that an implicational relationship where C2 liquids imply coda liquids would manifest such that each inventory with a liquid in C2 would have the same liquid in singleton coda. The results did not entirely support this prediction; there were inventories with a liquid in C2 but without the same liquid in singleton coda.

However, Barlow and Gierut (2008) did find that 68% of inventories inspected did in fact support the prediction that use of a segment in C2 implies its use in singleton coda. This tendency was stronger for the lateral liquid than for rhotic liquids. Of inventories with Cl clusters, only 15% did not also exhibit final [l], whereas 52% of grammars with rhotic clusters did not have final rhotics. They also found that participants who produced liquids in coda position exhibited higher accuracy on liquid clusters than participants who did not produce liquids in coda. However, this isn't entirely surprising, since this comparison is in essence between children using liquids in at least one syllabic position (C2) and children using liquids in at least two syllabic positions (C2 and singleton coda). Because Barlow and Gierut were investigating the predicted link between singleton coda and C2 only, they did not include data on liquids in singleton onset. Therefore, we don't have information about whether children acquired liquids in any of the three orders predicted by the Split Margin approach, or in singleton onset first, as predicted by the Structural Markedness and Frequency approach.

2.2 Positional Acquisition of Liquids in Spanish and English

The current study builds on Barlow and Gierut (2008), and examines the acquisition of liquids across singleton coda, C2, and singleton onset in Mexican Spanish and American English. Like Barlow and Gierut (2008), we consider word-initial onset clusters, and word-final singleton codas, but we additionally consider word-initial singleton onsets. We evaluate predictions made by the Structural Markedness and Frequency approach and by the Split Margin approach. We briefly outline the details of the distribution and positional frequency of occurrence of liquids in Spanish and English below, followed by a comparison of predicted inventory stages in acquisition according to the approaches discussed above.

While Spanish and English each use laterals and rhotics across positions, there are some differences between languages in liquid phonology, allophony, and phonetic realization.

Table 2.1 Distribution of liquid phonemes and allophones across syllabic positions in Spanish and English.

	Singleton Onset (word-initial)	C2	Singleton Coda
English	l (ɫ), ɹ	l (ɫ), ɹ	ɫ (l), ɹ
Spanish	l, r	l, ɾ	l, ɾ (r)

As shown in Table 2.1, Spanish uses a clear /l/ in singleton onset, C2, and singleton coda, while it uses the alveolar trill in singleton onset, and the tap in C2 and in coda (Proctor, 2009). Spanish rhotics are contrastive only intervocalically, and variation between them occurs in coda (Hualde, 2005; Proctor, 2009). English /l/ occurs in all three positions, but tends to be darker in C2 and coda than in singleton onset (Sproat & Fujimura, 1993; Huffman, 1997), and is darker relative to Spanish /l/ in all contexts (Proctor, 2009). Clear /l/ is articulated with the tongue body towards the front of the oral cavity and is associated with higher F2 values (where F2>1200Hz is typically perceived as clear), while dark /l/ is articulated with the tongue body towards the back of the oral cavity, sometimes with the back of the tongue body raised toward the velum, and is associated with lower F2 values (where F2<1200Hz is typically perceived as dark) (Huffman, 1997; Recasens, 2004; Recasens & Espinoza, 2005; Proctor, 2009). English uses approximant /ɹ/ in all three positions. For convenience and to avoid confusion, we henceforth use the symbols ***l*** and ***r*** to refer to the lateral and rhotic liquids in both languages.

In order to make frequency-based predictions, we must consider the distributional frequencies of the liquids in both languages. We obtained these frequencies using the SUBTLEX corpora for English ($\text{SUBTLEX}_{\text{US}}$) and Spanish ($\text{SUBTLEX}_{\text{ESP}}$), which are based on spoken language using subtitles from films and television series. The $\text{SUBTLEX}_{\text{US}}$ (Brysbaert & New, 2009) corpus contains 51 million words, while the $\text{SUBTLEX}_{\text{ESP}}$ (Cuetos, Glez-Nosti, Barbon, & Brysbaert, 2011) corpus contains 40 million words. Brysbaert & New (2009) showed that corpora of 16-30 million words yield reliable word frequency norms (without significant advantages for corpora exceeding 30 million words), while Brysbaert, Keuleers, & New (2011) and Cuetos et al. (2011) showed that $\text{SUBTLEX}_{\text{US}}$ and $\text{SUBTLEX}_{\text{ESP}}$ respectively best predicted word processing times, even compared to larger written language corpora. This research suggests that the SUBTLEX corpora are currently the best available resources for determining word frequencies in spoken language, and are thereby appropriate for determining phonotactic pattern frequencies in spoken language.

We take these frequencies to be generally representative of the phonotactic patterns in the spoken language to which children are exposed, based on research suggesting that frequencies derived from adult language corpora are appropriate for use in child language acquisition research. Storkel and Hoover (2010) showed that phonotactic probability and neighborhood density were positively correlated between adult (dictionary-based) and child production corpora. Gierut and Dale (2007) similarly showed that child and adult receptive and expressive corpora are consistent with each other, concluding that any large lexical corpus should be suitable for use in child language acquisition research. Moreover, Jusczyk, Luce, & Charles-Luce (1994), showed that positional phoneme and biphone frequencies are largely similar in adult-directed and child-directed speech corpora. Given that researchers have shown that adult language corpora can appropriately be used in child language research, and given that currently available corpora for child-directed speech are small (particularly in the case of Spanish), we chose to use the robust frequency information derived from the SUBTLEX corpora for each language. While frequencies obtained from the speech each participant was exposed to would have been ideal, these data were unavailable.

We obtained positional token frequency counts for liquids from the SUBTLEX corpora using the CMU Pronouncing Dictionary (Carnegie Mellon Speech Group, 1993) and a syllabification algorithm (Gorman, 2013) for English[3], and a syllabification algorithm for Spanish (Cuayáhuitl, 2004). In our frequency analyses, we categorized intervocalic liquids as singleton onsets. While this classification is

[3] Note that we modified this syllabification algorithm to count syllable-final syllabic rhotics as instances of singleton coda ***r***.

consistent with adult syllabification of Spanish (Harris, 1983; Colina, 1997), the status of intervocalic consonants in English is less clear (Borowsky, 1986; Blevins, 1995). Furthermore, syllabification of intervocalic consonants may be subject to individual differences in the developing grammars of children (Bernhardt & Stemberger, 2002; Barlow, 2007). Calculating positional liquid frequencies only at word edges (word-initial singleton onsets and clusters, word-final singleton codas) changes the relative frequencies between singleton onset and singleton coda for English ***l*** and Spanish ***r***. For word edges, English ***l*** appears to be slightly more frequent in singleton coda than in singleton onset (2.98% of words end in singleton coda ***l*** compared to 2.26% of words that start with singleton onset ***l***), unlike the pattern found over syllables where ***l*** is slightly more frequent in singleton onsets (3.91% of syllables start with singleton onset ***l***, while 3.38% of syllables end with singleton coda ***l***). However, calculating over words or syllables, the frequency counts for English ***l*** in singleton onset and coda are within a single percentage point of each other, suggesting that they occur in these positions with similar frequency. The difference for Spanish ***r*** is far more substantial, where 1.49% of words start with singleton onset ***r*** and 5.15% of words end with singleton coda ***r***, compared to 10.49% of syllables starting with singleton onset ***r*** and 9.86% of syllables ending in singleton coda ***r***. Given that intervocalic consonants in Spanish are syllabified as onsets, and given that the difference in frequency between English singleton onset and singleton coda ***l*** is small under either analysis, we chose to categorize intervocalic consonants as onsets in both languages for consistency, following the principle of onset maximization (Selkirk, 1982).

The following counts represent the frequencies with which liquids appear in each syllabic position over the total number of syllable tokens in each corpus. For example, 3.91% of syllables in $\text{SUBTLEX}_{\text{US}}$ and 10.08% of syllables in $\text{SUBTLEX}_{\text{ESP}}$ had an ***l*** in singleton onset.

Table 2.2 Liquid Frequency Data calculated from $\text{SUBTLEX}_{\text{US,ESP}}$. Rhotics are collapsed for Spanish under the symbol ***r***, while allophones of English /l/ are collapsed under the symbol ***l***.

	English			Spanish		
	Singleton Onset	Singleton Coda	C2	Singleton Onset	Singleton Coda	C2
l	**3.91%**	3.38%	1.20%	**10.08%**	5.42%	1.52%
r	3.38%	**8.25%**	2.85%	**10.49%**	9.86%	6.47%
Total	*7.29%*	*11.58%*	*4.05%*	*20.57%*	*15.28%*	*7.99%*

The lateral in Spanish and English is most frequent in singleton onset followed by singleton coda, and least frequent in C2. While frequency of ***l*** in English is quite similar between singleton onset and coda, Spanish ***l*** is much more frequent in singleton onset. For English, ***r*** is most common in singleton coda followed by singleton onset, where it is slightly more common than in C2. This differs from Spanish, where ***r*** is most common in singleton onset, slightly less common in singleton coda, and least common in C2. Given that the liquids in both languages occur in singleton coda more frequently than in C2, the Structural Markedness and Frequency approach, which appeals to frequency in this case, predicts that children should acquire liquids in coda before acquiring them in C2.

Because the data are cross-sectional rather than longitudinal, we have access not to orders but to complete and semi-complete inventories. Semi-complete inventories, those with a liquid in some but not all positions, allow for inferences about the orders of acquisition that occur in each language. If structural markedness and frequency guide the positional acquisition of segments[4] as they guide the acquisition of syllable types, then children should produce liquids first in singleton onset, followed by coda, since liquids are more frequent in coda than in C2. We therefore expect semi-complete inventories with liquids in singleton onset alone, and with liquids in singleton onset and coda. By contrast, the Split Margin approach predicts that liquids may be acquired at any point in singleton onset, but that they must be acquired in singleton coda before being acquired in C2. In this case, we expect semi-complete inventories with liquids in singleton coda alone, in singleton onset alone, with liquids in coda and C2, and with liquids in singleton onset and coda. Predicted longitudinal orders and cross-sectional inventories are given in Table 2.3.

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[4] In this and subsequent chapters, I make the assumption that children's use or acquisition of a consonant in a given position within a word is representative of their use or acquisition of syllabic structure associated with that position. For example, use of word-final [n] in /spun/, 'spoon', indicates use of singleton coda structure. This assumption reflects syllable-based approaches to consonantal phonotactics. It should be noted that other approaches to consonantal phonotactics (e.g. Steriade, 1999; Blevins, 2003), do not posit the existence of syllable structure, and instead use string-based constraints on linear representations to account for segmental sequencing patterns. However, in this dissertation I employ terminology and assumptions from more widely used syllable-based approaches, following Barlow (2001; 2004; 2005), Barlow & Gierut (2008); Kirk & Demuth (2003; 2005), Lleó et al. (2003), and Levelt, Schiller, & Levelt (1999/2000), among many others.

Table 2.3 Predicted longitudinal orders and corresponding semi-complete inventories from cross-sectional grammars.

	Structural Markedness & Frequency	Split Margin
Longitudinal Orders	LV > CVL > CLV	LV > CVL > CLV CVL > LV > CLV CVL > CLV > LV
Cross-Sectional Inventories		
One position	LV	LV CVL
Two positions	LV + CVL	LV + CVL CVL + CLV

Both approaches predict that liquids will be acquired in singleton coda before being acquired in C2.

In the following sections, we examine liquids in the positional phonetic inventories of monolingual children acquiring American English or Mexican Spanish, and compare these inventories to those predicted by the Structural Markedness and Frequency and Split Margin approaches. Aside from establishing possible patterns in the positional acquisition of liquids in these languages, we examine the effects of language-specific factors. Following our discussion of monolinguals, we investigate positional liquid acquisition in bilinguals, who are exposed to distributional information from each of their languages.

2.3 Monolingual Inventories

Participants

Data were drawn from the archives of a larger study on monolingual and bilingual acquisition of Spanish and English by children in the Southern California and Baja California area. We examined 28 phonetic inventories (14 Spanish, 14 English) contributed by 23 child participants (14 Spanish monolinguals, 9 English monolinguals). Monolingual English participants 1, 2, and 3 contributed more than one inventory at different ages (three, three, and two inventories respectively). These cross-sectional inventories give snapshots of children's developing systems at different stages, each indicating what a possible sound system looks like. This approach is similar to that of Cataño, Barlow, & Moyna (2009) in their typological investigation of complexity in cross-sectional inventories. Participants were monolingual speakers of Spanish or English, with normal hearing and general development as determined by a parent questionnaire. Spanish monolinguals (10 female, 4 male) ranged in age from 2.25-6.5 (mean age: 4.51 years), while English monolinguals (5 female, 4 male) ranged from 2.33-8.42 (mean age: 4.95 years).

Materials and analysis

Positional phonetic inventories were obtained from the participants' productions on the Assessment of English Phonology (AEP; Barlow, 2003a) or the Assessment of Spanish Phonology (ASP; Barlow, 2003b). These phonological probes were administered as a picture-naming task to elicit single-word responses (spontaneously and in the appropriate language, e.g. "What's this? It's a _____", or with delayed imitation when necessary, e.g. “It’s a lemon. What is it?”). Each assessment targets all phonemes of the respective language in a minimum of five words per relevant context. As in Barlow and Gierut (2008), consideration of positions was constrained to the beginnings or ends of words, such that word-medial onsets, onset clusters, and codas were excluded from analysis. The ASP targets 25 Spanish ***l*** words and 28 Spanish ***r*** words in word-initial singleton onset, word-final singleton coda, and word-initial cluster contexts. The AEP targets 32 English ***l*** words and 71 English ***r*** words in the same positional contexts. Participants' productions were digitally recorded onto a Dell Latitude 7200 laptop with Adobe Audition® 1.5 software via a SONY ECM-MS907 omnidirectional electret condenser microphone. The recording parameters included a single-channel input and 16-bit resolution, with a 44.1 kHz sampling rate. The recordings were saved in an uncompressed format.

Positional phonetic liquid inventories were established for each participant using transcriptions of his or her productions elicited by the probe. Transcribers were trained in the use of narrow notation of the IPA for both English and Spanish. Spanish productions were transcribed by native Spanish speakers, while native English speakers transcribed English productions. Reliability was measured via re-transcription of 20% of the data by a second transcriber. Point-to-point interjudge reliability for each target probe word was 88% for Spanish transcriptions and 91% for English transcriptions. For the purposes of the current study, we followed a typical criterion for establishing phonetic inventories, and recorded a sound as ‘present’ in a given position in a given phonetic inventory if it occurred in the child’s productions a minimum of two times in that position (Stoel-Gammon, 1985; Dinnsen, Chin, Elbert, & Powell, 1990; Powell & Miccio, 1996; Cataño, Barlow, & Moyna, 2009, among others). For example, for an inventory to include /l/ in all positions under consideration, the child would have produced [l] at least twice as a word-initial onset, at least twice in word-initial C2, and at least twice in word-final singleton coda. Transcriptions of [l] and [ɫ] were both counted as instances of the lateral liquid in English since variation in velarization of /l/ is attested in the ambient language (Proctor, 2009). Similarly, since variation between [ɾ] and [r] occurs outside of intervocalic contexts in Spanish (Proctor, 2009), transcriptions of [ɾ] and [r] were both counted as instances of rhotic liquids, ***r***.

2.3.1 Results

Of the 14 monolingual Spanish inventories, 12 had ***l*** in at least one position, including eight complete inventories (with ***l*** in all positions under consideration). There were similarly 12 inventories with ***r*** in at least one position, seven of which had ***r*** in all positions. Of the 14 monolingual English inventories, 11 had ***l*** in at least one position, including eight complete inventories with ***l*** in all positions. Eleven English inventories included ***r*** in at least one position, and eight had ***r*** in all positions. Four Spanish inventories with ***l*** and five with ***r*** were semi-complete, while for English there were three semi-complete inventories in the case of each liquid.

Table 2.4 presents inventories with liquids in C2, and shows where else liquids occur in these inventories. In every inventory with a liquid in C2, the same liquid occurred in at least one other position (i.e. no inventory contained a liquid in C2 only). In fact, all monolingual inventories with a liquid in C2 were complete except for a single Spanish inventory in which ***l*** occurred in singleton onset and C2, but not in coda.

Table 2.4 Monolingual inventories with liquids in C2

		Spanish	English
l in C2		9	8
	…alone	-	-
	…and singleton onset	1	-
	…and singleton coda	-	-
	…and both singleton onset and coda (all positions)	8	8
r in C2:		7	8
	…alone	-	-
	…and singleton onset	-	-
	…and singleton coda	-	-
	…and both singleton onset and coda (all positions)	7	8

In other words, a liquid in C2 implied the existence in that inventory of the same liquid in both singleton onset and singleton coda. The only exception to this was the case of Spanish ***l*** for one child, where ***l*** in C2 only implied ***l*** in singleton onset.

Table 2.5 presents semi-complete inventories that included a liquid in some position, but not in C2. Both Spanish liquids appeared in singleton onset only, and in both singleton onset and singleton coda. One Spanish inventory had ***r*** in singleton coda only. In English inventories, both liquids occurred alone in singleton coda, and in both singleton onset and coda. One English inventory had ***r*** in singleton onset only.

Table 2.5 Monolingual inventories with liquids not in C2

		Spanish	English
l in	singleton onset only	2	-
	singleton coda only	-	2
	singleton onset and singleton coda	1	1
r in	singleton onset only	3	1
	singleton coda only	1	1
	singleton onset and singleton coda	1	1

These data show directly that rhotic liquids in both languages can be acquired first in singleton onset or singleton coda, and that the lateral liquid can be acquired first in singleton onset in Spanish, or in singleton coda in English. Tables 2.4 and 2.5 together show that while liquids overall occurred in singleton onset or singleton coda alone, they did not occur in C2 without also appearing in another position. The semi-complete inventories attested in the monolingual data from English and Spanish are summarized in Table 2.6.

Table 2.6 Semi-complete inventories

		Spanish	English
Liquid in	one position:	LV (5) CVL (1)	LV (1) CVL (3)
	two positions:	LV + CVL (2) LV + CLV (1)	LV + CVL (2)

2.3.2 Discussion of Monolingual Inventories

In both languages, inventories with liquids in one position showed that rhotics were acquired first in either singleton onset or singleton coda, although more Spanish inventories had onset ***r*** than coda ***r***. Inventories also showed that Spanish ***l*** was acquired first in singleton onset, whereas English ***l*** was acquired first in singleton coda. While we did not find direct evidence of English monolinguals' primary acquisition of ***l*** in singleton onset, it cannot be ruled out as a possible first stage for some of the larger inventories. Data from other acquisition studies have shown that English monolinguals can also acquire ***l*** in singleton onset before acquiring it in coda (e.g. Stoel-Gammon, 1985). More data are also needed to determine whether ***l*** in Spanish can be acquired first in singleton coda.

The absence of inventories with liquids only in C2 was consistent with both the Structural Markedness and Frequency approach and the Split Margin approach. The Structural Markedness and Frequency approach correctly predicted inventories with liquids only in singleton onset, but failed to predict those with liquids only in singleton coda, as this is a more complex structure. The Split Margin approach made no predictions regarding order of emergence of these two categories, essentially leaving individual choice or other factors to determine whether liquids are acquired first in singleton onset or singleton coda. Inventories with liquids in one position therefore suggest that participants were behaving as predicted by the Split Margin approach, or at the very least that acquisition was influenced by both structure (singleton onset first) and sonority (singleton coda first). Note that if frequency were considered alone, it would predict no preference for coda or onset position for ***l*** in English or ***r*** in Spanish, but should prefer singleton onset ***l*** in Spanish and coda ***r*** in English. In fact, Spanish inventories favored onset position for both liquids, and English inventories showed a preference for coda ***l***, but no preference for coda ***r***.

Inventories with liquids in two positions differed between Spanish and English. English inventories were limited to liquids in singleton onset and coda, predicted by either approach. Some Spanish inventories also had liquids in singleton onset and coda, which again is predicted by both approaches. The Split Margin approach predicted the existence of inventories with liquids in singleton coda and C2 but not singleton onset, but these did not occur in the data. Of the 28 inventories with a liquid in C2, we found that 27 (96.4%) also had the same liquid in singleton coda, which supports findings from Barlow and Gierut (2008) that inventories with liquids in C2 tend to have the same liquid in singleton coda. However, all 28 inventories with a liquid in C2 had the same liquid in singleton onset, a position that Barlow and Gierut did not consider. One Spanish inventory had ***l*** in C2 and singleton onset, but not in singleton coda. This semi-complete inventory, (LV, CLV) is not predicted by either approach. Inventories with a liquid only in singleton onset or in singleton onset and coda did exist. Taken together, these data suggest an implicational relationship in acquisition between C2 and singleton onset such that a liquid in C2 implies the existence of the same liquid in singleton onset.

Most semi-complete Spanish inventories contained liquids in singleton onset. All four semi-complete inventories with ***l*** had it in this position, including two inventories where ***l*** occurred in singleton onset exclusively. Four out of five semi-complete inventories with ***r*** had it in singleton onset, including three inventories where ***r*** occurred in singleton onset only. Most semi-complete inventories in English, by contrast, contained liquids in singleton coda. All three semi-complete inventories with ***l*** had it in singleton coda, two of which contained ***l*** in singleton coda alone. Two of three semi-complete inventories with ***r*** had it in singleton coda. Overall, the shapes of monolingual phonetic inventories suggest that structural markedness strongly influenced the positional acquisition of liquids, given that liquids were acquired first or second in singleton onset (there is no evidence that liquids were acquired in singleton onset last). However, positional sonority preferences also appear to exert an influence, given that liquids were also acquired first in singleton coda. In English, all but one semi-complete inventory included a liquid in singleton coda. It's possible that structural markedness played a greater role in guiding positional liquid acquisition for some children while sonority may have played a greater role for others, and that attention to structure versus sonority produces a source of variation in acquisition patterns.

Furthermore, rather than the positional frequency of liquids, syllable type frequency overall may take part in directing children's attention. Singleton codas are very frequent in English, but less frequent in Spanish, which is correlated with earlier acquisition of coda structure in English (Demuth, 2001; see also Lleó et al. 2003 for data on singleton coda acquisition in German and Spanish). Whereas over half (56.7%) of English syllables have codas, 47.9% of which are singleton codas, only one third (31.9%) of Spanish syllables do, almost all of which (31.8%) are singleton codas ($SUBTLEX_{US,ESP}$). However, 84.4% of Spanish syllables have onsets, 4.2% of which are complex onsets, while 78.8% of English syllables have onsets, 5.4% of which are complex. The greater asymmetry in the frequency of occurrence of onsets versus codas in Spanish syllables may result not only in later acquisition of coda structure, but in a greater tendency to acquire segments in syllable onsets before acquiring them in codas. Similarly, the prevalence of closed syllables in English may support the primary acquisition of segments in singleton coda position, especially in the case of high sonority segments. We turn now to the phonetic inventories of bilingual children.

2.4 Bilingual Inventories

For monolinguals, we found evidence that learners attended to structural and sonority-based markedness pressures (some participants acquired a liquid first in singleton onset, others in coda), to distributional frequency patterns (liquids in C2 only occurred in inventories with liquids in singleton onset or singleton onset and coda), and to systematic structural preferences (the low frequency of coda syllables in Spanish may result in later acquisition of this structure, and of segments in this syllabic position). Below we investigate whether these results are generalizable to bilinguals' acquisition of liquids, or whether bilinguals' positional phonetic inventories exhibit characteristics different from the inventories of monolinguals. It is possible that exposure to distributional information about liquids or the frequency of syllable types from one language may influence the positional order of acquisition of liquids in the other language.

Participants

Data were drawn from the same archives as the monolingual data, collected as part of a larger study on monolingual and bilingual acquisition of Spanish and English by children in the Southern California and Baja California area. We examined 18 bilingual phonetic inventories (9 Spanish, 9 English) contributed by 9 child participants (5 female, 4 male), who ranged in age from 3.5-8.25 (mean age: 5.5 years). Each participant contributed two inventories, one in each language. All bilingual participants had normal hearing and general development as determined by a parent questionnaire. Parents reported that bilingual participants had a minimum of 20% input and output in Spanish and English (following Pearson, Fernandez, Ledeweg, & Oller, 1997). Furthermore, all bilingual participants were exposed to Spanish from birth and started learning English before age 5 (one participant was exposed to both languages from birth), meaning that all started learning their second language before the first was fully established. Participants were determined by these criteria to be early bilinguals (McLaughlin, 1978; Flege, 1991; Flege, Munro, & MacKay, 1995; Hamers & Blanc, 2000; Gildersleeve-Neumann & Wright, 2010, among others).

Materials and analysis

Data collection methods and analysis were identical to those described for monolinguals. Both the ASP and the AEP were administered to bilingual participants. Elicitation for each of a bilingual's languages took place in separate sessions. As in experiment 1, reliability was measured via re-transcription of 20% of the data by a second transcriber. Point-to-point interjudge reliability for each target probe word was 88% for Spanish transcriptions and 90% for English transcriptions.

2.4.1 Results

Of the nine bilingual Spanish inventories, all had ***l*** in at least one position, including eight complete inventories (with ***l*** in all positions under consideration). There were eight inventories with ***r*** in at least one position, four of which had ***r*** in all positions. Of the nine bilingual English inventories, eight had ***l*** in at least one position, including four with ***l*** in all positions. All nine bilingual English inventories had ***r*** in at least one position, including five with ***r*** in all positions. One Spanish inventory with ***l*** and four with ***r*** were semi-complete, while for English there were four semi-complete inventories in the case of both ***l*** and ***r***.

Inventories with liquids in C2 are outlined in Table 2.7. As was the case for monolinguals, liquids never occurred in C2 alone; every bilingual inventory with a liquid in C2 contained the same liquid in at least one other position.

Table 2.7 Bilingual inventories with liquids in C2

		Spanish	English
l in C2		8	7
	…alone	-	-
	…and singleton onset	-	3
	…and singleton coda	-	-
	…and both singleton onset and coda (all positions)	8	4
r in C2:		6	5
	…alone	-	-
	…and singleton onset	2	-
	…and singleton coda	-	-
	…and both singleton onset and coda (all positions)	4	5

While most bilingual inventories with a liquid in C2 were complete, five inventories included a liquid in singleton onset and C2 but not in singleton coda. This was the case for ***l*** in three English inventories, and for ***r*** in two Spanish inventories. Overall, a liquid in C2 implied the existence in that inventory of the same liquid in singleton onset. For ***l*** in Spanish and ***r*** in English, existence of that liquid in C2 implied the same liquid in both singleton onset and singleton coda.

Semi-complete inventories that included a liquid in some position, but not in C2 are given in Table 2.8. The one semi-complete Spanish inventory with ***l*** had it in singleton onset, and two semi-complete inventories with ***r*** had it in singleton onset and singleton coda. One English inventory contained ***l*** in singleton onset and singleton coda. Semi-complete inventories with English ***r*** contained the liquid in singleton onset (one inventory), singleton coda (one inventory), or in both singleton onset and coda (two inventories).

Table 2.8 Bilingual inventories with liquids not in C2

		Spanish	English
l in	singleton onset only	1	-
	singleton coda only	-	-
	singleton onset and singleton coda	-	1
r in	singleton onset only	-	1
	singleton coda only	-	1
	singleton onset and singleton coda	2	2

These data show directly that bilinguals may acquire English ***r*** first in singleton onset or singleton coda, and that the lateral liquid can be acquired first in singleton onset in Spanish. Tables 2.7 and 2.8 together show that while liquids overall occurred in singleton onset or singleton coda alone, they did not occur in C2 without also appearing in another position. The semi-complete positional liquid inventories found in the bilingual data from English and Spanish are summarized in Table 2.9.

Table 2.9 Semi-complete inventories

		Spanish	English
Liquid in	one position:	LV (1)	LV (1) CVL (1)
	two positions:	LV + CVL (2) LV + CLV (2)	LV + CVL (3) LV + CLV (3)

2.4.2 Discussion of Bilingual Inventories

Overall, bilinguals' semi-complete inventories included the same types found for monolinguals. Liquids occurred alone in singleton onset, as predicted by both the Split Margin and Structural Markedness and Frequency approaches, or singleton coda, as predicted by the Split Margin approach. Both approaches correctly predicted that liquids would not occur alone in C2. When liquids occurred in two positions, they occurred in singleton onset and coda, or in singleton onset and C2, a pattern that both the Structural Markedness and Frequency approach and the Split Margin approach predict should not occur. In both languages, bilinguals' semi-complete inventories almost always contained a liquid in singleton onset. Inventories with liquids in one position showed that bilinguals could acquire Spanish ***l*** first in singleton onset, similar to the Spanish monolingual data. These inventories also showed that bilinguals could acquire English ***r*** first in singleton onset or singleton coda.

Bilinguals showed different patterns of liquid acquisition between their two languages. All semi-complete bilingual Spanish inventories contained ***r*** in singleton onset, half of which also had ***r*** in C2 and half of which also had ***r*** in singleton coda. In English, however, ***r*** occurred in semi-complete inventories equally often in singleton onset and coda, with two inventories containing ***r*** in each position alone, and two containing ***r*** in both positions, resembling the pattern of results for ***r*** in monolingual English inventories. Bilinguals were more advanced in their acquisition of Spanish ***l*** compared to English ***l***; eight of nine Spanish inventories had ***l*** in all positions, compared to four complete inventories of seven with ***l*** in English. Bilingual inventories with English ***l*** included a pattern found in Spanish monolingual inventories with ***l***, but not in English monolingual inventories, where ***l*** occurred in singleton onset and C2 but not in singleton coda. Furthermore, bilingual English inventories with ***l*** always contained the liquid in singleton onset, unlike monolingual English inventories with ***l***, which always had it in singleton coda. Bilinguals' Spanish and English inventories with ***l*** resemble Spanish monolinguals' inventories more closely than English monolinguals' inventories. The lateral liquid is acquired relatively early in Spanish (Jiménez, 1987; Cataño, Barlow & Moyna, 2009), and it is possible that bilinguals are using their earlier expertise with Spanish ***l*** to support their acquisition of English ***l***, resulting in an acquisition pattern that appears more Spanish-like. This finding complements research suggesting that Spanish-English bilinguals acquire /l/ early in English compared to English monolinguals (Goldstein & Washington, 2001), and that Spanish-English bilinguals' productions of prevocalic [l] are categorically equivalent (Barlow, Branson & Nip, 2013).

Future research on bilinguals' positional acquisition of segments should additionally consider measures of participants' language proficiency or dominance, which have been shown to influence bilinguals' speech production abilities during acquisition. It is unknown whether language dominance might affect bilinguals' patterns of positional segmental acquisition, though less ability in or experience with a language have been associated with lower rates of consonant production accuracy (Goldstein, Bunta, Lange, Rodríguez, & Burrows, 2010) and higher rates of consonant error (Gildersleeve-Neumann et al., 2008) in the same language. All participants in the current study were able to interact with the experimenter and to complete the experimental task in the target language in a manner suggesting similar language proficiency. However, it is possible that measures of language ability (based on testing or parent report) might have revealed differences in bilingual participants' proficiency or dominance, which should be accounted for in future work.

2.5 General Discussion

Summarizing the results for all language backgrounds, liquids in mono- and bilingual Spanish often occurred in singleton onset. There was also evidence that Spanish monolinguals could acquire ***r*** first in singleton coda. When liquids occurred in two positions in mono- and bilingual Spanish inventories, they occurred in singleton onset and C2, or singleton onset and coda. In monolingual Spanish inventories, ***l*** in C2 implied ***l*** in singleton onset only, whereas ***r*** in C2 implied ***r*** in both singleton onset and coda. In bilingual Spanish inventories, ***l*** in C2 implied ***l*** in both singleton onset and coda, while ***r*** in C2 implied ***r*** only in singleton onset. Liquids in semi-complete monolingual English inventories often occurred in singleton coda or singleton onset. All monolingual English inventories with liquids in C2 were complete inventories, meaning that a liquid in C2 implied the same liquid in both singleton onset and coda. These patterns also applied in the case of ***r*** in English bilinguals' inventories. However, English bilinguals' inventories with ***l*** more closely resembled monolingual inventories for Spanish ***l***, where ***l*** in C2 implied ***l*** in singleton onset.

Many inventories with a liquid in C2 did contain the same liquid in coda, which is consistent with both the Structural Markedness and Frequency approach and the Split Margin approach. This was the case for liquids in English monolinguals' inventories, and for ***r*** in Spanish monolinguals' and English bilinguals' inventories.

Nevertheless, it was also possible for a liquid to occur in C2 and singleton onset but not in singleton coda. This pattern occurred for ***l*** in the Spanish inventories of monolinguals and the English inventories of bilinguals, and for ***r*** in the Spanish inventories of bilinguals. These inventories support neither the Split Margin approach nor the Structural Markedness and Frequency approach, which predict that liquids will be acquired in singleton coda before being acquired in C2.

Instead, we found evidence that positional acquisition of liquids was non-deterministically guided by structural markedness and sonority pressures as well as by syllable type frequencies in each language. Spanish uses codas far less frequently than English, and has a high percentage of syllables with onsets. The relative low frequency of codas is correlated with later acquisition of coda structure by Spanish monolinguals (Lleó et al. 2003). We argue that it also guides the positional acquisition of liquids such that they are usually acquired in onset positions before being acquired in coda. In addition to structural markedness pressures, it is possible that the perceptual prominence of word-initial syllables (Smith, 2002) may influence earlier acquisition of sounds at the beginnings of words compared to the ends of words, and acquisition of liquids in singleton onset and C2 before coda could be supported by the perceptual salience of these positions word-initially. However, some children are influenced by positional sonority preferences, and acquire liquids in singleton coda before other positions. Of the semi-complete inventories of monolingual English speakers, many had liquids in singleton coda. It's possible that more frequent exposure to codas may have drawn children's attention less toward structural markedness, and more toward sonority-based markedness.

Turning specifically to the bilinguals, we found differences in liquid acquisition patterns between their two languages, suggesting separate, language-specific systems affected by language-specific factors. Bilinguals' acquisition patterns for Spanish liquids were similar to those of Spanish monolinguals, and their acquisition of English ***r*** was similar to English monolinguals'. However, bilinguals experienced interaction in their acquisition of English ***l***. This interaction was evident in their semi-complete English inventories with ***l***, which resembled those of Spanish monolinguals. This finding contributes to evidence suggesting that bilinguals' acquisition of English ***l*** is in some way supported by acquisition of Spanish ***l***. Aside from earlier acquisition of English ***l*** in bilinguals compared to monolinguals (Goldstein & Washington, 2001) and categorical equivalence in bilinguals' productions of prevocalic English and Spanish ***l*** (Barlow, Branson, & Nip, 2013), we have shown that acquisition of Spanish ***l*** affects the trajectory of bilinguals' acquisition of English ***l***.

2.6 Conclusions

This study examined Spanish and English learners' phonetic inventories to evaluate predictions made by the Structural Markedness and Frequency approach and by the Split Margin approach regarding the positional order of acquisition of liquids. The phonetic inventory data presented here do not support the Split Margin approach, which predicts that a liquid must be acquired in singleton coda before it is acquired in C2. The Structural Markedness and Frequency approach also did not accurately predict all the data, which exhibited variation for each language and background. However, the pattern of results suggested the influence of both structural and sonority-based markedness, mediated by syllable type frequency in the language.

Future research exploring the influence of markedness and frequency on acquisition should investigate differences in the influences of different sources of markedness, including sonority, structural markedness, and segmental markedness. Research should also examine interaction between these markedness pressures and different kinds of frequency, as well as other factors such as prominence in perception or production. Data from younger children would also be valuable. In the current study, many of the grammars had all liquids in all positions, which resulted in the use of a smaller proportion of the data to establish inventory patterns. Additionally, the use of longitudinal grammars within participants may provide further insights about trends in acquisition order.

Future work should also systematically address potential effects of stress or of consonants elsewhere in the word on production of liquids in clusters and in word initial and word final positions, as suggested by two anonymous reviewers. For instance, Bernhardt & Stemberger (1998) proposed that features of the preceding consonant in clusters can facilitate or restrict the production of segments in C2 during acquisition, and thereby affect the acquisition of liquids in this position. Additionally, Hoffman (1983) and Hoffman, Schuckers, & Daniloff (1980) showed differing effects of treatment dependent on training using [ɹ] in stressed versus unstressed positions. Systematic investigations of the effects of stress or of preceding or following segmental context should be performed in future research designed to specifically address these factors. A larger number of inventories would additionally be needed for these analyses.

In their examination of effects of frequency on syllable type acquisition, Levelt, Schiller, & Levelt (1999/2000) showed that the token frequency of syllable types predicted the order in which syllable types were acquired (when implicational markedness relationships between types were indeterminate). Token frequency has also been shown to affect children's acquisition of segments. In Finnish, /d/ is acquired late compared to other languages due to its limited frequency, and the affricate /tʃ/ is acquired earlier in Spanish (Macken, 1995), where it is more frequent, than in English, where it is less frequent. Effects of token frequency have also been shown in the acquisition of coda segments in English (Zamuner, 2003; Stites, Demuth, & Kirk, 2004). In this study, we similarly calculated token frequencies for liquids between syllable positions. However, while ***l*** and ***r*** are frequently occurring sounds in both Spanish (Alarcos Llorach, 1991) and English (Zamuner, 2003; Mines, Hanson, & Shoup, 1978), there are differences between languages in the morphological distributions of liquids. Rhotics are used in grammatical morphemes in both languages, including Spanish verb forms (-*er*, -*ar*) and English agentive and comparative suffixes (-*er*), and Spanish uses ***l*** in a large proportion of articles and clitic pronouns (*el*, *la*, *los*, *las*, *le*, *lo*, *les*). In addition to token frequency, it would be valuable to consider the functional load for each liquid in each language. Various studies have suggested that functional load affects age or order of acquisition of speech sounds. For instance, Pye, Ingram, & List (1987) showed that the higher functional load of /tʃ/ in Quiché is correlated with earlier acquisition of the affricate compared to English, where the affricate has a lower functional load. Cataño, Barlow, & Moyna (2009) argued that the higher functional load of ***l*** in Spanish compared to English explains the earlier acquisition of this liquid in Spanish than in English, and Van Severen, Gillis, Molemans, Van Den Berg, De Maeyer, and Gillis (2013) showed that functional load accounts for the order of acquisition of word-initial consonants in Dutch better than token frequency. However, these studies were examining the age or order of acquisition of segments between languages or relative to other segments within a language rather than the positional order of acquisition for a given segment. Future work should additionally consider the morphophonemic distribution of liquids in each language, and investigate the role of type frequency or functional load on the positional acquisition order of segments.

Finally, since differences between bilinguals and monolinguals were found, future research should also examine bilingual and monolingual populations in more depth to investigate variability in acquisition patterns between these groups. Such differences should also be taken into consideration when assessing bilinguals' phonological abilities in a clinical setting. Our data suggest that for monolinguals acquiring ***l*** in Spanish and for bilinguals acquiring ***r*** in Spanish and ***l*** in English, a liquid in C2 implied the existence of the same liquid in singleton onset. Under the complexity approach to treating speech sound disorders (Gierut, 2001; 2007 for review), these results suggest that training with liquids in C2 will likely result in greater generalization than training with liquids in singleton onset. English monolinguals with liquids in C2 had the same liquids in both singleton onset and coda. The same pattern held for Spanish monolinguals' acquisition of ***r***, and for bilinguals' acquisition of English ***r***. This suggests that, concerning liquids for English monolinguals and English ***r*** for bilinguals, training with liquids in C2 will likely result in greater generalization than training with liquids in singleton onset or coda.

Our conclusions regarding English /ɹ/ are supported by Elbert & McReynolds (1975), who showed that training using [Cɹ] onset clusters or singleton onset [ɹ] resulted in greater improvement on trained items as well as greater generalization to untrained items across syllabic contexts. Similarly, Kent (1982) provided evidence from clinical and research reports demonstrating that production of [ɹ] is facilitated in [Cɹ] clusters. However, Hoffman (1983) and Hoffman, Schuckers, & Daniloff (1980) suggested that training using prestressed [ɹV, CɹV] or stressed postvocalic [ɹ] all result in more generalization to untrained items and contexts compared to unstressed postvocalic [ɹ]. Conclusions regarding treatment outcomes for each language background remain to be tested in a treatment study.

2.7 Chapter Appendix

This appendix outlines a set of key terms and their definitions from the Optimality Theory framework.

Term		Definition
Faithfulness constraint	-	constraint penalizing changes between input and output forms (e.g. MAX penalizes deletion, DEP penalizes epenthesis)
Markedness constraint	-	constraint penalizing marked forms (e.g. NOCODA penalizes forms that include syllable codas)
Constraint ranking	-	different grammars rank universal constraints differently with respect to each other
	-	in a given grammar, optimal output forms incur the fewest violations of the highest ranked constraints.
Input form	-	underlying representation of a form
Output form	-	surface realization of a form, the optimal selection among other candidates according to a given constraint ranking
Candidate	-	possible output form, assigned violations by relevant constraints
*	-	a violation, assigned to a form by a constraint
*!	-	a fatal violation, assigned to candidates that are comparatively less optimal in a given constraint ranking
☞	-	marks the optimal output candidate
NOCODA	-	constraint penalizing forms containing a syllable coda
*COMPLEX	-	constraint penalizing forms containing tautosyllabic consonant clusters
FAITH	-	generalized faithfulness constraint representing constraints that assign violations for difference between the input form and output candidates

2.8 Acknowledgements

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Chapter 3

Effects of Language-Specific Frequency and Complexity on Bilinguals' Acquisition of Syllable Structure

3.1 Introduction

Monolinguals face a number of tasks when acquiring the phonological system of their language, including but not limited to learning and mastering the set of sounds used, how these sounds interact within the phonological system, and how the sounds of their language can be organized into syllables. Bilinguals must do the same, but for two languages rather than one, in the same amount of time monolinguals take to acquire a single language. This raises many questions regarding how bilinguals manage these tasks, including whether and how they separate properties such as the sounds or syllable types of the languages they are learning. Much of the literature on bilingual phonological acquisition suggests that bilinguals employ two separate but interdependent linguistic systems based on evidence of both separation and interaction (Barlow, Branson, & Nip, 2013; Fabiano-Smith & Goldstein, 2010; Gawlitzek-Maiwald & Tracy, 1996; Gildersleeve-Neumann, Kester, Davis, & Peña, 2008; Kehoe, 2001; Lleó, 2002; Lleó, Kuchenbrandt, Kehoe, & Trujillo, 2003; Paradis & Genesee, 1996; Weinreich, 1953, among others).

Paradis and Genesee (1996) argued that interaction in bilingual language acquisition can manifest in three different ways, including acceleration, deceleration[5], or transfer. Subsequent studies have provided evidence for each kind of interaction (see below). Deceleration and acceleration both reference bilinguals' rate of acquisition in comparison to monolinguals. Deceleration denotes cases where some aspect of bilingual acquisition is slower relative to monolingual acquisition (e.g. for syntax, Swain, 1972; Vihman, 1982; or phonology, Gildersleeve, Davis and Stubbe, 1996; Gildersleeve-Neumann et al., 2008; Goldstein and Washington, 2001; Kehoe, 2002). Acceleration denotes cases where bilingual acquisition is faster relative to monolingual acquisition (e.g. for syntax, Gawlitzek-Maiwald & Tracy, 1996; Hsin, 2012; or phonology, Lleó et al., 2003). Transfer does not concern rate of acquisition, but refers to the use of some linguistic property that is specific to one language in the bilingual's other language (e.g. Barlow, 2003c; Fabiano-Smith & Barlow, 2010; Keshavarz & Ingram, 2002; Paradis & Genesee, 1996). Finally, multiple kinds of interaction may co-occur, such as transfer and deceleration, though this has not been widely researched or discussed (see, however, Almeida, Rose, & Freitas, 2012; Fabiano-Smith & Goldstein, 2010; Paradis & Genesee, 1996). While a number of studies have provided evidence that interaction occurs during bilingual acquisition, predicting what kind(s) of interaction will appear in what contexts is nontrivial. The

[5] Paradis & Genesee use the term 'delay', but we adopt the term 'deceleration', following Fabiano-Smith and Goldstein 2010 to avoid incorrect clinical associations.

aim of this study is to determine whether differences between language systems in the frequency of occurrence or complexity of phonological properties can predict the existence and direction of interaction in bilinguals' acquisition of those properties in each language. We present evidence from monolinguals' and bilinguals' acquisition of syllable types in English and Spanish suggesting that interaction is predictable based on the frequency of occurrence and complexity of syllable types in each language. Since our study focuses on the rate at which bilingual acquisition proceeds, the following discussion will focus on deceleration and acceleration.

3.1.1 Deceleration

A number of previous studies on interaction in bilinguals have presented evidence of deceleration. However, many of the existent phonological studies have found deceleration for general categories, comparing consonant or vowel accuracy overall, consonant accuracy for different consonant classes, or error rates in general (Gildersleeve, Davis and Stubbe, 1996; Gildersleeve-Neumann et al., 2008; Goldstein and Washington, 2001), sometimes in the form of case studies of one or two children (e.g. Holm & Dodd, 1999 on the phonological development of sequential Cantonese-English bilinguals). These findings are valuable, especially given the scarcity of information in the literature about bilingual development in general. Nevertheless, there is still a need for studies that investigate potential causes of deceleration during bilingual phonological acquisition.

Kehoe (2002) investigated vowel acquisition in Spanish-German bilinguals, and predicted interaction patterns on the basis of systemic differences in complexity. One prediction was that bilinguals' exposure to German's more complex vowel system (German employs a length contrast) would result in neither decelerated nor accelerated acquisition of the less complex Spanish vowel system (i.e. bilinguals and monolinguals would exhibit comparable rates of acquisition of the Spanish vowel system). A second prediction was that the influence of the less complex Spanish vowel system (framed as a decrease in positive evidence of a vowel length contrast due to its less frequent occurrence in bilingual input overall) would result in decelerated bilingual acquisition of the more complex German vowel system compared to German monolinguals. Kehoe found support for both hypotheses using accuracy measures (i.e. percentages of successful sound production attempts out of all respective production attempts) applied to naturalistic speech data from three German monolingual, two Spanish monolingual, and three German-Spanish bilingual children from the onset of word-production to age 3. As predicted, vowel accuracy in Spanish did not differ between bilinguals and monolinguals. However, bilinguals exhibited lower accuracy scores for both short and long vowels in German at all points when compared to German monolinguals. This difference in accuracy is interpreted as a case of deceleration, where less frequent exposure to the German length contrast (possibly coupled with exposure to a system that does not exhibit a vowel length contrast, i.e. Spanish) caused bilinguals to acquire the target vowel system of German more slowly than monolinguals.

Providing more evidence linking deceleration with decreased exposure to language-specific phonological phenomena, Fabiano-Smith and Goldstein (2010) compared consonant accuracy measures for Spanish and English bilinguals and monolinguals. They followed Flege (1981, 1987) in hypothesizing that bilingual learners lump phonetically similar sounds (including non-identical sounds) into the same phonemic category, accessible in both languages. This implies that bilingual learners would have more frequent experience, in both perception and production, with shared compared to unshared categories across their two systems. If more experience with a category correlates with greater accuracy in the production of that category during acquisition, then bilinguals' productions of phonetically similar sounds in each language should be more accurate than their own productions of phonetically dissimilar, unshared sounds in each language. Fabiano-Smith and Goldstein (2010) analyzed single-word and connected speech productions of 24 participants ages 3;0-4;0 (8 monolingual Spanish, 8 monolingual English, 8 bilingual Spanish-English). As predicted, analysis showed that bilinguals produced the set of shared sounds in each language with greater accuracy than the set of unshared sounds specific to Spanish or English. No such difference was found for English monolinguals. However, Spanish monolinguals produced the set of shared sounds with greater accuracy than the set of unshared sounds, despite monolinguals not 'sharing' sounds with another language. Further analysis suggested that this effect was driven by low accuracy among Spanish monolinguals on the flap and trill, which are typically acquired later (Acevedo, 1993; Jimenez, 1987). Accordingly, comparisons of shared and unshared sounds should also take the complexity of those sounds into account. Fabiano-Smith and Goldstein's (2010) analysis of overall consonant accuracy additionally showed that bilinguals were less accurate in their production of Spanish consonants compared to Spanish monolinguals, but comparably accurate in their production of English consonants compared to English monolinguals. Further analyses suggested that, in particular, bilinguals exhibited lower accuracy on the trill, fricatives, and glides in Spanish compared to Spanish monolinguals, and on stops and fricatives in English compared to English monolinguals, suggesting decelerated acquisition in bilinguals for these particular manner classes. However, for other sounds, bilinguals were performing age-appropriately by monolingual standards in both languages.

Further evidence of deceleration is presented by Gildersleeve-Neumann et al. (2008). This study analyzed consonant and vowel productions from elicited English single-word productions from 33 participants (10 monolingual English, 20 exposed predominantly to English with 10 or fewer hours of weekly exposure to Spanish, and 3 balanced bilinguals with equivalent exposure to Spanish and English). Participants were recorded twice, once at the beginning and once at the end of the same academic year. The authors found some evidence of deceleration in bilinguals' productions of interdentals and affricates in that fewer bilinguals in both groups were producing these sounds at the beginning of the year compared to monolinguals. However, the authors did not find any significant differences between groups on measures of overall vowel and consonant production accuracy. Examination of common consonant error patterns, however, found that both bilingual groups exhibited significantly higher average consonant error rates than the monolingual group, and that the difference between the two bilingual groups on this measure approached significance. This suggests that Spanish-English bilinguals were producing common consonant errors more frequently than English monolinguals, and that the less exposure the child had to English, the higher the consonant error rate was likely to be. For all three groups, word-final consonant devoicing was the most common consonant error, followed by gliding of liquids. Although bilinguals made more of the errors being examined, the types of errors made are not unusual in monolingual acquisition of English.

In terms of structural acquisition, both bilingual groups in Gildersleeve-Neumann et al.'s study were less likely than monolinguals to produce word-initial, -medial, and -final consonant clusters (i.e. bilinguals were more likely than monolinguals to lack clusters in their phonetic inventories). These differences were most pronounced for the 3 balanced bilinguals. It is possible that bilinguals' less frequent exposure to structurally complex syllables in English (e.g. complex codas) compared to that of English monolinguals resulted in their decelerated acquisition of structural complexity. However, it is difficult to determine whether bilinguals produced different complex syllable types with different levels of accuracy, since structural analysis addressed consonant clusters in general across word-positions. In terms of syllable-level errors, Gildersleeve-Neumann et al. reported that whole cluster deletion was uncommon in all groups, while final consonant deletion and cluster reduction were more common. While each group improved on these measures between the beginning and end of the year, there was a non-significant trend suggesting that bilingual groups exhibited higher rates of these errors than did monolinguals at the beginning of the year. This indicates that, while complex syllable structures were difficult for all learners, bilinguals' acquisition of these structures may initially have been decelerated.

While Gildersleeve-Neumann et al.'s study contributes a significant amount of information to the literature on the phonological acquisition of bilinguals, there were some shortcomings in the design that hinder its generalizability, as acknowledged by the authors. First, the bilingual and monolingual participant sets were not balanced, meaning that there was much more information collected about children whose exposure was all English (N=10) or predominantly English (N=20) compared to children whose exposure to both Spanish and English was more balanced (N=3). The authors additionally noted that, because the study was focused on English production, no information was available regarding bilinguals' phonological development in Spanish, how this compared to their own development in English, or how it compared to monolingual Spanish phonological development. Considered broadly, these findings suggest that investigations of interaction in bilingual phonological acquisition where segmental inventories and syllable type frequencies differ between languages should examine syllable structure, as well as consonant production accuracy in different syllabic positions. Taken in sum, the literature on deceleration in bilinguals' acquisition of phonology suggests that further investigations should focus on cases where languages do not share a linguistic property (e.g. Fabiano-Smith & Goldstein, 2010 on decelerated acquisition of unshared sounds; Kehoe, 2002 on decelerated acquisition of the vowel length contrast in German-Spanish bilinguals), or more generally where languages use a property with different frequency (e.g. Fabiano-Smith & Goldstein, 2010 on shared and unshared sounds; Gildersleeve-Neumann et al., 2008 on syllabic structure). In either case, deceleration in terms of accuracy has been found in cases where bilinguals receive less frequent exposure to a linguistic property compared to monolinguals due to differences in the frequency of occurrence of that property between their languages.

3.1.2 Acceleration

Evidence also shows that the influence of one language can promote accelerated acquisition in a bilingual's other language, though the literature on this outcome is less developed. In terms of bilingual syntactic development, Gawlitzek-Maiwald and Tracy (1996) described evidence of interaction in syntactic acquisition of a German-English bilingual child, Hannah, whose production of infinitival phrase structure in English during acquisition was aided by her knowledge of infinitival phrase structure in German. With respect to phonological development, Johnson and Lancaster (1998) presented the case study of Andreas, a 2-year-old learning Norwegian and English. Andreas employed a larger set of sounds in his phonetic inventories compared to monolinguals in either language, including phonetically dissimilar, unshared sounds between the two languages. The authors hypothesized that Andreas developed larger, more varied phonetic inventories as a consequence of trying to distinguish his language-specific productions. Almeida, Rose, and Freitas

(2012) provided further evidence of acceleration in the case of complex onset structure acquisition by Barbara, a Portuguese-French bilingual child. Barbara’s acquisition of complex onset structure in Portuguese was accelerated compared to Portuguese monolinguals’, and proceeded in both languages with patterns resembling French monolinguals’ acquisition of complex onsets. Almeida et al. argued that this acceleration was due to Barbara’s exposure to positive evidence of complex onset structure in both languages. This contrasts with Barbara’s typical acquisition of word-medial codas in Portuguese coupled with her decelerated acquisition of word-medial codas in French, which the authors argued was at least partially the result of her exposure to comparatively extreme segmental restrictions on this position in Portuguese. However, in each case it is difficult to generalize from the results of case studies that examine the productions of individual children.

Also regarding acquisition of syllable structure, Lleó et al. (2003) investigated bilingual and monolingual acquisition of singleton codas in Spanish and German, measuring structurally accurate coda production rates in the speech of 3 German monolinguals, 3 Spanish monolinguals, and 5 German-Spanish bilinguals in both languages. Structurally accurate coda production referred to producing a coda if the target syllable had a coda, regardless of segmental accuracy. Data (naturalistic speech samples) were collected longitudinally, from the onset of word production (about 1 year of age) until age three. Bilinguals were born in Hamburg, had Spanish-speaking mothers, and were simultaneously acquiring German and Spanish. German and Spanish both allow closed syllables, but codas are more frequent in German (67% of syllables) than Spanish (26.7% of syllables) (Meinhold & Stock, 1980, reported in Lleó et al., 2003, p. 193). German also allows a greater variety of segments in coda position compared to Spanish, which only allows some coronal codas word-finally (/θ, ð, n, s, l, ɾ/ for Castilian Spanish, Lleó et al. 2003) and labial and dorsal codas in addition to coronals word-medially. Furthermore, Harris (1983, p. 17-18) notes that obstruent codas other than /s/ are infrequent in Spanish compared to sonorant codas. German, by contrast, beyond allowing a wide variety of segments in singleton coda, allows coda clusters of multiple segments, which are also highly varied. Coda clusters ending in /s/ are possible in Spanish, but are very infrequent, appear primarily word-internally, and are frequently reduced (Harris, 1983). Singleton coda input to monolingual acquirers of German is therefore more frequent and more varied than singleton coda input to monolingual acquirers of Spanish.

Since frequency of exposure to syllable types influences the rate of acquisition of those syllable types (Kirk & Demuth, 2003; Levelt, Schiller & Levelt, 1999/2000), we should expect German monolinguals to exhibit higher coda structure production accuracy earlier than Spanish monolinguals. Indeed, this is what Lleó et al. found; at all time points, German monolinguals produced a greater proportion of target codas than did Spanish monolinguals. By the end of the second year, the German monolinguals produced on average almost 90% of target codas whereas the production rate for Spanish monolinguals on average was still less than 50%. For bilingual learners, Lleó et al. hypothesized that the difference in frequency of exposure to codas in their input as compared to Spanish and German monolinguals could result in acceleration of bilinguals' acquisition of Spanish codas, or deceleration of bilinguals' acquisition of German codas, or both. They found that bilinguals produced codas in German at similar proportions to monolingual German speakers, suggesting a lack of deceleration in German. However, the percentage of Spanish target codas produced by bilinguals substantially exceeded that of Spanish monolinguals at all points, suggesting that bilinguals' acquisition of Spanish codas was accelerated due to the high frequency of occurrence of codas in German. Furthermore, bilinguals produced more codas in final stressed syllables in both Spanish and German, similar to German monolinguals but unlike Spanish monolinguals who showed a weak preference for medial codas. Bilinguals also first produced nasal, liquid, and obstruent codas in both languages, unlike Spanish monolingual participants, who tended to produce coda glides first. If it is the case that bilinguals tended to produce more varied codas in Spanish earlier than monolinguals, this could also be seen as a kind of acceleration. Lleó et al. found that the greater frequency of codas in German promoted faster acquisition of syllable codas in the Spanish of Spanish-German bilinguals. Their results also suggested that bilinguals exposed to languages with differing levels of segmental restrictedness in a given position might experience acceleration in the acquisition of different types of segments in this position in the more restrictive language. However, as Almeida et al. (2012) found in the case of Barbara, it is also possible that bilinguals could experience decelerated acquisition of different types of segments in the less restrictive language. Overall, these results suggest that studies investigating acceleration in bilingual phonological acquisition should consider acquisition of syllable types in languages that use similar syllable types with different frequency, or with different positional phonotactics.

All the studies discussed above reporting acceleration used naturalistic language samples. This methodology provides certain advantages, including more natural productions in context, and potentially less danger of imitation of target words, though it is still possible for children to imitate their interlocutors (something that is undesirable if researchers wish to obtain data that are representative of the child's phonological system in general). However, there are also disadvantages. For instance, the child may not spontaneously produce sounds or structures of interest during a particular recording session, or the number of the child's attempts to produce a structure or sound of interest may vary greatly between sessions, meaning that accuracy percentages must always be taken in the context of the number of attempts made (although this can also be seen as an advantage, if researchers wish to track changes in the number of spontaneous attempts made over time). Phonological probes that elicit productions of a set of targets, as used by some of the studies describing deceleration (e.g. Fabiano-Smith and Goldstein, 2010; Gildersleeve-Neumann et al., 2008), present a potential solution to these specific issues because they allow researchers to target any and all linguistic elements of interest, and to give multiple and equal opportunities for production between participants.

3.2 Current Study

The literature discussed above suggests that cross-language differences in systemic frequency of occurrence of linguistic properties are a source of acceleration and deceleration in bilingual phonological acquisition. Aside from frequency, linguistic complexity may also influence interaction. Though there are multiple dimensions of complexity associated with language systems and their acquisition (including epistemic, ontological, and functional complexity; see Gierut, 2007 for a review), I use 'complexity' here and below to refer to typologically marked sounds or structures and to the hierarchical implicational markedness relationships that exist between elements within linguistic systems. Exposure to linguistic complexity in the input has been argued to promote monolinguals' acquisition of syntactic (Wexler 1982) and phonological structure (Dinnsen & Elbert, 1984; Gierut, 1999, 2001, 2007; Gierut, Morrisette, Hughes, & Rowland, 1996; Tyler & Figurski, 1994). In terms of syllable structure in particular, Gierut (1999) found that children with delayed onset cluster production exhibited enhanced learning when treated on more linguistically complex, marked clusters (those with small sonority differences: Clements, 1990; Davis, 1990; Steriade 1990) compared to those treated on less marked clusters (those with larger sonority differences). Hsin (2012) provided evidence that more exposure to syntactic complexity in the C-domain[6] in Spanish not only supported earlier acquisition of CP in Spanish monolinguals compared to English monolinguals, but

[6] The left periphery of sentences, which is involved in the formation of questions and embedded clauses, among other discursive constructions (Rizzi, 1997).

that Spanish-English bilinguals' exposure to this structural complexity in Spanish promoted their accelerated acquisition of English wh-questions compared to monolinguals. Additionally, Almeida et al. (2012) argued that Barbara's exposure to complex onsets in both French and Portuguese resulted in accelerated acquisition of this structure in Portuguese compared to Portuguese monolinguals. Furthermore, acceleration has also been found in English-Polish bilingual 7- to 8-year-olds' acquisition of word-initial English s + obstruent onset clusters based on the results of a non-word repetition task (Tamburelli, Sanoudaki, Jones, & Sowinska, 2015). While s + obstruent consonant clusters are more frequent both word-initially and word-medially in Polish than in English, bilinguals were not more accurate than monolinguals in their repetition of non-words with word-medial s + obstruent clusters. Bilinguals did, however, achieve higher accuracy than monolinguals on their productions of word-initial s + obstruent clusters. Instead of a frequency-based explanation, Tamburelli et al. argued that bilinguals' acquisition of word-initial clusters was accelerated due to greater complexity in Polish onset clusters. Polish allows sonority plateaus in onset clusters, whereas English does not. Polish also allows larger sonority falls in onset clusters (e.g. /pt/, /mʃ/), which are more marked (Berent, Steriade, Lennertz, & Vaknin, 2007) than the smaller sonority falls (e.g. /sp/) that are also allowed in English. English-Polish bilinguals therefore have exposure to greater onset cluster complexity compared to English monolinguals, which supported bilinguals' acquisition of less marked English onset clusters.

Conversely, Lleó and Cortés (2013) argued that bilinguals may experience decelerated acquisition of marked linguistic properties. Like Kehoe (2002), they found that German-Spanish bilinguals' acquisition of long vowels in German was decelerated. The Spanish vowel system does not use a length contrast. As a result, bilinguals are exposed to a vowel system that does not use this dimension of contrast, and are exposed to the vowel length contrast less frequently than are German monolinguals. It is possible that bilinguals' decelerated acquisition of long vowels in German arises from their less frequent exposure to this contrast rather than from its marked status. Indeed, Lleó and Cortés also found that bilinguals exhibited accelerated acquisition of singleton codas in Spanish. Singleton codas are linguistically marked, but occur in both languages. Like Lleó et al. (2003), Lleó and Cortés argue that bilinguals' accelerated acquisition of singleton codas in Spanish is due to the high frequency of occurrence of this structure in German.

Here, we predict that cross-language differences in both frequency and complexity can influence the manifestation of interaction in bilingual phonological acquisition. We test the following hypotheses:

i. Cross-language differences in the systemic frequency of occurrence of a linguistic property will result in different rates of acquisition of that property between bilinguals and monolinguals. If property X is more frequent in language A and less frequent in language B, bilinguals' acquisition of property X may be decelerated in language A or accelerated in language B.

ii. Exposure to linguistic complexity in one language will motivate bilinguals' accelerated acquisition of that property or related properties in the other language.

In other words, we expect the frequency of occurrence of a property across bilinguals' languages to affect their acquisition of that property in each language. We expect this to manifest as acceleration and deceleration compared to monolingual acquisition, since cross-language differences in systemic frequency of a property will provide bilinguals with greater overall exposure to that property compared to monolinguals learning one language, and less overall exposure to that property compared to monolinguals learning the other language. Similarly, if a bilingual is exposed to a kind of linguistic complexity in one language, we expect them to benefit from that exposure when acquiring similar structures in both languages. Bilinguals should therefore show accelerated acquisition compared to monolinguals in the language that does not employ the kind of linguistic complexity in question.

In the study presented here, we test these hypotheses for Spanish and English mono- and bi-linguals' productions of singleton codas and onset clusters[7] in each

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[7] In this chapter, as in chapters 2 and 4, I frame my discussion according to syllable-based approaches to phonotactics. Following Almeida, Rose, & Freitas (2012), Barlow (2001; 2004; 2005), Kirk & Demuth (2003; 2005), and Lleó et al. (2003), among others, I assume that a child's use of a consonant in a given position within a word indicates their use of syllabic structure associated with that position. For example, use of word-initial [fl] in /fli/, 'flea', indicates use of onset cluster structure. It would also be possible to frame discussion in terms of theories that derive phonotactics from string-based constraints on linear representations rather than from syllable structure (e.g. Steriade, 1999; Blevins, 2003).

language. English uses singleton codas with greater frequency compared to Spanish. Onset clusters occur with similar frequency in the two languages, but each language allows different kinds of complexity to occur in this syllable position. We follow Fabiano-Smith and Goldstein (2010), Gildersleeve-Neumann et al. (2008), Kehoe (2002), and Lleó et al. (2003), among others, in treating cross-sectional production accuracy rates as indicative of acceleration or deceleration. Lower accuracy rates in bilinguals' productions compared to monolinguals' productions indicate deceleration for the property being measured, whereas higher accuracy rates in bilinguals' compared to monolinguals' productions indicate acceleration.

The frequencies with which codas and onset clusters occur in Spanish and English syllables (including word medial and initial or final codas and onsets) and words (including only word initial or final codas and onsets) are listed in Table 3.1. These frequencies were obtained from the SUBTLEX corpora, which consist of orthographic transcriptions of spoken language from film and television series subtitles, for Spanish ($SUBTLEX_{ESP}$) and English ($SUBTLEX_{US}$). $SUBTLEX_{US}$ (Brysbaert & New, 2009) contains 51 million words, and $SUBTLEX_{ESP}$ (Cuetos, Glez-Nosti, Barbon, & Brysbaert, 2011) contains 40 million words. Research by Brysbaert & New (2009) and Cuetos et al. (2011) has demonstrated that the $SUBLTEX_{US}$ and $SUBTLEX_{ESP}$ corpora (respectively) are currently the best available resources for calculating word frequencies in spoken English or Spanish. Corpora of 16-30 million words generate reliable word frequency norms (Brysbaert & New, 2009), and $SUBTLEX_{US}$ and $SUBTLEX_{ESP}$ predicted word processing times in English

(Brysbaert, Keuleers, & New, 2011) and Spanish (Cuetos et al., 2011) better than written language corpora of various sizes, including larger corpora.

From the word frequency counts obtained through the SUBTLEX corpora, we are additionally able to calculate the frequencies of different syllable types that the words in each corpus are composed of. The CMU Pronouncing Dictionary (Carnegie Mellon Speech Group, 1993) and a syllabification algorithm (Gorman, 2013) for English were used to parse $\text{SUBTLEX}_{\text{US}}$ words into syllables. Similarly, and a syllabification algorithm for Spanish (Cuayáhuitl, 2004) was used to obtain syllable frequency counts from $\text{SUBTLEX}_{\text{ESP}}$. We treat these frequencies as representative, by and large, of the syllable type frequencies in the spoken language to which children are exposed. This assumption is based on research demonstrating that frequencies derived from adult language corpora are generally appropriate for use in studies on child language acquisition. This research has shown that phonotactic probability and neighborhood density are positively correlated between adult (dictionary-based) and child production corpora (Storkel & Hoover, 2010), and that child and adult receptive and expressive corpora are mainly consistent with each other (Gierut & Dale, 2007). Jusczyk, Luce, & Charles-Luce (1994), furthermore found a large degree of similarity in positional phoneme and biphone frequencies between adult-directed and child-directed speech corpora. Based on these findings, we assume that the robust syllable type frequency counts derived from the SUBTLEX corpora for adult spoken language are able to appropriately represent syllable type frequencies in the language children are exposed to. While it would have been ideal to use syllable type frequencies from the input to each participant in the study, these data were unavailable.

Table 3.1 Syllable type frequency (by tokens). Capital Cs indicate structures relevant to the current study.

	Structure	Spanish	English
Syllable-final	All Codas (total %)	31.92%	56.73%
	Singleton Codas: (onset)vC	31.79%	47.94%
	Complex Codas: (onset)vCC(C+)	0.13%	8.79%
Word-final	All Codas (total %)	34.23%	55.98%
	Singleton Codas: (onset)vC	34.20%	46.70%
	Complex Codas: (onset)vCC(C+)	0.03%	9.28%
Syllable-initial	All Complex Onsets (total %)	4.23%	5.46%
	2-element Complex Onsets: CCv(coda)	4.23%	5.25%
	3-element Complex Onsets: CCCv(coda)	0%	0.21%
Word-initial	All Complex Onsets (total %)	3.21%	4.61%
	2-element Complex Onsets: CCv(coda)	3.21%	4.44%
	3-element Complex Onsets: CCCv(coda)	0%	0.17%

While singleton codas make up approximately a third of syllabic input in Spanish, nearly half of the syllabic input in English uses singleton codas. Extending consideration to syllables or words with codas in general does not greatly change the proportion of codas in the input in Spanish, since complex codas are infrequent.

However, coda frequency in English increases by almost 10%. By contrast, the proportions of syllables with onset clusters are similar between Spanish and English.

The frequency of occurrence of a phonological property in the input can influence how early monolinguals acquire it (Levelt et al., 2000; Stites, Demuth & Kirk, 2004). Consequently, we expect English monolinguals to exhibit higher average accuracy rates than age-matched Spanish monolinguals on productions of singleton codas during acquisition. If cross-language syllable type statistics are a source of interaction in bilingual phonological acquisition, we should expect bilinguals to show accelerated acquisition of singleton codas in Spanish (where bilinguals have more overall exposure to codas than monolinguals), and decelerated acquisition of codas in English (where bilinguals have less overall exposure to codas than monolinguals). Given the small difference between languages in the frequency of occurrence of onset clusters, we do not expect frequency to affect interaction in bilingual acquisition of this structure in either language.

Turning to complexity, English and Spanish differ in both codas and onset clusters. English allows greater structural complexity in syllable codas than Spanish does. While Spanish does allow some 2-element complex codas, they are rare, and significantly restricted in terms of permissible segments (Harris, 1983; Trapman, 2007), whereas English allows morphologically simple coda clusters of up to 3 consonants in length (and up to 4 consonants in morphologically complex coda clusters), with many possible segmental combinations (Kreidler, 1989). If exposure to complex linguistic structure facilitates learning, then we should expect to see accelerated acquisition of Spanish singleton codas by bilinguals compared to monolinguals, since bilinguals are exposed to greater structural complexity in English codas.

Regarding onset clusters, both Spanish and English phonologies exhibit complexity, but do so in different ways. English onset clusters may have two elements or three (always s-initial). Most two-element clusters allow a liquid or glide closest to the vowel, with a stop or voiceless fricative in initial position, as in Figure 3.1.

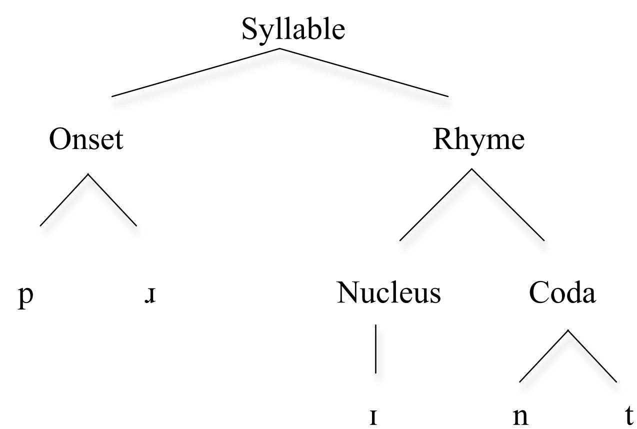

Figure 3.1 Two-element onset cluster (/pɹɪnt/, ‘print’)

However, English also allows s-initial clusters, which behave differently from other clusters. S-initial clusters may be followed by nasals or voiceless stops, or by most two-element clusters that start with a voiceless stop. Much evidence suggests that /s/ in sC(C) sequences is an adjunct (Davis, 1990; 1992; Giegerich, 1992; Kenstowicz, 1994) or appendix (Selkirk, 1982). In English, s-initial clusters pattern differently from true clusters in acquisition and in the treatment of phonological delays (Barlow, 2004, 2001; Gierut, 1999), further supporting their treatment as adjuncts. S-adjuncts creating clusters with three elements (e.g. in /spɹɪnt/) increase the complexity of onset structure in English, shown in Figure 3.2.

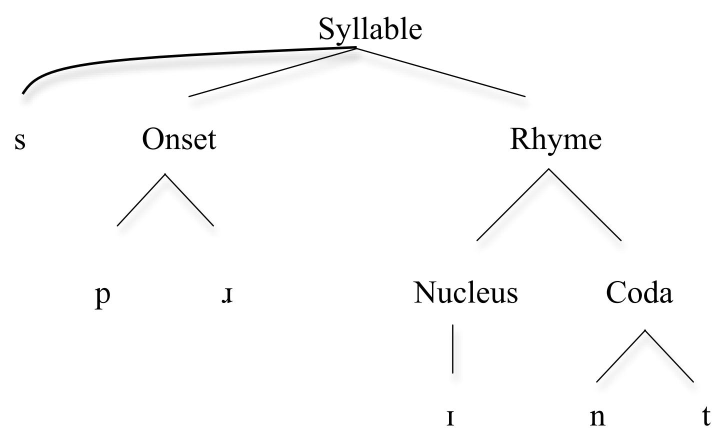

Figure 3.2 Three-element onset cluster with adjunct (/spɹɪnt/, 'sprint')

The effects of exposure to this source of complexity in acquisition are evident in studies such as that of Gierut and Champion (2001), which showed that a child with a speech sound disorder trained on a 3-element cluster (/spl-/) showed generalization learning of 2-element true and adjunct onset clusters.

Like English, Spanish also allows two-element clusters with a liquid closest to the vowel and a stop or voiceless fricative in initial position, corresponding to large, rising sonority differences between the two consonants. However, Spanish allows greater complexity in terms of sonority differences between onset cluster consonants.

We follow Bakovic (1994), Barlow (2003c), and Danesi (1982), among others, in treating [b d g] as allophones of underlying approximants /β ð ɣ/. Aside from voiceless stop- and f-initial clusters, Spanish allows approximant-liquid clusters (/βl/ /βɾ/ /ðɾ/ /ɣl/ /ɣɾ/), where the sonority difference between approximants /β ð ɣ/ and a following liquid is smaller than the sonority difference between obstruents and liquids (Bakovic, 1994; Parker, 2002[8]). Onset clusters with larger sonority differences are implicationally less marked than onset clusters with smaller sonority differences, both crosslinguistically (Davis, 1990; Steriade, 1982) and in acquisition (Gierut, 1999). In other words, a system with onset clusters with smaller sonority differences implies the existence of onset clusters with larger sonority differences in the same system. Literature on the treatment of speech sound disorders has furthermore shown that training on onset clusters with smaller sonority differences results in generalization to onset clusters with larger sonority differences, but not the reverse (Anderson, 2002; Gierut, 1999), as expected by the complexity approach to the treatment of speech sound disorders (Gierut, 2001, 2007, and references therein). While English phonotactics allow onset clusters with greater structural complexity, Spanish phonotactics allow onset clusters with more marked (i.e. smaller) sonority differences. Because bilinguals are exposed to an additional source of increased onset cluster complexity across their languages, we expect them to show accelerated acquisition of onset clusters compared to monolinguals in each language.

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[8] Parker (2002) categorizes /β ð ɣ/ not as approximants, but as voiced fricatives, to which he assigns a higher sonority value than to any other category of obstruents.

Our specific predictions are summarized in Table 3.2, following from our discussion of cross-language differences in frequency and complexity.

Table 3.2 Predictions for bilingual versus monolingual acquisition separated by language and structure

	Singleton Codas	Onset Clusters
Spanish	Bilingual > Monolingual (Acceleration)	Bilingual > Monolingual (Acceleration)
English	Monolingual > Bilingual (Deceleration)	Bilingual > Monolingual (Acceleration)

We expect bilinguals to exhibit accelerated acquisition of singleton codas in Spanish, due to their more frequent exposure to singleton codas compared to Spanish monolinguals and their exposure to greater coda structure complexity in English. Conversely, we expect them to show decelerated acquisition of singleton codas in English, due to their less frequent exposure to singleton codas across their input compared to English monolinguals. Finally, we predict that bilinguals will exhibit accelerated acquisition of onset clusters in each language due to their exposure to different kinds of onset cluster complexity in Spanish and English, even though onset clusters are similarly frequent in each language. While monolinguals learning these languages have exposure to increased structural complexity in English or increased sonority-based complexity in Spanish, bilinguals have exposure to both.

Beyond structural accuracy, we also evaluate positional segmental accuracy. Because bilinguals have less frequent exposure than monolinguals to each particular segment produced in codas or onset clusters in either language, it is possible that their segmental accuracy in these positions may be decelerated apart from their acquisition of the syllabic structure more generally. In other words, it is possible that exposure to syllable structure across languages supports acquisition of that structure in each language, but that this same exposure may not enable bilinguals to initially 'keep up with' monolinguals in terms of the positional acquisition of individual segments. This may be especially true in the case of English singleton codas. While English allows most consonants to appear in singleton coda (Kreidler, 1989), Spanish only allows a small set of segments in this position, which is even more restricted word-finally (Harris, 1983). Since there are many individual segments to master in singleton coda in English and fewer in Spanish, and because bilinguals have less frequent exposure to coda types and tokens in each language compared to monolinguals, we expect deceleration to occur in terms of bilinguals' lower segmental accuracy in coda, apart from or in addition to decelerated acquisition of English coda structure. Performing separate analyses to evaluate structural and segmental accuracy for each position will allow us to determine whether this is the case.

3.2.1 Methods

Participants

Data were collected from 27 child participants, including 12 monolingual speakers of English (mean age (SD): 41.1 m.o. (9.3 months), range: 29.2 - 58.7 m.o.), five monolingual speakers of Spanish(mean age (SD): 37.82 m.o. (9.4 months), range: 28.4 - 48.0 m.o.), and 10 bilingual English-Spanish speakers(mean age (SD): 45.8

m.o. (9.0 months), range: 25.5 - 56.8 m.o.). Independent one-way ANOVAs revealed no significant differences in age between bilinguals and English monolinguals, $F(1,20)=1.431$, $p=0.246$, or between bilinguals and Spanish monolinguals, $F(1,13)=2.55$, $p=0.134$. Data from 15 of the 27 participants, including MLE01-05, MLS01-05, and BL01-05, were drawn from the archives of a larger study of the phonological acquisition of Spanish and English by monolingual and bilingual children in the Southern California and Baja California area. Further data were prospectively collected from seven monolingual English speakers (MLE06-12) and five bilingual speakers (BL06-10) living in the same geographical region. All were determined to be typically developing with normal hearing and normal linguistic, cognitive, and motoric development based on parents' responses to a child history questionnaire evaluating their development, language input, and language output. Table 3.3 gives demographic information for monolingual participants. Demographic information for bilingual participants is presented in Table 3.4.

Table 3.3 Demographic data for monolingual participants

Participant ID	Age (years; months)	Gender	Language
MLE01	2;05	Male	English
MLE02	2;05	Female	English
MLE03	4;01	Male	English
MLE04	4;02	Female	English
MLE05	2;08	Male	English
MLE06	3;01	Male	English
MLE07	4;10	Male	English
MLE08	3;02	Male	English
MLE09	3;05	Female	English
MLE10	3;07	Female	English
MLE11	3;04	Female	English
MLE12	3;06	Female	English
MLS01	2;04	Female	Spanish
MLS02	4;00	Female	Spanish
MLS03	2;09	Female	Spanish
MLS04	4;02	Female	Spanish
MLS05	2;11	Female	Spanish

Bilingual status was decided based on results from an extensive questionnaire, evaluating the child's language development, input, and output (following Gutiérrez-Clellen and Kreiter, 2003; Pearson, Fernandez, Ledeweg and Oller, 1997; Restrepo, 1998). Children classified as 'bilingual' had a minimum of 20% input in both English and Spanish, following findings from Pearson et al. (1997) showing that at least 20% exposure was required for bilinguals to readily produce utterances in the target language. Language input and output percentages were based on parent report. Furthermore, bilingual participants were able to interact with experimenters in each language and to perform both Spanish and English versions of the picture-naming task. We use the term 'early bilingual' to categorize the bilingual participants in this study, given that that all started acquiring their L2 before their L1 was fully established (before the age of 5 or 6 years, following Flege, 2007; Flege et al., 1999; Hamers and Blanc, 2000; McLaughlin, 1978).

Table 3.4 Demographic data for bilingual participants

Participant ID	Age (years;months)	Gender	Input (%)		Output (%)	
			English	Spanish	English	Spanish
BL01	2;01	Female	80	20	90	10
BL02	3;06	Female	27	73	10	90
BL03	4;06	Male	33	66	33	66
BL04	3;06	Male	33	66	33	66
BL05	4;07	Male	46	54	46	54
BL06	3;11	Male	60	40	60	40
BL07	4;08	Female	40	60	25	75
BL08	3;11	Female	60	40	50	50
BL09	3;11	Female	50	50	50	50
BL10	3;04	Female	20	80	20	80

Data

Data were transcriptions of participants' productions of target words with singleton codas or onset clusters, elicited using the Assessment of English Phonology (AEP: Barlow, 2003a) or the Shorter Protocol for the Evaluation of English

Phonotactics (Little PEEP: Barlow, 2012), and/or the Assessment of Spanish Phonology (ASP: Barlow, 2003b). These assessments are single-word phonological probes targeting all phonemes of Spanish (the ASP) and English (the AEP and Little PEEP) in all permitted syllable positions. Productions were obtained in isolation in the corresponding language using non-imitation elicitation via a picture-naming task (e.g. "*What's this? It's a…*"/ "*¿Qué es esta? Es una…*") with delayed imitation when necessary, (e.g. "*It's a flower. What is it? It's a…*" / "Es *una flor. ¿Qué es? Es una…*"). The AEP targets 256 words, and provided participants with 78 opportunities to produce onset clusters and 189 opportunities to produce singleton codas in English (mostly word-initial or -final, some word-medial), while the Little PEEP targets 285 words, including 122 onset cluster production opportunities and 231 singleton coda production opportunities, also mostly word-initial or word-final. The ASP targets 156 words, and provided participants with 36 opportunities to produce onset clusters and 96 opportunities to produce singleton codas in Spanish (word-initial, -final, and -medial). Not all participants attempted to produce all targets of a given probe (though inclusion of a participant as a random effect helped to control for these differences during statistical analysis). These differences were due to constraints on participant and experimenter availability and on participant attention. Productions were phonetically transcribed by judges trained in the use of narrow transcription with the IPA. Judges were native speakers of English and/or Spanish. English productions were transcribed by native English speakers and Spanish productions were transcribed by native Spanish speakers. Twenty percent of the data was re-transcribed by a second judge for calculation of transcription reliability, with point-to-point inter-judge reliability for each target word at 87% for English and 82% for Spanish.

Analyses

We performed two kinds of accuracy analysis on the cross-sectional data: analysis of structural accuracy, and analysis of positional segmental accuracy. Whereas analysis of structural accuracy counted consonant substitutions as correct (similar to the analysis in Lleó et al., 2003), analysis of positional segmental accuracy did not. Consonant deletions were counted as incorrect in both analyses. The purpose of the structural accuracy analysis was to evaluate participants' accuracy in producing singleton coda and onset cluster structure, without considering their accuracy in producing the sets of segments allowed in these syllabic positions. The purpose of the positional segmental analysis was to evaluate participants' accuracy in terms of the segmental phonotactics of singleton codas and onset clusters.

Structural accuracy for each target production for each participant was calculated such that any consonant production in coda for a singleton coda target or any consonant cluster production for an onset cluster target (matching the number of cluster segments present in the target) counted as a hit, regardless of segmental accuracy. Unintelligible productions and unattempted targets were not counted as attempts. Accuracy percentages for each structure were based on the number of successful attempts to produce the structure divided by the total number of attempts to produce the structure (total number of hits and misses). For example, if a child attempted to produce *leaf, spill, door, hug, drum*, and *glass* and produced outputs of [lif], [pɪoʊ], [dowɹ], [hʌd] [dʒɹʌm] and nothing for *glass*, she would have a mean accuracy percentage of 60% for singleton codas (3 hits/5 attempts) and a mean accuracy percentage of 50% for onset clusters (1 hit/2 attempts). This structural analysis is similar to what Lleó et al. (2003) performed in their examination of bilingual and monolingual acquisition of singleton codas in Spanish and German.

Segmental accuracy for each target production was calculated such that a faithful production of the coda or onset was recorded as a hit, whereas consonant deletions or substitutions were recorded as misses. Again, unintelligible productions and unproduced targets were not included as attempts. Accuracy percentages for each structure were based on the number of successful attempts or hits for the structure divided by the total number of attempts for the structure (total number of hits and misses). To compare these measures, let us consider the same example used above. Given the child's productions of *leaf, spill, door, hug, drum*, and *glass* as [lif], [pɪoʊ], [dowɹ], [hʌd] [dʒɹʌm] and nothing for *glass*, she would have a mean accuracy percentage of 40% for singleton codas (2 hits/5 attempts) and a mean accuracy percentage of 50% for onset clusters (1 hit/2 attempts).

3.2.2 Results

We analyzed the data using mixed effects logistic regression, which allowed us to model production accuracy, a binomially distributed response variable, for each analysis ('hit' or 'miss' for each production attempt). Mixed logit models additionally allowed us to control for random effects of participant and item. Analyses were performed within language and within syllabic structure, since we do not make between-language or between-structure comparisons. All analyses included participant background (monolingual vs. bilingual) as a fixed effect and participant and item as random effects. Significance of the fixed effect predictor was determined using model comparison where the null model did not include the fixed effect (background). All statistical analyses were performed using R statistical software (R Development Core Team, 2015) and the lme4 package (Bates, Maechler, Bolker, & Walker, 2014) for mixed effects models. We first report the results for singleton codas, followed by the results for onset clusters.

Singleton Codas

Mixed logit models found that bilinguals' productions of Spanish singleton codas were more accurate than monolinguals' Spanish singleton coda productions in both the structural ($\beta = 1.4448$, s.e. = 0.6214; $\chi2(1) = 4.5904$, $p < 0.05$) and segmental ($\beta = 1.5989$, s.e. = 0.6322; $\chi2(1) = 5.3327$, $p < 0.05$) analyses, as predicted. Results for English singleton coda production accuracy did not indicate differences between the productions of bilinguals and monolinguals. A numerical trend in the predicted direction was found in the structural analysis suggesting that bilinguals may have produced singleton coda structure less accurately than monolinguals, however this trend failed to reach statistical significance ($\beta = -0.7888$, s.e. = 0.5026; $\chi2(1) = 2.3463$, p = 0.1256). Similarly, no difference was indicated between bilinguals and monolinguals in the segmental analysis of English singleton coda productions (β = -0.4702, s.e. = 0.5206; χ2(1) = 0.7996, p = 0.3712). Figure 3.3 displays Spanish singleton coda accuracy score means for participants grouped by background (bilinguals versus monolinguals) for the structural analysis, and Figure 3.4 displays accuracy score means for the segmental analysis. Figures 3.5 and 3.6 present these values for English singleton coda productions.

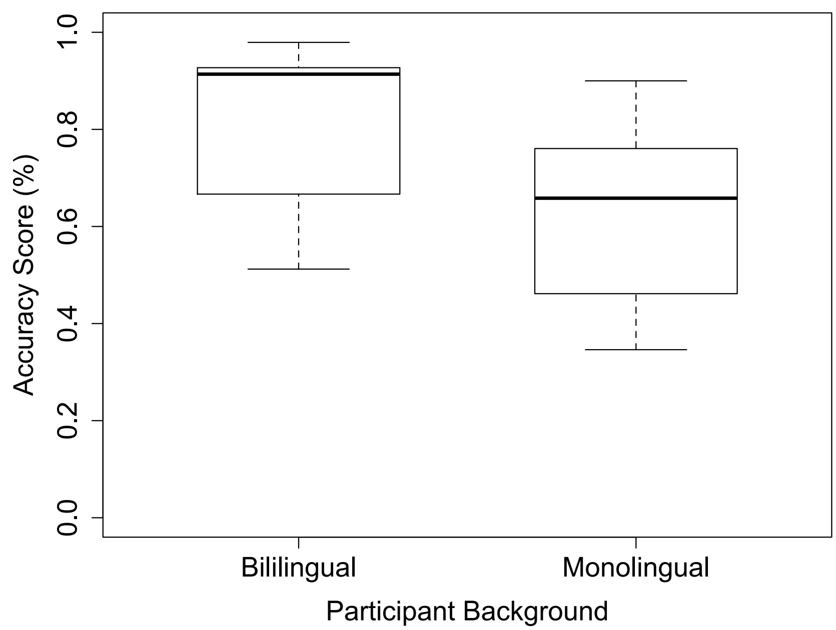

Figure 3.3 Spanish Singleton Codas: Structural accuracy

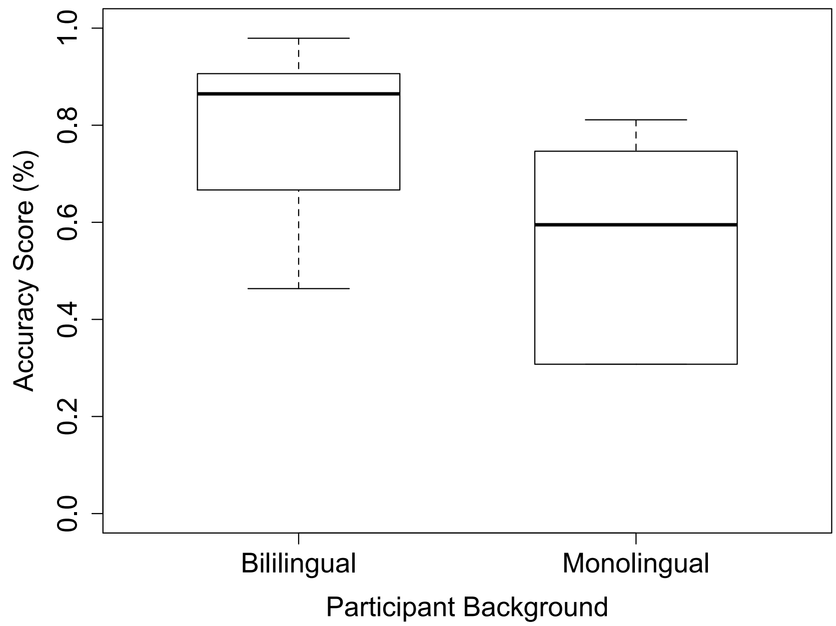

Figure 3.4 Spanish Singleton Codas: Segmental Accuracy

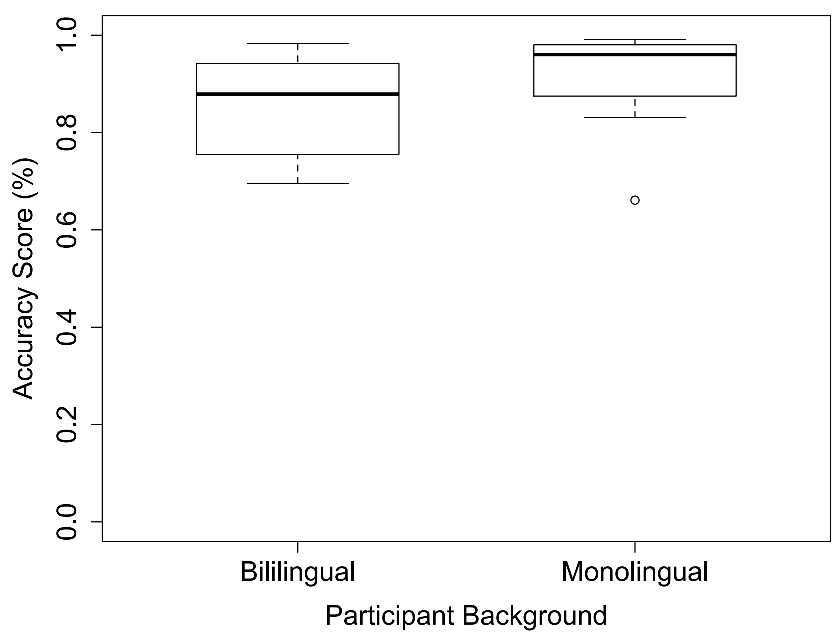

Figure 3.5 English Singleton Codas: Structural Accuracy

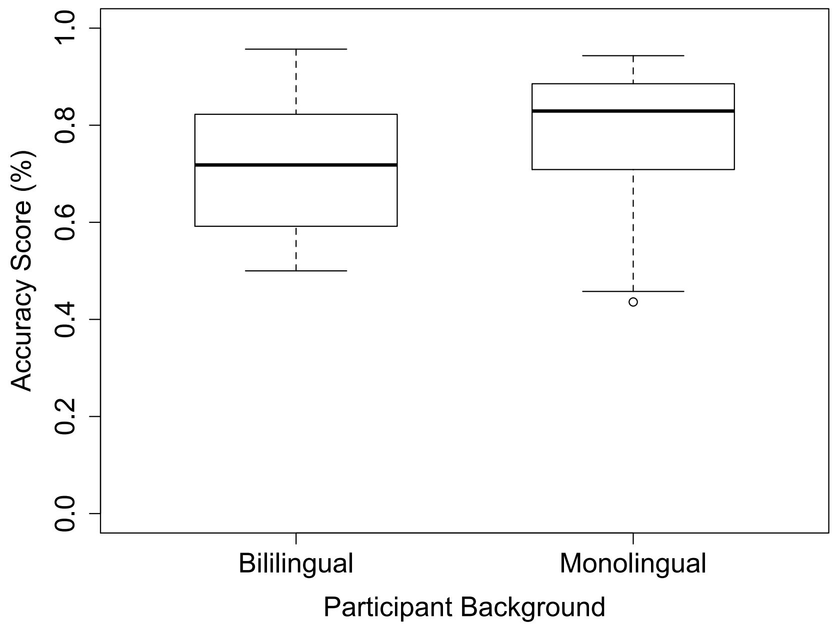

Figure 3.6 English Singleton Codas: Segmental Accuracy

Onset Clusters

We now turn to analyses of onset cluster production. Results indicated that, as predicted, bilinguals were more accurate than monolinguals in their structural (β = 2.3708, s.e. = 1.0344; $\chi2(1) = 4.3505$, $p < 0.05$) and segmental (β = 2.7911, s.e. = 1.1590; $\chi2(1) = 4.8148$, $p < 0.05$) productions of Spanish onset clusters. In English, structural and segmental analyses obtained different results. No significant difference in accuracy was found between bilinguals' and monolinguals' productions of English onset cluster structure (β = 1.0956, s.e. = 0.8850; $\chi2(1) = 1.4589$, $p = 0.2271$). However, bilinguals' productions of English onset cluster segments were found to be more accurate than monolinguals' productions (β = 1.5431, s.e. = 0.6186; $\chi2(1)$ =

5.4825, $p < 0.05$). Participants' production accuracy score means grouped by background are presented in Figures 3.7-8 and 3.9-10 for Spanish and English onset clusters, respectively. Figures 3.7 and 3.9 display data from the structural analyses while Figures 3.8 and 3.10 present data segmental analysis.

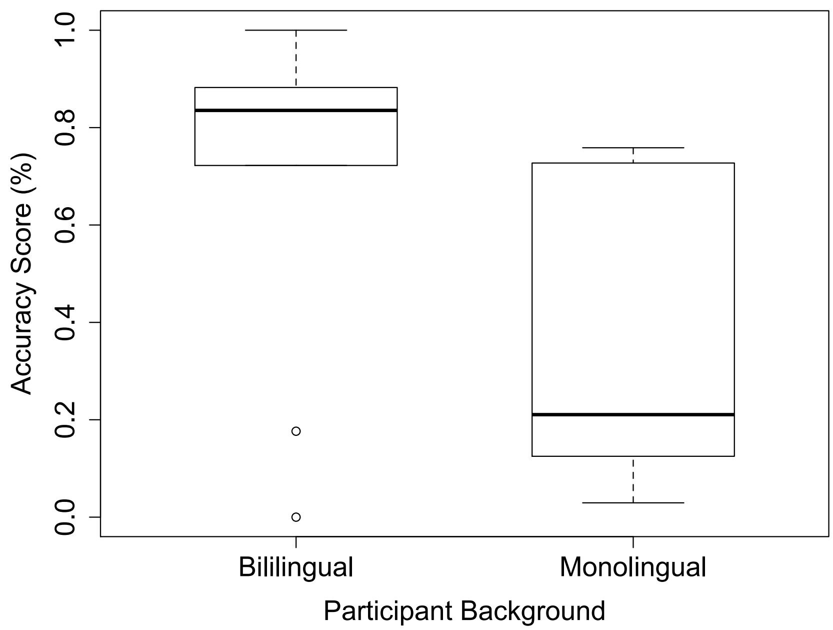

Figure 3.7 Spanish Onset Clusters: Structural accuracy

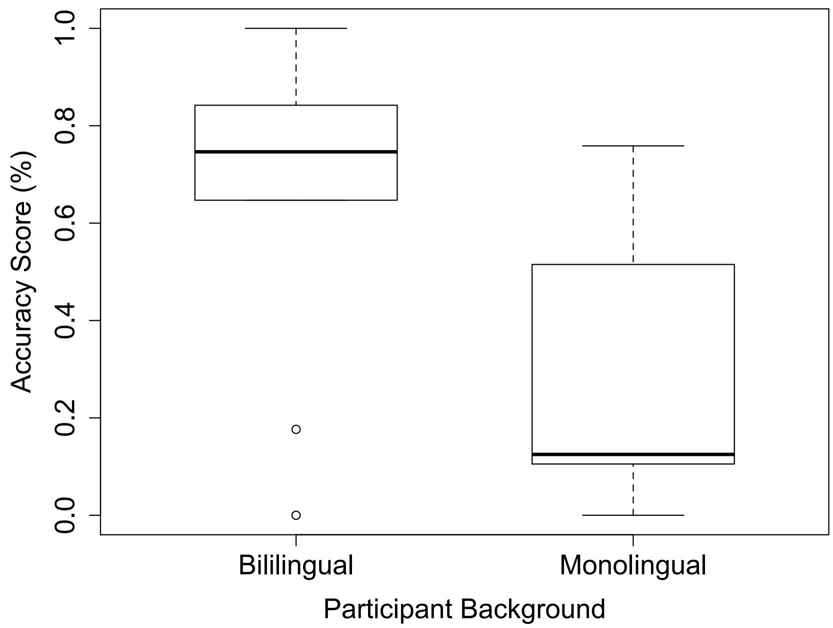

Figure 3.8 Spanish Onset Clusters: Segmental accuracy

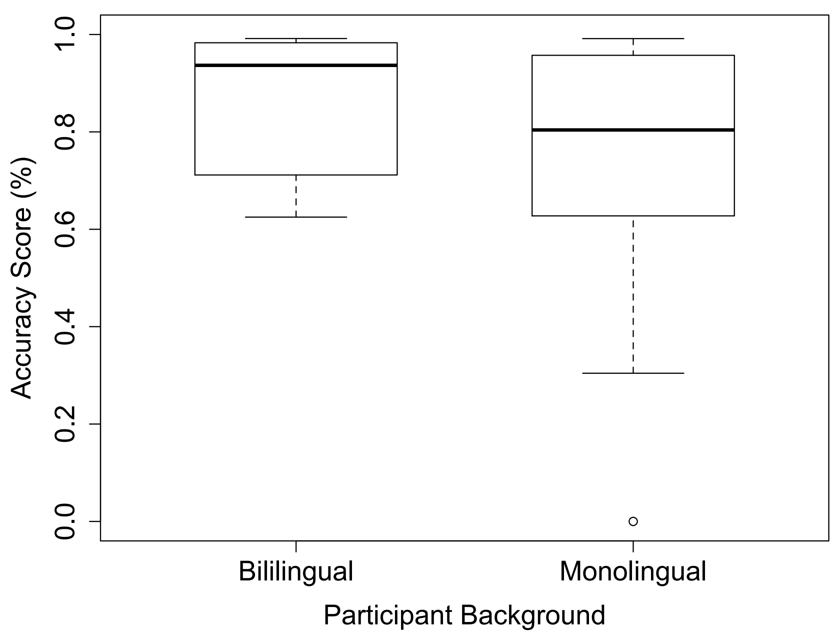

Figure 3.9 English Onset Clusters: Structural accuracy

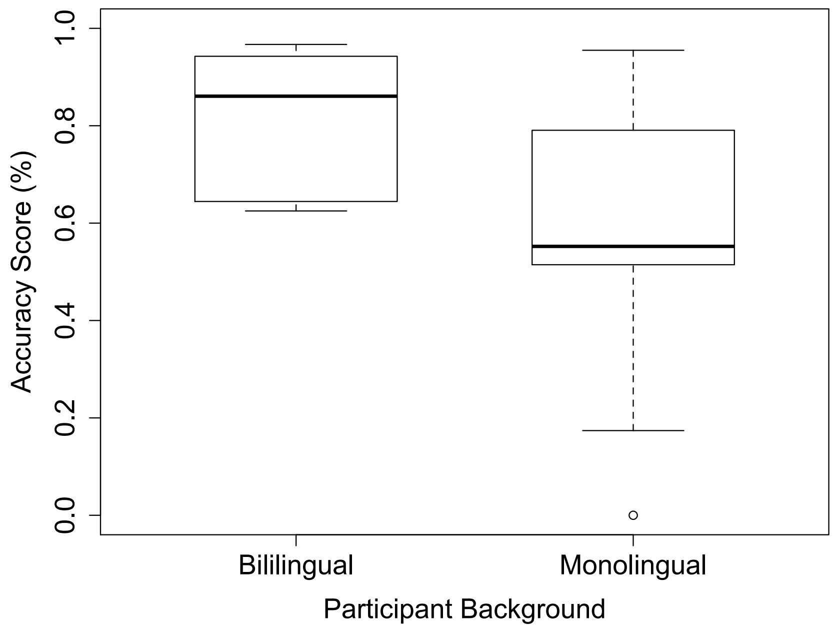

Figure 3.10 English Onset Clusters: Segmental accuracy

In sum, statistical analyses indicated that bilinguals were more accurate than monolinguals in their productions of Spanish singleton codas, for both structural and segmental measures. Bilinguals were also more accurate than monolinguals in their productions of Spanish onset cluster structure, and in their productions of Spanish and English onset cluster segments. Numerical differences in the predicted direction were found between bilinguals' and monolinguals' production accuracy rates for English singleton coda structure, but these differences failed to reach significance. Similarly, no differences were found between bilinguals and monolinguals in terms of their production accuracy rates for English singleton coda segments or onset cluster structure.

3.3 Discussion

Based on differences in the frequency of occurrence of singleton codas between Spanish (where singleton codas are less frequent) and English (where singleton codas are more frequent), we predicted that bilinguals would show accelerated acquisition of codas in Spanish relative to Spanish monolinguals and decelerated acquisition of codas in English relative to English monolinguals. We also predicted that bilinguals' acquisition of Spanish singleton codas would be accelerated due to their exposure to complexity in English coda structure. Our predictions were confirmed in the case of Spanish. Bilinguals were more accurate than monolinguals in their productions of singleton coda segments, and in their productions of singleton coda structure more generally. Bilinguals were both substituting and deleting Spanish singleton coda consonants less often than monolinguals, indicating that bilinguals' acquisition of singleton codas was accelerated relative to Spanish monolinguals'. We cannot determine from these results whether bilinguals' accelerated acquisition of Spanish singleton coda structure and segments was influenced by the greater frequency of occurrence of singleton codas in English, by the existence of complex codas in English, or by both factors.

However, deceleration was not found in bilinguals' acquisition of English singleton codas, despite the lower frequency of occurrence of singleton codas in Spanish. Numerical differences between the bilinguals' and monolinguals' production accuracy rates for English singleton coda structure failed to reach statistical significance, but were in the predicted direction. Future research should use data from larger numbers of participants to ensure that there is sufficient statistical power to determine whether the trend observed here is indicative of a real difference, or if bilingual and monolingual accuracy levels are indeed commensurate in the case of English singleton codas.

Interestingly, accuracy rates for English singleton codas were high for both groups in both analyses (group accuracy means > 70% in all cases), suggesting that the current study's participants were relatively advanced in their acquisition of English singleton codas. Future research using data from younger participants may detect any group differences in accuracy that could exist at earlier stages of singleton coda development. However, our results also mirror those from Lleó et al. (2003), who found acceleration in bilinguals' acquisition of singleton coda structure in Spanish and no evidence of deceleration in bilinguals' acquisition of singleton coda structure in German, even though their participants (ages 1-3 y.o.) were younger than those in the current study. Given the results from both studies, interaction in bilinguals' singleton coda acquisition may have been more strongly influenced by cross-linguistic differences in complexity than by cross-linguistic differences in frequency of occurrence.

Future work should investigate positional segmental production in greater depth. While bilinguals did not exhibit decelerated acquisition of English singleton codas despite the lower frequency of this structure in Spanish, they may differ in the accuracy with which they produce coda segments that are shared or unshared in this position between their languages, as suggested by Fabiano-Smith & Goldstein (2010).

Beyond singleton codas, future research should also investigate bilinguals' and monolinguals' acquisition of coda clusters, which are relatively frequent in English (Delattre & Olsen, 1969) but very infrequent in Spanish (Guffey, 2002). Furthermore, Spanish coda clusters only end in /s/, which has been analyzed as an adjunct or appendix (Harris, 1983; Hualde, 1999; Colina 2009; 2012), allowing the generalization that Spanish in fact lacks true coda clusters.

Turning to onset clusters, our predictions were based on differences in complexity between Spanish and English while the frequency of occurrence of onset clusters was constant between languages. Due to the language-specific onset cluster phonotactics of Spanish and English, bilinguals were exposed to complexity across their input that monolinguals for either language were not exposed to. We predicted that bilinguals' exposure across their languages to additional complexity compared to monolinguals would result in bilinguals' accelerated acquisition of onset clusters in both languages. Statistical analyses confirmed that bilinguals were more accurate than monolinguals in their productions of onset cluster structure in Spanish, and onset cluster segments in Spanish and English. While bilinguals were less likely than monolinguals to substitute segments in English onset clusters, they altered the structure of English onset clusters by deleting or epenthesizing at rates similar to monolinguals.

More in depth investigation into participants' productions of English onset clusters revealed that the difference in accuracy rates between bilinguals' and monolinguals' segmental productions was driven in part by a higher incidence of liquid gliding in the onset cluster productions of monolinguals (e.g. producing /tɹi/, ‘tree’, as /twi/). Producing liquids in obstruent-liquid clusters as glides lowers the complexity of the onset cluster because it increases the sonority difference between the segments in the cluster (Davis, 1990; Gierut, 1999; Steriade, 1982). Compared to English monolinguals, bilinguals were exposed via Spanish to increased complexity in terms of sonority differences between onset cluster segments. Exposure to this complexity promoted bilinguals’ acquisition of English onset clusters with less complex sonority differences. However, bilinguals’ acquisition of English onset cluster structure more generally was not more advanced than monolinguals’. This is consistent with our account, given that both bilinguals and English monolinguals are exposed to increased structural complexity in onset clusters. Our results are similar to those in Tamburelli et al. (2015), who found that the increased complexity in Polish onset clusters promoted bilinguals’ acquisition of word-initial s + obstruent clusters in English.

In sum, bilinguals’ acquisition of onset clusters was accelerated in both languages; exposure to increased structural complexity in English onset clusters facilitated their acquisition of Spanish onset cluster structure and segments, and exposure to smaller onset cluster sonority differences in Spanish facilitated their acquisition of English onset cluster segments. These results extend findings from research on monolingual acquirers, whose use of more marked onset clusters implies their use of less marked onset clusters (Elbert, Dinnsen, & Powell, 1984; Gierut, 1999; Gierut & Champion, 2001), to bilingual child language acquisition. Like monolinguals, exposure to phonological complexity promoted acquisition of phonological structure in bilinguals. Furthermore, exposure to phonological complexity in each language promoted acquisition of phonological structure in the other language, resulting in accelerated acquisition compared to monolinguals in either language.

One factor that was not considered in this study was the socioeconomic status (SES) of participants' families, which has been shown to affect aspects of children's language acquisition. Children from families with higher SES are advanced in their vocabulary development compared to children from families with lower SES (Hoff, 2003; Fernald, Marchman, & Weisleder, 2013). Children's vocabulary development is in turn linked to their phonological development (review in Stoel-Gammon, 2011). However, research is still needed to determine how phonological development might be affected by SES. Because Hispanics in the U.S. fare worse than non-Hispanic Whites on various indicators of socioeconomic status (Saenz, 2010), it is possible that bilingual and monolingual Hispanic and Latino Spanish-speaking participants on average came from families with lower SES than did English-speaking monolingual participants, who came mostly from non-Hispanic White families. Data about family SES were not collected for the current study, therefore each group's average SES is unknown. However, even if Spanish-speaking participants came from lower SES families, it is expected that use of data from Spanish-speakers from families with higher SES would have resulted in the same overall findings as the current study. Bilinguals' onset cluster and singleton coda production accuracy scores may simply have been a bit higher, meaning that they would still outperform English monolinguals in onset cluster production accuracy, and that their singleton coda productions would likely still be comparable to English monolinguals'. Future research, however, should account for potential differences in SES between bilingual and monolingual participant groups.

In addition to SES, future research should account for potential effects of language proficiency or dominance, which some research has shown might influence bilinguals' developing speech production abilities. Less experience with or ability in a language has been associated with lower rates of consonant production accuracy (Goldstein, Bunta, Lange, Rodríguez, & Burrows, 2010) and higher rates of consonant error (Gildersleeve-Neumann et al., 2008) in the same language. In the current study, Spanish and English input and output percentages (see Table 3.4) were generally similar between bilingual participants, though a few participants had more asymmetrical Spanish or English input and output (e.g. BL01, BL02, BL10). Additionally, all participants were able to interact with experimenters and to complete the experimental task in the target language in a manner suggesting similar language proficiency. However, it is possible that parent report or direct measures of language ability (e.g. MLU or picture vocabulary test scores) might have revealed differences between bilingual participants' in language proficiency or dominance. Future research should collect measures of participants' language proficiency to account for the possible influence of proficiency or dominance when analyzing bilingual data.

Overall, our results show that interaction in bilingual phonological acquisition is influenced by cross-language differences the linguistic complexity of phonological properties, and possibly by cross-language differences in the frequency of occurrence of those properties. Bilinguals exhibited different behavior from monolinguals in their productions of singleton coda and onset cluster structure and segments, and these differences in each language were influenced by the statistical and grammatical (phonological) patterns that bilinguals were exposed to via their other language.

3.4 Chapter Appendix

This appendix contains target words with word-medial and word-final or word-initial singleton codas and onset clusters from the Assessment of English Phonology (AEP: Barlow, 2003a), the Shorter Protocol for the Evaluation of English Phonotactics (Little PEEP: Barlow, 2012), and the Assessment of Spanish Phonology (ASP: Barlow, 2003b).

Table 3.5 AEP singleton codas

Word-final				
(french) fry-s	door	knife	ride	stretch
badge	drive	ladder	ride-ing	sun
bath	drive-ing	laugh	ring	swim
bed	drum	laugh-ing	robe	swim-ing
beehive	duck	leaf	rocket	swing
blow-ing	fall	lemon	rub	swing-ing
break	fall-ing	light/lamp	rub-ing	teacher
break-ing	father	magic(ian)	run	teeth
bridge	feather	mop	run-ing	them
brother	finger	moth	shave	there
brush	fish	mother	shave-ing	thermometer
buzz	flower	mouth	shoe-s	these/them
buzz-ing	fly-ing	mud	shovel	this/that
cage	frog	music	shower	throw-ing
car	game	nail	sing	thumb
catch	glass-s	noise	sing-ing	thunder
catch-ing	glove	nose	skate	toe-s
chain	goat	nothing	skate-ing	tooth
chair	green	ocean	sleep	train
chalk	guitar	off	sleep-ing	treehouse
cheese	gum	other	smile	tub
chicken	hammer	page	smile-ing	vacuum
climb	hanger	peach	smoke	van
climb-ing	hat	pig	snail	vase
cloud	hill	plate	snow-ing	wagon
cob	hiss	please	soap	watch
comb	hiss-ing	prince(ss)	sock	water
cough	hug	queen	space	web
cough-ing	hug-ing	quiet	splash	wish
crash	ice	rabbit	splash-ing	witch
crash-ing	jeep	rain	spoon	yawn
cup	judge	rain-ing	spring	
dig	juice	rake	square	
dig-ing	jump(rop)-ing	rake-ing	stir	
dog	kiss	read	stir-ing	
doll	kiss-ing	read-ing	stove	
Word-medial				
finger	ring-i	thermometer		
hanger	sing-ing	thirsty		
popcorn	spring-i	thunder		
prince(ss)	swing-ing			

Table 3.6 Little PEEP singleton codas

Word-final				
above	dive	laugh-ing	scrub	sweep
anything	dive-ing	leaf	scrub-ing	sweep-ing
asleep	dog	leash	seven	swim
awake	doll	lemon	shave	swim-ing
badge	door	magician	shave-ing	swing
badge-s	drawbridge	mammoth	shovel	swing-ing
balloon	drive	moth	shower	teacher
bath	drive-ing	mother	shrug	teeth
bathrobe	drum	mud	sing	that
beautiful	everything	music	sing-ing	them
bed	father	mustache	skate	there
beehive	feather	noise	skate-ing	thermometer
before	finger	nose	sleep-ing	these
blanket	fish	nothing	sleeve	this
bridge	flag	ocean	smile	thread
bridge-s	flower	other	smoke	throw-ing
brother	forehead	page	smooth	thumb
brush	frog	page-s	sneeze	thunder
brush-s	gallop	parade	snore-ing	tooth
bulldog	game	path	snow-ing	toothache
caboose	garbage	peach	soap	train
cage	giraffe	peach-s	sock	treehouse
cage-s	glass	photograph	spider	tub
catch	glass-s	pig	spill	twinkle
catch-ing	globe	princess	splash	underneath
chain	glove	push	splash-ing	vacuum
chair	grass	push-ing	splinter	vase
cheese	guitar	quack	split	venom
chicken	gumball	quack-ing	spray-ing	wagon
climb	hanger	quake	spring	watch
climb-ing	hill	queen	square	watch-s
cloud	hopscotch	rabbit	squeak	wing
clown	hug	read	squeeze	yawn
cobweb	hug-ing	read-ing	squeeze-ing	yawn-ing
cockroach	jeep	ride	star	yes
cough	judge	ride-ing	starfish	zip
cough-ing	juice	ring	stove	zip-ing
crawl	kiss	ring-ing	strawberry-s	zipper
crayon	kiss-ing	rocket	street	
cute	knife	school	strong	
dig	ladder	scratch	sugar	
dig-ing	laugh	scratch-ing	surprise	
Word-medial				
airport	earmuff-s	gumball	splinter	thunder
bathrobe	everything	hanger	sprinkle-s	twinkle
blanket	finger	hopscotch	starfish	underneath
bulldog	forehead	iceberg	thermometer	underneath
cobweb	garbage	princess	thirsty	window

Table 3.7 ASP singleton codas

Word-final				
árbol	ciudad	flores	mujer	robot
árboles	ciudades	globos	nadar	sartén
autobus	clavar	gracias	nariz	sartenes
azul	cruces	heuvos	nopal	seis
bailan	cruz	jabón	nopales	sol
béisbol	cumpleaños	jalar	papel	tambor
cachetes	delfín	labios	paraguas	tambores
camarón	dos	lápiz	pared	tren
camarones	dragón	llaves	paredes	
carros	dragones	luces	plátanos	
chancl(et)as	flor	luz	reloj	
Word-medial				
árbol	chango	espuma	gordo	princesa
árboles	corriendo	estrella	grande	sartén
béisbol	cumpleaños	fantasma	granja	sartenes
blanco	delfín	fantasma	lengua	sombrero
bombero	dormido	feliz	llanta	tambor
brinca	dulce	frente	llorando	tambores
campana	elefante	fuente	manzana	tortuga
castillo	escoba	gancho	pintura	verde
chancl(et)as	espejo	gente	prende	

Table 3.8. AEP onset clusters

Word-initial				
(french) fry-s	crayon-s	plate	smoke	stove-i
blow	drive	please	snail	strawberry
blow-ing	drive-ing	present	snow	stretch
blue	drum	prince(ss)	snow-ing	swim
break	flower	queen	space	swim-ing
break-ing	fly	quiet	splash	swing
bridge	fly-ing	screw	splash-ing	swing-ing
bridge-i	frog	skate	spoon	three
brother	frog-i	skate-ing	spring	throw
brush	glass-s	skunk	spring-i	throw-ing
climb	glove	sleep	square	train
climb-ing	glove-i	sleep-ing	square-i	train-i
cloud	grape-s	slipper-s	stir	treehouse
crash	green	smile	stir-ing	twelve
crash-ing	music	smile-ing	stove	twin-s
Word-medial				
thirsty	vacuum	zebra		

Table 3.9 Little PEEP onset clusters

Word-initial				
beautiful	drum-s	quack-ing	snore-ing	street
blanket	flag	quake	snow-ing	stripe-s
block-s	flower	queen	spaghetti	strong
blue	fly	scarf	spider	sweep
bridge	friend	school	spill	sweep-ing
bridge-s	frog	scratch	splash	swim
brother	front	scratch-ing	splash-ing	swim-ing
brush	glass	screw	splinter	swing
brush-s	glass-s	scrub	split	swing-ing
climb	globe	scrub-ing	spray-ing	thread
climb-ing	glove	shrank	spring	three
cloud	grandma	shrimp	sprinkle-s	throw-ing
clown	grape-s	shrug	square	train
crab-s	grass	skate	squeak	tree
crawl	grass-y	skate-ing	squeak-y	treehouse
crayon	music	sleep-ing	squeeze	trunk
crayon-s	planet-s	sleeve	squeeze-ing	twin-s
cute	plant	slipper-s	stamp	twinkle
drawbridge	playground	smile	star	twist
drink	present	smoke	star-y	
drive	pretty	smoke-y	starfish	
drive-ing	princess	smooth	stove	
drum	quack	sneeze	strawberry-s	
Word-medial				
asleep	mustache	thirsty		
cockroach	photograph	vacuum		
drawbridge	playground	zebra		
hopscotch	surprise			

Table 3.10 ASP onset clusters

Word-initial				
blanco	clavo	flecha	gracias	princesa
bloque	crema	flor	grande	tráfico
brinca	cruces	flores	granja	tren
bruja	cruz	frente	plátanos	
clase	dragón	fresa	plato	
clavar	dragones	globos	prende	
Word-medial				
bicicleta	cuatro	lágrima		
chancl(et)as	cumpleaños	sombrero		
chicle	estrella	tigre		

3.5 Acknowledgements

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Chapter 4

Asymmetries in Monolinguals' and Bilinguals' Acquisition of English Coda Clusters

4.1 Introduction

Language acquisition proceeds differently for bilingual and monolingual children. While many surface patterns appear similar during bilinguals' and monolinguals' linguistic development, bilinguals' acquisition is affected by their exposure to multiple languages. As was discussed in Chapters 2 and 3, research has demonstrated both that bilingual children acquire two separate language systems, and that these systems are interdependent and are capable of interacting during the acquisition process, which results in learning patterns that may differ from those of monolinguals (Almeida, Rose, & Freitas, 2012; Barlow, Branson, & Nip, 2013; Gawlitzek-Maiwald & Tracy, 1996; Gildersleeve-Neumann, Kester, Davis, & Peña, 2008; Gollan, Montoya, Fennema-Notestine, & Morris, 2005; Kehoe, 2002; Lleó, 2002; Lleó, Kuchenbrandt, Kehoe, & Trujillo, 2003; Mayr, Howells, & Lewis, 2014, Paradis & Genesee, 1996; Tamburelli, Sanoudaki, Jones, & Sowinska, 2015, Weinreich, 1953, among others). While many patterns of acquisition are similar between monolinguals and bilinguals, differences in bilinguals' language acquisition due to cross-language interaction can manifest in a number of ways. As discussed in Chapter 3, bilinguals may acquire some linguistic properties at a faster or slower rate relative to monolingual peers, or they may use some property specific to one language in their other language. These patterns are known as ACCELERATION, DECELERATION (or delay), and TRANSFER, respectively (Paradis & Genesee, 1996; Fabiano-Smith & Goldstein, 2010).

Evidence of each kind of interaction has been found in bilinguals' acquisition of syntax (e.g. Gawlitzek-Maiwald & Tracy, 1996; Hsin, 2012; Swain, 1972; Vihman, 1982) and phonology (e.g. Fabiano-Smith and Goldstein, 2010; Gildersleeve-Neumann et al., 2008; Goldstein and Washington, 2001; Kehoe, 2002; Lleó et al., 2003). Though many studies have shown that interaction does occur during bilingual children's language acquisition, it is not yet well understood why interaction occurs, or what factors promote the different patterns of interaction noted above. Evidence from several recent studies, however, has suggested that interaction appears when bilinguals' languages differ in the frequency of occurrence of some linguistic property. Statistical properties of the input have been shown to affect monolingual language acquisition in various linguistic domains (Jusczyk, Luce, & Charles-Luce, 1994; Kuhl, 1993; Maye, Werker, & Gerken, 2002; Werker & Tees, 1984; Saffran, Aslin, & Newport, 1996; Seidenberg, 1997; Zamuner, 2003, among others). Thus we might reasonably expect that distributional characteristics of the input for each language will affect bilinguals' acquisition, given the possibility for cross-system interaction. For example, acceleration has been shown in Spanish-German bilingual children's acquisition of Spanish singleton codas (Lleó et al. 2003; Lleó & Cortés, 2013), a syllable structure that exists in both languages but that occurs less frequently in Spanish than in German. Similar results were found in Chapter 3 for Spanish-English bilinguals' acquisition of English singleton codas. The study in Chapter 3 additionally revealed a marginal effect of background on production accuracy of English singleton coda structure, where Spanish-English bilinguals' accuracy rates were numerically lower than monolinguals'. This trend was also attributed to differences between languages in the frequency of occurrence of singleton codas. Because of this reduced frequency in Spanish, singleton codas consequently occur less frequently across the input to bilinguals compared to English monolinguals. However, Lleó et al. did not find evidence of deceleration in bilinguals' acquisition of German singleton codas, despite similar differences in frequency between German and Spanish. Instead, monolinguals and bilinguals demonstrated commensurate accuracy levels in their productions of German singleton codas.

Similar to the hypothesis that cross-language frequency differences will induce interaction is the hypothesis that acceleration will occur when there is significant overlap for some property between linguistic systems, while deceleration will occur in cases where there is less or a lack of overlap. For instance, Mayr, Howells, & Lewis (2014) and Mayr, Jones, & Mennen (2014) found that English-Welsh bilinguals' acquisition of English coda clusters and onset clusters (respectively) was accelerated relative to English monolinguals' acquisition. Coda and onset clusters are also possible syllable structures in Welsh (though some differences exist between languages in terms of the segments and segment sequences allowed in clusters). Comparisons in these studies were made between data collected from bilingual speakers and existing data from a study of monolingual acquisition of English (Templin, 1957). No monolingual data were available for comparison of bilinguals' and monolinguals' Welsh cluster productions (due to a lack of monolingual Welsh children). Therefore, it is unknown how bilinguals' acquisition of Welsh clusters compared to that of monolinguals. Mayr and colleagues followed Goldstein & Bunta (2012) in arguing that overlap between bilinguals' phonological systems leads to enhanced cue strength and reliability for common properties, and that this in turn results in accelerated acquisition of those properties by bilingual learners. Almeida, Rose, & Freitas (2012) likewise found accelerated acquisition of Portuguese onset clusters by a French-Portuguese bilingual child, citing a high degree of overlap between the two languages in terms of onset cluster phonotactics. However, the same child exhibited decelerated acquisition of word-medial singleton codas in French, which the authors attributed to differences between languages in phonotactic restrictions. French allows nearly any consonant to act as a word-medial singleton coda, whereas Portuguese allows only three segments to occur in this position, namely the fricative /s/ and liquids /l, ɾ/. While the languages overlap at the level of syllabic structure, they diverge in their positional restrictions on segments. Deceleration has also been found in cases where languages do not share a given property at all. Kehoe (2002) examined German and Spanish bilinguals' and monolinguals' acquisition of vowels, and found that bilinguals acquired the German vowel length contrast at a decelerated rate. Since the Spanish vowel system does not employ a length contrast, Spanish-German bilinguals' overall input contains less frequent evidence of contrastive vowel length compared to German monolinguals, as well as evidence from Spanish that vowel length is not contrastive.

Overlap between systems may also affect interaction at the segmental level. For example, Fabiano-Smith & Goldstein (2010) found that bilingual children were less accurate in their productions of unshared sounds in each language compared to their productions of shared sounds. Following Flege (1981; 1987), the authors argued that bilingual learners treat phonetically similar sounds between languages as a single category, a shared sound accessible in both languages. Consequently, bilinguals would have more frequent perception and production experience with shared sounds between languages than they would with unshared sounds specific to one language. The greater frequency of shared sounds across bilinguals' input might explain their greater production accuracy on shared sounds compared to unshared sounds. However, Spanish monolinguals also produced the set of shared sounds more accurately than the set of unshared sounds, despite not 'sharing' these sounds with another language system. Fabiano-Smith and Goldstein noted that the set of unshared sounds in Spanish contained marked sounds that tend to be acquired later by monolinguals, including the trill (Acevedo, 1993; Jimenez, 1987). This suggests that bilinguals' and monolinguals' lower accuracy rates on productions of unshared sounds in Spanish may have been due, at least in part, to increased phonological markedness in the set of unshared sounds. Bilinguals' productions were also less accurate than monolinguals' productions for several manner classes in each language, including the trill, fricatives, and glides in Spanish and stops and fricatives in English, despite some of the sounds in these classes being shared between languages.

Gildersleeve-Neumann et al. (2008) also found evidence of deceleration in Spanish-English bilingual preschoolers' (most of whom were exposed primarily to English) acquisition of English segments, including interdentals and affricates, as well as word-initial, medial, and final consonant clusters. Gildersleeve-Neumann et al. furthermore found numerical trends in their data suggesting that more exposure to English was correlated with fewer errors on productions of English sounds and sound sequences. However, bilinguals and monolinguals generally performed similarly on measures of overall consonant and vowel accuracy. Measures of overall consonant accuracy from Fabiano-Smith & Goldstein (2010) and of consonant and vowel accuracy from Goldstein & Bunta (2012) were also comparable between monolinguals and bilinguals. Fabiano-Smith and Goldstein interpreted this result as a variation of acceleration, given that bilinguals received less input in each language compared to monolinguals of either language, and yet achieved production accuracy levels similar to those of monolinguals.

Acceleration in terms of segmental production accuracy has additionally been demonstrated in the language acquisition of English-Maltese bilinguals. Grech & Dodd (2008) found that bilinguals' consonant productions were more accurate and more consistent than the consonant productions of Maltese monolinguals. Rather than citing overlap between systems, the authors suggested that bilinguals' accelerated acquisition was due to enhanced phonological awareness fostered by a bilingual environment. Similarly, a case study that examined the language acquisition of a Norwegian-English child, Andreas, found that he employed larger phonetic inventories in each language compared to monolinguals, including sounds that were unshared between languages (Johnson & Lancaster, 1998). The authors interpreted this acceleration in Andreas' acquisition as an emergent consequence of his efforts to differentiate the two languages.

Beyond quantitative differences in the distribution of linguistic properties, the degree of overlap between language systems, or acceleration due to bilingualism more generally, recent research has also suggested that the linguistic complexity[9] of properties in each language can influence the appearance of interaction during bilinguals' acquisition. Exposure to linguistic complexity in the input has been shown to promote monolinguals' acquisition of syntactic (Wexler 1982) and phonological structure (Dinnsen & Elbert, 1984; Gierut, 1999, 2001, 2007; Gierut, Morrisette, Hughes, & Rowland, 1996; Tyler & Figurski, 1994). Complexity in this context includes typological markedness patterns (for review, see Gierut, 2001; 2007). In a study of bilingual syntactic acquisition, Hsin (2012) found that Spanish-English bilinguals acquired English wh-questions earlier than English monolinguals due to the bilinguals' exposure to Spanish, which features greater syntactic complexity in the C-

[9] Where complexity, again, is used to refer to concepts of typological markedness, including marked sounds or structures, and the implicational markedness relationships that exist between elements within a system.

domain. This complexity also promoted earlier acquisition of CP by Spanish monolinguals compared to English monolinguals. Research on bilingual phonological acquisition has also demonstrated interaction in bilinguals' acquisition of onset clusters due to cross-language differences in onset cluster complexity. Tamburelli, Sanoudaki, Jones, & Sowinska (2015) showed via a nonce word repetition task that English-Polish bilingual 7- to 8-year-olds were more accurate than English monolinguals in repeating nonce words with initial s + obstruent onset clusters. Though s + obstruent consonant clusters are more frequent both word-initially and word-medially in Polish, Tamburelli et al. argued that bilinguals' accelerated acquisition was instead due to greater complexity in terms of Polish onset cluster sonority differences. Unlike English, Polish allows sonority plateaus and larger sonority falls in onset clusters (e.g. /pt/, /mʃ/), which some have argued are more marked than the smaller sonority falls (e.g. /sp/) allowed in both languages (Berent, Steriade, Lennertz, & Vaknin, 2007). Based on this assumption, bilinguals have access to increased onset cluster complexity in their input compared to English monolinguals. The authors consequently argued that acceleration was due in this case to differences in complexity rather than frequency, given that bilinguals' acquisition of word-medial, heterosyllabic s + obstruent clusters was not accelerated relative to English monolinguals despite the greater frequency of these clusters in Polish. However, it is also unclear whether we should expect frequency of occurrence of a segmental sequence across syllable boundaries in the input to affect acquisition in the same way as a segmental sequence within the same syllable structure.

Neither frequency nor complexity was directly considered as a possible source of interaction in English-Welsh bilinguals' acquisition of coda or onset clusters (Mayr, Howells, & Lewis, 2014; Mayr, Jones, & Mennen, 2014). However, Welsh allows greater complexity than English in onset clusters in terms of both structure and sonority (e.g. clusters /kn-, gwr-, gwl- gwn-/[10]). It is possible that bilinguals' accelerated acquisition of English onset clusters resulted from their exposure to this additional complexity in Welsh. As for coda clusters, the relative markedness allowed by Welsh and English is somewhat less clear. Both languages allow final consonant clusters with falling or level sonority, which obey the Sonority Sequencing Principle, or rising sonority, which do not. However, English allows only rising sonority coda clusters that end in /s/ (e.g. [-ps], [-bz]) while Welsh additionally allows /l/ and /n/ -final clusters (including /-bl, -dl, -tl, -gl, -vn/).

Complexity differences have also been shown to promote acceleration in each of a bilingual's languages. The results presented in Chapter 3 demonstrated acceleration in Spanish-English bilinguals' acquisition of onset clusters in English and Spanish due to cross-language differences in onset cluster complexity. Corpus analysis showed that onset clusters occur at a similar rate in each language, and thus cluster frequency was held constant. However, the languages differ in terms of the kinds of increased complexity they allow in onset clusters. English allows word-initial consonant clusters of up to 3 segments, whereas Spanish maximally allows 2-element

[10] Note that Ball & Williams (2001) analyzed [g + w + sonorant] sequences as 2-element clusters with an initial labialized stop, [g^w]. However, even 2-element clusters ending in nasals are still more complex in terms of the sonority distances between segments than the clusters allowed in English.

clusters. English therefore exhibits greater structural complexity in onset clusters. Spanish, on the other hand, allows approximant-liquid onset clusters (/βl/, /βɾ/, /ðɾ/, /ɣl/, /ɣɾ/) with smaller sonority rises than English allows in true (non-adjunct) onset clusters. Smaller sonority rises in onset clusters are more marked than and imply the existence of larger sonority rises both typologically (Davis, 1990; Steriade, 1982) and in acquisition (Barlow, 2005; Elbert, Dinnsen, & Powell, 1984; Gierut, 1999; Smith, 1973). The results of the study in Chapter 3 showed that bilingual 2- to 4-year-olds achieved higher production accuracy rates for onset clusters compared to age-matched monolingual peers in both languages due to these sources of complexity in their language input. While both Spanish and English allow onset clusters and use them with similar frequency, bilinguals benefitted from exposure to two dimensions of increased onset cluster markedness (structure and sonority) while monolinguals of either language were exposed to increased complexity in only one of these dimensions.

While complexity has been linked to acceleration, some have also argued that the existence of linguistic complexity in the input can cause decelerated acquisition in bilinguals. Along these lines, Lleó & Cortés (2013) cited Kehoe's (2002) finding that Spanish-German bilinguals acquired German long vowels later than German monolinguals, noting that contrastive vowel length, specific to German, is a marked property. However, because Spanish does not use vowel length contrastively, bilinguals are exposed to this property less frequently across their input than are German monolinguals. It is difficult to determine, therefore, whether bilinguals' decelerated acquisition of German long vowels resulted from less frequent evidence of contrastive vowel length in their input, from lack of overlap in this property in the vowel systems (or competing evidence that vowel length is not contrastive), from the markedness associated with contrastive vowel length, or from some combination of these factors. It seems unlikely that the cause of deceleration in this case was simply the complexity of the German vowel system. Indeed, Lleó and Cortés, like Lleó et al. (2003), did not find deceleration in Spanish-German bilinguals' acquisition of singleton codas in German, despite the markedness of this syllabic structure.

4.2 Current Study

Taken together, the findings from the literature discussed above suggest that interaction will arise when language systems differ in the frequency of occurrence of overlapping properties, in their restrictions on overlapping properties, or in the complexity of the properties they allow. In Chapter 3, it was found that bilinguals acquired Spanish singleton codas at an accelerated rate compared to monolingual peers. This acceleration was a result of their exposure to either the greater frequency of English codas, the greater complexity of English codas, or a combination of the increased frequency and complexity of English codas relative to Spanish codas. Bilinguals' accuracy rates for English singleton coda productions were numerically lower than those of monolinguals, though this result was not statistically significant, suggesting that bilinguals' acquisition of English singleton codas was proceeding at a rate similar to that of monolinguals despite the lower frequency of codas in Spanish.

The following study advances the investigation of Spanish-English bilinguals' acquisition of English codas by examining their acquisition of coda clusters[11], again comparing their performance to the performance of age-matched monolingual peers.

While both English and Spanish allow closed syllables, they occur relatively frequently in English, and relatively infrequently in Spanish (see Table 3.1, Chapter 3). English allows nearly every consonant in its inventory to act as a singleton coda, and permits a wide variety of segmental combinations to occur in syllable-final consonant clusters (Roach, 2002). In fact, coda clusters occur more frequently than onset clusters in English, and certain coda clusters tend to precede onset clusters in English monolinguals' acquisition of syllable types (see especially Barlow, to appear:18-20; Dodd, 1995; Kirk & Demuth, 2003; Templin, 1957). Spanish, however, places more segmental restrictions on what can occur in the coda, especially word finally, where it allows primarily coronal segments as singleton codas. Spanish does allow some consonant clusters syllable-finally. However, all of these end in /s/, as in *pe**rs**.pec.tive* 'perspective', *so**ls**.ti.cio* 'soltice', *i**ns**.cri.bir* 'to inscribe', *a**bs**.trac.to* 'abstract', *bi.ce**ps*** 'biceps', and *to.ra**x*** (/**ks**/) 'thorax' (Colina, 2009; Hualde, 1999).

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[11] Again in chapter 4, as in previous chapters, I assume that children' use of a consonant in a given position within a word indicates their use of syllabic structure associated with that position. For example, use of word-final [nt] in /plænt/, 'plant', indicates use of coda cluster structure. The use of this assumption, following Almeida, Rose, & Freitas (2012), Barlow (2001; 2004; 2005), Kirk & Demuth (2003; 2005), and Lleó et al. (2003), among others, reflects syllable-based approaches to phonotactics. It would also be possible form similar assumptions in terms of theories that do not posit the existence of syllable structure and instead derive phonotactics from string-based sequencing constraints on linear representations of segments (e.g. Steriade, 1999; Blevins, 2003).

Because Spanish does not allow s-initial onset clusters, /s/ in these sequences is not considered part of a word-medial onset. Rather, post-consonantal, syllable-final /s/ is often analyzed as an adjunct or appendix (Colina 2009; 2012; Harris, 1983; Hualde, 1999) of the preceding syllable, which allows the generalization that Spanish phonotactics do not permit coda clusters. Syllable-final consonant clusters are very infrequent in the language, and they are furthermore often reduced in speech to [s] (Colina, 2009; Harris, 1983; Hualde, 1999). Moreover, Spanish coda clusters such as those listed above tend to occur in words that young children are unlikely to know.

We obtained coda cluster frequencies from the SUBTLEX corpora for English ($\text{SUBTLEX}_{\text{US}}$). The SUBTLEX corpora are orthographic transcriptions of spoken language from film and television series subtitles, and the $\text{SUBTLEX}_{\text{US}}$ (Brysbaert & New, 2009) corpus contains 51 million words. Corpora of 16-30 million words or above have been shown to yield reliable word frequency norms (Brysbaert & New, 2009). Furthermore, $\text{SUBTLEX}_{\text{US}}$, a spoken language corpus, was better than even larger written language corpora at predicting word processing times, according to analysis of a number of studies measuring participants' reaction times in lexical decision or naming tasks (Brysbaert, Keuleers, & New, 2011). The SUBTLEX corpora are currently the best available resources for determining word frequencies in spoken language, from which we can determine the frequency of occurrence in speech of syllable types that make up the words in the corpus. We treat these frequencies as representative of syllable type frequencies in the spoken language that children hear given research that suggests frequencies derived from adult language corpora are suitable for use in child language acquisition research. For instance, phonotactic probability and neighborhood density are positively correlated between adult (dictionary-based) and child production corpora (Storkel and Hoover, 2010). Gierut and Dale (2007) similarly showed large consistencies between child and adult receptive and expressive corpora, and suggest that large lexical corpora are appropriate for use in child language acquisition research. Furthermore, positional phoneme and biphone frequencies are largely similar in adult-directed and child-directed speech corpora (Jusczyk, Luce, & Charles-Luce, 1994). Based on the general correspondence this research has shown between adult and child language corpora, and that the corpora currently available for child-directed speech tend to be comparatively small, we chose to use the reliable frequency counts derived from SUBTLEX corpora. Ideally, frequencies would have been obtained from the language exposure of each participant in the study. However, these data were unavailable.

The frequency of coda clusters in English was calculated for word and syllable tokens from $\text{SUBTLEX}_{\text{US}}$ using the CMU Pronouncing Dictionary (Carnegie Mellon Speech Group, 1993) and a syllabification algorithm (Gorman, 2013) for English[12]. We calculated coda cluster frequencies for syllable and word tokens in Spanish using $\text{SUBTLEX}_{\text{ESP}}$ (Cuetos, Glez-Nosti, Barbon, & Brysbaert, 2011), the Spanish language SUBTLEX corpus of 40 million words, and a syllabification algorithm for Spanish (Cuayáhuitl, 2004). Syllable level frequency counts included word-final (coda)

[12] Note that we modified this syllabification algorithm to count schwa+r and syllabic rhotics followed by N consonants as coda clusters rather than categorizing the rhotic as part of the syllable nucleus.

clusters as well as medial clusters, whereas word level frequency counts included only word-final coda clusters. Frequency counts for coda clusters in word and syllable tokens can be found in Table 4.1. The frequency counts for onset clusters presented in Chapter 3 are also repeated here for convenience (see below).

Table 4.1 Distributional statistics for Spanish and English coda and onset clusters from SUBTLEX corpora.

	English	Spanish
Word-final consonant clusters (%)	9.28%	0.03%
Syllable-final consonant clusters (%)	8.79%	0.13%
Word-initial consonant clusters (%)	4.61%	3.21%
Syllable-initial consonant clusters (%)	5.46%	4.23%
Total word tokens in corpus	49,719,560	40,017,237
Total syllable tokens in corpus	53,829,329	74,905,826

Because these frequency counts are based on orthographic transcriptions of spoken language, it is not possible to determine how often consonant clusters were reduced in the speech the corpora are based on. However, it is apparent that syllable-final clusters occur far more frequently in English than in Spanish. In addition to its more frequent use of coda clusters, English is less restrictive than Spanish in the segmental combinations it allows to occur in codas (Roach, 2002), though many English coda clusters end in [s, z, d, t] due to word-final verbal and nominal morphology, including clusters with more than two segments (e.g. ‘stamps’, ‘widths’, ‘sixths’). In summary, Spanish and English differ in the frequency and complexity of their closed syllables, particularly with regard to coda clusters. English allows true coda clusters while Spanish does not, and English uses coda clusters with far greater frequency.

Given these distributional differences between languages (lower frequency of coda clusters in English, more restrictions on Spanish coda clusters), we predict that Spanish-English bilinguals will exhibit decelerated acquisition of English coda clusters. We evaluate these predictions by comparing accuracy scores for English coda cluster productions elicited from English monolingual and Spanish-English bilingual preschoolers (see section 4.2.1 below). However, it is also possible that the high frequency of this syllable structure in English will promote bilinguals' coda cluster acquisition in spite of the rarity of Spanish coda clusters. For instance, Kehoe & Lleó (2003) found that Spanish-German bilinguals acquired coda clusters before onset clusters in German, despite the lower frequency of occurrence of coda clusters in their overall input compared to German monolinguals, and despite the existence of onset clusters in both languages. In view of this finding, as well as research showing that English monolinguals tend to acquire coda clusters before less frequently occurring onset clusters (Kirk & Demuth, 2003), we additionally compare production accuracy rates between onset cluster and coda cluster productions for monolingual and bilingual participants. Considering that onset clusters exist in both Spanish and English, and that Chapter 3 demonstrated that bilinguals' acquisition of onset clusters was accelerated in both languages, it is possible that bilinguals' acquisition of onset clusters will be more advanced than their acquisition of coda clusters. However, it is expected that English monolinguals will be more advanced in their acquisition of coda clusters compared to onset clusters, given that coda clusters are the more frequently occurring structure in English.

Both structural and segmental accuracy were measured when evaluating children's productions of English coda clusters, following the approach used in the study presented in Chapter 3. These measures allow us to analyze children's acquisition of structural and segmental patterns separately, which may be especially relevant in case of interaction in bilinguals' acquisition given previous findings of segmental acceleration and deceleration in bilinguals' phonological development. We predict that bilinguals' acquisition of English coda clusters will be decelerated, and that consequently their production accuracy scores for English coda clusters will be lower than those of monolinguals. We additionally predict that bilinguals will exhibit higher production accuracy scores for onset clusters than for coda clusters, whereas monolinguals are expected to exhibit higher accuracy in their productions of coda clusters compared to onset clusters.

4.2.1 Methods

Participants

Twenty children participated in this study, including ten monolingual speakers of English (mean age (SD): 43.41 m.o. (8.34 months), range: 29.4 m.o. – 58.7 m.o.) and ten bilingual speakers of English and Spanish (mean age (SD): 45.77 m.o. (8.97 months), range: 25.5 m.o. – 56.8 m.o.). An independent one-way ANOVA revealed no significant difference in age between groups, $F(1,18)=0.372$, $p=0.55$. Based on parents' responses to a case history questionnaire, each participant was determined to be typically developing with normal hearing and normal linguistic, cognitive, and motoric development. Data from participants BL01, BL02, BL03, BL04, BL05, MLE02, MLE03, and MLE04 were drawn from the archives of a larger study investigating the acquisition of Spanish and English phonology by monolingual and bilingual children in the Southern California and Baja California area. The remainder of the data in this study were collected prospectively from participants living in the same geographical region. Data from the archives were included in the current study to increase statistical power. All participants included in this study also participated in the study in Chapter 3. However, participants MLE01 and MLE05 were excluded because they did not attempt to produce any targets with coda clusters. Tables 4.2 and 4.3 provide information about the general characteristics of the study's participants, as well as additional information about language input and output for the bilingual participants.

Table 4.2. Demographic information for English monolingual participants

Participant ID	Age (months)	Gender
MLE02	29.4	Female
MLE03	51.6	Male
MLE04	50.8	Female
MLE06	37.2	Male
MLE07	58.7	Male
MLE08	38.9	Male
MLE09	41.2	Female
MLE10	43.6	Female
MLE11	40.5	Female
MLE012	42.2	Female

Table 4.3 Demographic information for Spanish-English bilingual participants

Participant ID	Age (mo)	Gender	Input (%)		Output (%)	
			English	Spanish	English	Spanish
BL01	25.5	Female	80	20	90	10
BL02	42.9	Female	27	73	10	90
BL03	54.5	Male	33	66	33	66
BL04	42.5	Male	33	66	33	66
BL05	53.1	Male	46	54	46	54
BL06	47	Male	60	40	60	40
BL07	56.8	Female	40	60	25	75
BL08	47.5	Female	60	40	50	50
BL09	47.9	Female	50	50	50	50
BL10	40	Female	20	80	20	80

Bilingual status was determined based on parents' responses to a questionnaire evaluating the participant's language development, input, and output (following Gutiérrez-Clellen and Kreiter, 2003; Pearson, Fernandez, Ledeweg and Oller, 1997; Restrepo, 1998). Participants classified as 'bilingual' for the purposes of this study had a minimum of 20% input in both English and Spanish. This criterion follows findings from Pearson et al. (1997) showing that at least 20% exposure was required for bilinguals to readily produce utterances in the target language. Language input and output percentages were collected based on parent report. Bilingual participants furthermore had to be able to interact with experimenters in each language and to perform both Spanish and English versions of the picture-naming task. We employ the term 'early bilingual' to describe the bilingual participants in this study, given that that all started acquiring their L2 before their L1 was fully established (before the age of 5 or 6 years, following Flege, 2007; Flege et al., 1999; Hamers and Blanc, 2000; McLaughlin, 1978).

Materials and procedure

We evaluated transcriptions of participants' productions of target words with word-final coda clusters. Because Spanish coda clusters occur so infrequently and occur in words that young children are unlikely to know, only English productions were examined. Productions were elicited using either the Assessment of English Phonology (AEP: Barlow, 2003a), or the Shorter Protocol for the Evaluation of English Phonotactics (Little PEEP: Barlow, 2012). These assessments target all phonemes of English in all permitted syllable positions. The AEP contains 16 opportunities to produce word-final coda clusters, while the Little PEEP contains 49 opportunities to produce word-final coda clusters[13]. Participants BL01, BL02, BL03, BL04, BL05, MLE02, MLE03, and MLE04 completed the AEP, while participants BL06, BL07, BL08, BL09, BL10, MLE06, MLE07, MLE08, MLE09, MLE10, MLE11, and MLE12 completed the Little PEEP. Single word productions were obtained using non-imitation elicitation of the assessment targets via a picture-naming task (e.g. "*What's this?*") with delayed imitation when necessary (e.g. "*It's a lemon. What is it?*"). Phonetic transcriptions of participants' productions were performed by judges trained in the use of narrow transcription with the IPA. English productions were transcribed by native speakers of English. A second judge re-transcribed twenty percent of the data for calculation of transcription reliability. Point-to-point inter-judge reliability for each target word was 87.7%.

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[13] Words from each assessment are listed in the Chapter 4 Appendix. The Little PEEP is a more recent assessment, and was developed based on the AEP. Data from participants who completed the AEP were collected prior to the development of the Little PEEP.

Analyses

We analyzed the accuracy of monolinguals' and bilinguals' productions of word-final coda clusters in two ways. Like Lleó et al (2003), we analyzed the structural accuracy of participants' productions, counting consonant substitutions as correct productions of complex coda structure. We additionally performed an analysis of the segmental accuracy of participants' complex coda productions, counting consonant substitutions as incorrect productions. Coda consonant deletions were recorded as incorrect productions in both analyses. The purpose of the structural accuracy analysis was to evaluate the accuracy of participants' productions of complex coda structure, ignoring the accuracy of their productions of specific segments in this position, whereas the segmental accuracy analysis evaluated participants' accuracy in terms of the segmental phonotactics of complex codas.

The structural accuracy of each target production was calculated such that any complex coda production matching the number of cluster segments present in a complex coda target was treated as correct, regardless of segmental accuracy. Unintelligible productions and missing productions (cases where a participant did not produce a given target) were not included in the analysis. Accuracy percentages for coda clusters were based on the number of successful productions divided by the total number of coda cluster attempts (total number of hits and misses). For example, if a participant attempted to produce *blocks, iceberg, playground,* and *twins*, and produced outputs of [blaks], [aɪsbəɹd], [pleɪgɹaund], and [twɪn], she would have a mean accuracy percentage of 75% for complex codas (3 hits/4 attempts).

The segmental accuracy analysis, by contrast, was calculated such that a faithful production of a complex coda was recorded as a hit while consonant deletions and substitutions were recorded as misses. Again, unintelligible productions and missing productions were not included in the analysis. Accuracy percentages for each structure in the segmental analysis were again calculated by dividing the number of successful attempts for the structure by the total number of attempts for the structure (total number of hits and misses). To compare these measures, let us consider the same example used above. Given the child's productions, as listed above, of [blaks], [aɪsbəɹd], [pleɪgɹaund], and [twɪn], she would have a mean accuracy percentage of 50% for coda clusters (2 hits/4 attempts). The consonant substitution in the child's production attempt for *iceberg* that was counted as a hit in the structural analysis is counted as a miss in the segmental analysis, while the cluster reduction in the child's production attempt for *twins* was counted as a miss in both analyses.

4.2.2 Results

Data were analyzed using mixed logit models. This method of statistical analysis was chosen because it is able to model binomially distributed response variables (such as raw accuracy scores of 1 or 0 for productions of each item) and furthermore allowed us to control for random participant and item effects. Both the structural and segmental analyses included participant background (monolingual vs. bilingual) as a fixed effect and participant and item as random effects. Significance of the fixed effect predictor was determined using model comparison where the null model did not include the fixed effect. All statistical analyses were performed using R statistical software (R Development Core Team, 2015) and the lme4 package (Bates, Maechler, Bolker, & Walker, 2014) for mixed effects models.

Statistical analyses did not find a significant effect of participant background on coda cluster production accuracy in either the structural ($\beta = -0.7824$, s.e. = 0.7009; $\chi 2(1) = 1.2221$, $p = 0.2689$) or segmental ($\beta = -0.5649$ s.e. = 0.7041; $\chi 2(1) = 0.6435$, $p = 0.4225$) analyses. Descriptive statistics for both analyses are presented in Table 4.4.

Table 4.4 Means and standard deviations (SD) of participants' production accuracy scores for structural and segmental analyses of coda clusters

	Bilinguals		Monolinguals	
	Mean	SD	Mean	SD
Coda cluster structural accuracy	64.2%	(29.9%)	80.4%	(15.8%)
Coda cluster segmental accuracy	54.7%	(27.8%)	68.5%	(16.2%)

While both structural and segmental coda cluster production accuracy group means were numerically higher for monolinguals, there was a greater amount of variance in the bilingual data. Average accuracy scores across participants are shown in Figure 4.1 (structural analysis) and Figure 4.2 (segmental analysis).

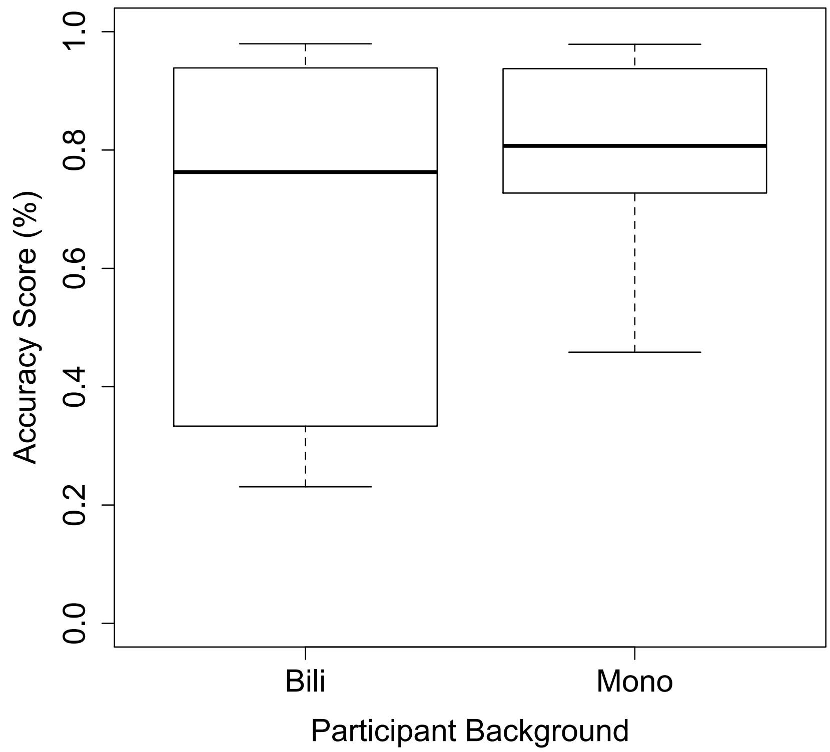

Figure 4.1 Structural accuracy score means for productions of coda clusters by bilingual (Bili) and monolingual (Mono) participants.

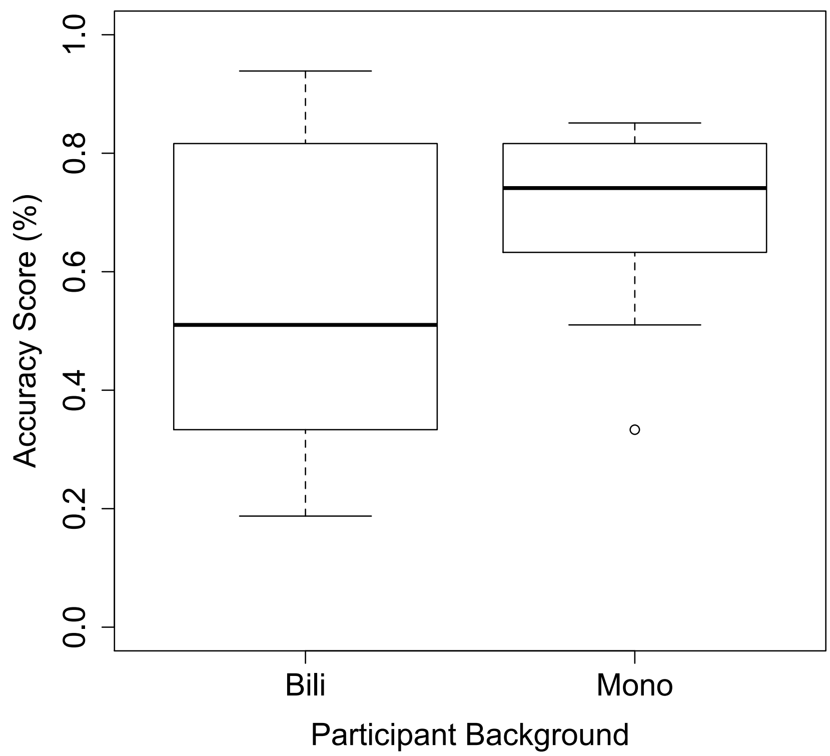

Figure 4.2 Segmental accuracy score means for productions of coda clusters by bilingual (Bili) and monolingual (Mono) participants.

We additionally obtained accuracy scores for participants' word-initial and word-medial onset cluster productions using structural and segmental analyses analogous to those used for analyses of coda clusters. Descriptive statistics for the onset cluster analyses are listed in Table 4.5, and Figures 4.3 and 4.4 show accuracy scores by background for both syllable structures.

Table 4.5 Means and standard deviations (SD) of participants' production accuracy scores for structural and segmental analyses of onset clusters

	Bilinguals		Monolinguals	
	Mean	SD	Mean	SD
Onset cluster structural accuracy	86.1%	(14.0%)	79.5%	(23.1%)
Onset cluster segmental accuracy	82.0%	(14.2%)	63.2%	(24.4%)

Wilcoxon signed rank tests (two-tailed) were used to determine whether bilingual and monolingual participants' mean production accuracy scores for onset clusters differed from their production accuracy scores for coda clusters[14]. Statistical analysis did not indicate differences in mean production accuracy scores for monolinguals under either the structural (onset cluster median = 80.4%, coda cluster median = 80.7%, $Z = 0.489$, $p = 0.625$, $r = 0.155$) or segmental analyses (onset cluster median = 55.7%, coda cluster median = 74.1%, $Z = 0.293$, $p = 0.7695$, $r = 0.093$). However, bilingual participants' productions of onset cluster structure (median = 93.7%) were significantly more accurate than their productions of coda cluster structure (median = 76.3%), $Z = 3.097$, $p < 0.01$, $r = 0.979$. Similarly, their productions of onset clusters (median = 86.1%) were more segmentally accurate than their coda cluster productions (median = 51.0%), $Z = 3.097$, $p < 0.01$, $r = 0.979$.

[14] For comparisons of monolinguals' and bilinguals' onset cluster productions, see Chapter 3, where bilinguals were shown to exhibit accelerated acquisition of onset clusters relative to monolinguals.

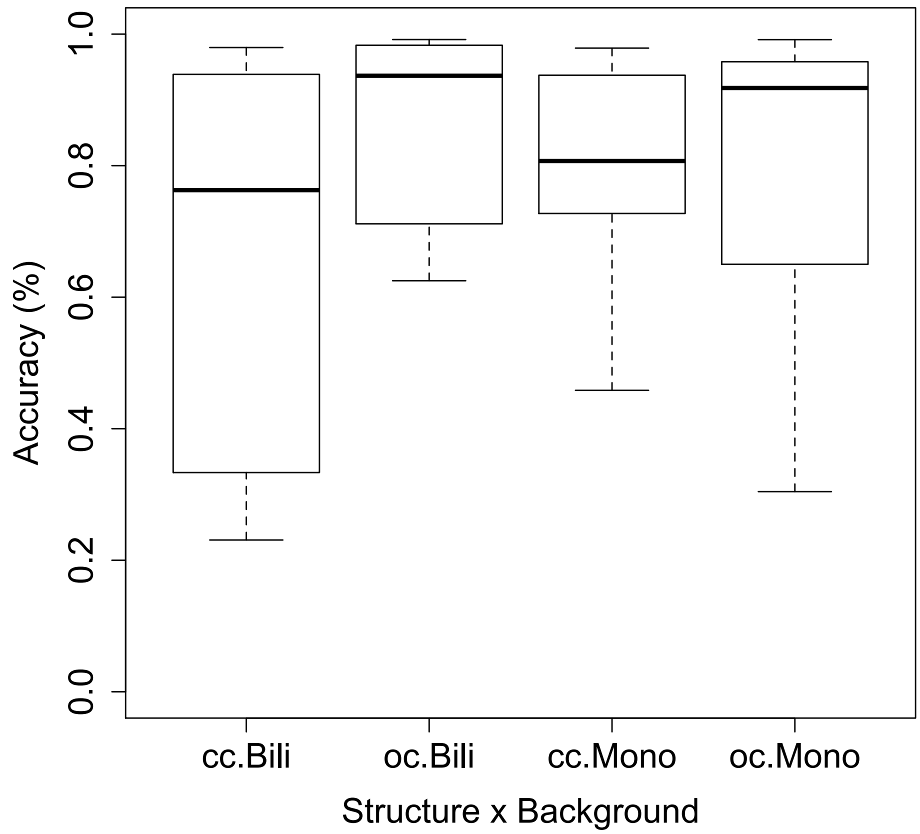

Figure 4.3 Structural accuracy score means for productions of onset (oc) and coda (cc) clusters by bilinguals (Bili) and monolinguals (Mono).

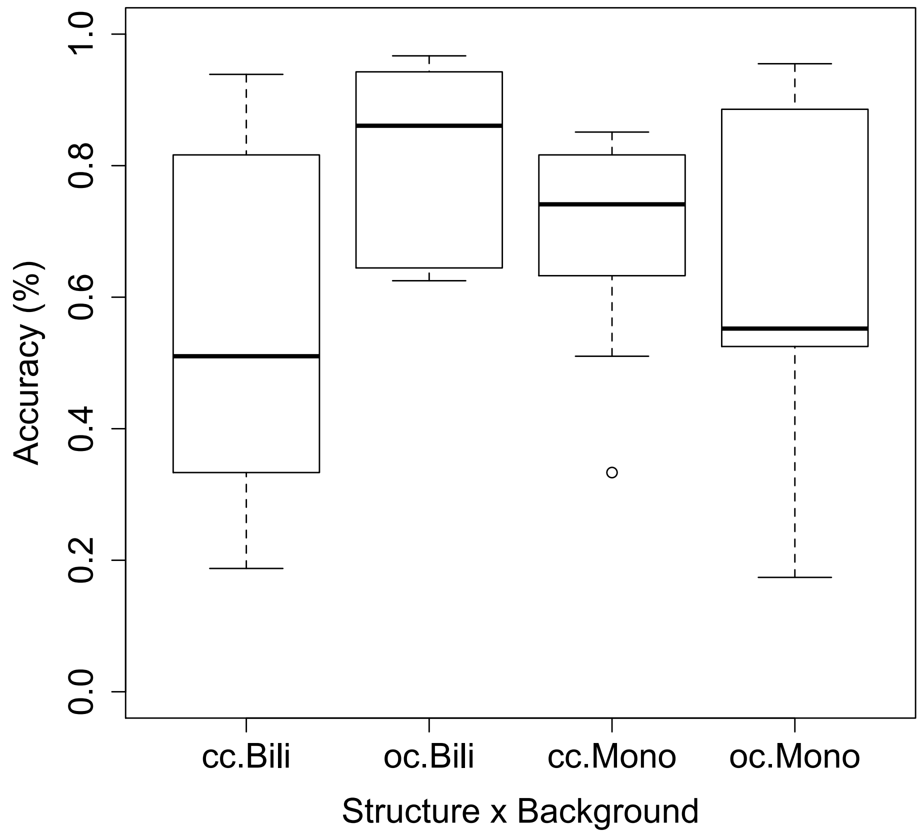

Figure 4.4 Segmental accuracy score means for productions of onset (oc) and coda (cc) clusters by bilinguals (Bili) and monolinguals (Mono).

4.3 Discussion

Contrary to our predictions, neither structural nor segmental accuracy differed between monolingual and bilingual participants' coda cluster productions. Bilinguals performed at accuracy levels similar to those of their monolingual peers, suggesting that bilinguals' acquisition of English coda clusters was not decelerated. However, there was greater variance in bilinguals' accuracy scores than in monolinguals' scores for both structural and segmental analyses (see Table 4.4). Coda cluster accuracy means for each bilingual and monolingual participant are displayed in Figures 4.5 (structural accuracy) and 4.6 (segmental accuracy) below.

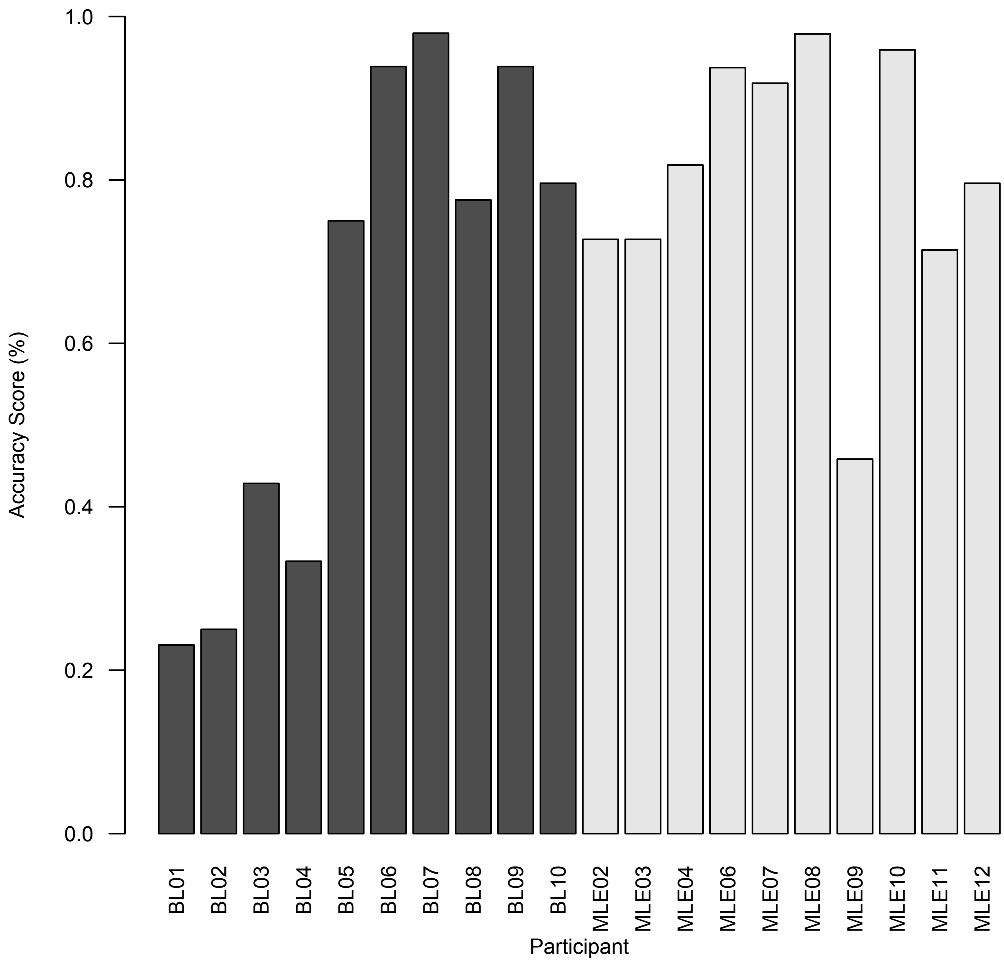

Figure 4.5 Structural analysis

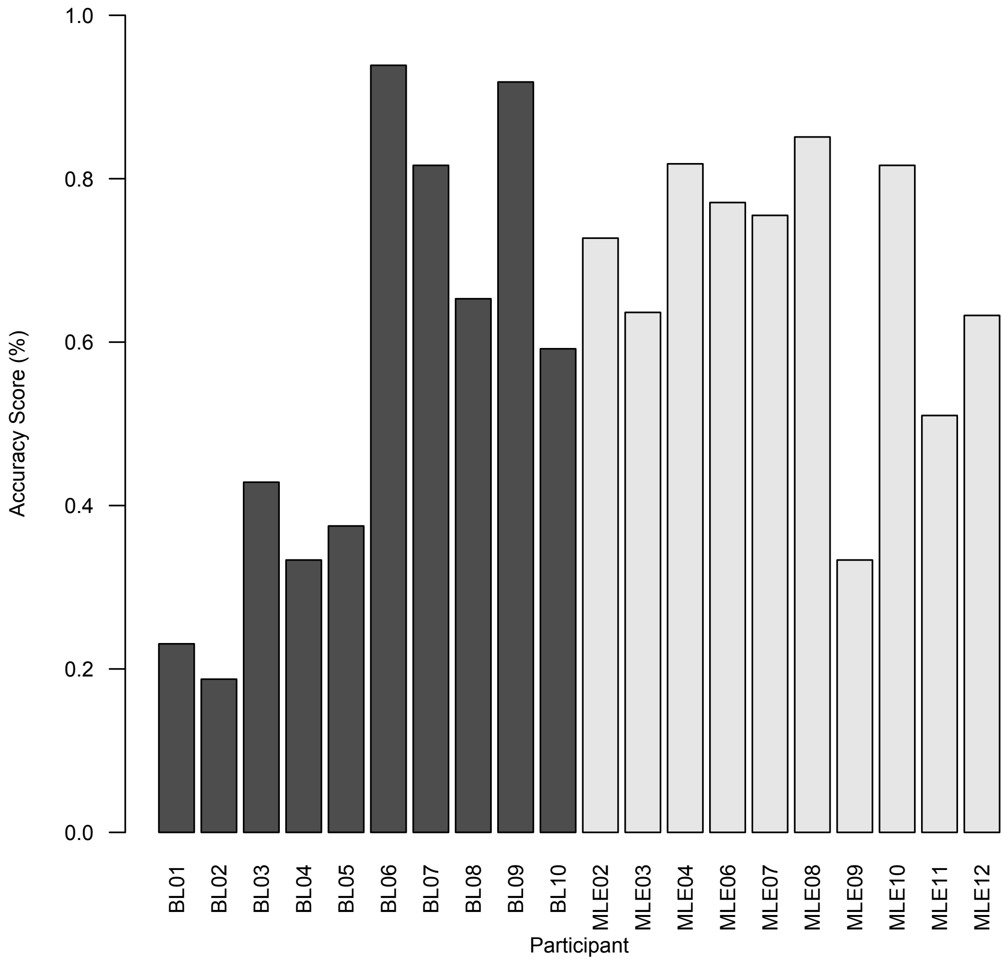

Figure 4.6 Segmental analysis

Visual inspection of the data reveals that accuracy score means were lower for BL01-BL04 in the structural analysis and for BL01-BL05 in the segmental analysis compared to accuracy means for other bilingual participants. While data from participants BL01-BL05 were taken from the archives of an earlier study and data from BL06-BL10 were collected prospectively, the two sets of participants were comparable in terms of age (Table 4.3 above). Language input and output measures were also similar between these sets of bilingual participants (Table 4.3 above), and all participants were able to interact with the experimenter and to complete the experimental task in the target language in a manner suggesting similar language proficiency. Language proficiency and dominance have been shown to influence bilinguals' developing speech production abilities. Less experience with or ability in a language is associated with lower rates of consonant production accuracy (Goldstein, Bunta, Lange, Rodríguez, & Burrows, 2010) and higher rates of consonant error (Gildersleeve-Neumann et al., 2008) in the same language. Though bilinguals' Spanish and English input and output percentages (see Table 4.3) were similar between data sets, it is possible that parent report or direct measures of language ability (e.g. MLU or picture vocabulary test scores) might have revealed differences in bilingual participants' proficiency or dominance. Future research should collect measures of bilingual participants' language proficiency or dominance to ensure that this factor is considered when analyzing bilinguals' productions.

Participants did differ in which assessment they were given; BL01-BL05 completed the AEP (Barlow, 2003a) whereas the remaining bilingual participants completed the Little PEEP (Barlow, 2012). However, construction of the Little PEEP was based on the AEP, and there is a large degree of overlap between the two assessments (see the appendix to this chapter for a complete list of relevant items from each assessment). The assessments do target different numbers of coda clusters; the AEP targets 16 distinct words with coda clusters, whereas the Little PEEP targets 49 distinct words with coda clusters. There were also differences between data collection practices for the archive data and the newly collected data such that participants from the more recent data set completed all or nearly all of the Little PEEP, whereas participants from the archive data set tended to complete less of the AEP. On average, bilingual participants who contributed to the archive data set attempted 9.4 targets with word-final coda clusters (range: 3-16 attempts), while each bilingual participant from the new data set attempted all 49 target words with coda clusters. These divergences in assessment completion were due to differences in participant availability; while experimenters collecting data for the archives were often limited to a single elicitation session with a given participant, those collecting data prospectively attempted to elicit the entire phonological probe, completing up to four sessions[15] with each participant toward this purpose. Note, though, that while monolingual participants MLE02, MLE03, and MLE04 also completed less of the AEP (each having attempted 11 target words with coda clusters), their accuracy scores do not appear to markedly differ from those of the other monolingual participants, who completed all or nearly all of the Little PEEP.

The difference found for bilingual participants carries some methodological implications. If only data from the archives had been assessed, this may have led to the conclusion that monolinguals' productions of coda clusters were more accurate than bilinguals' coda cluster productions, whereas no such difference would be found for the prospectively collected data. However, even with the inclusion of the bilingual data from the archives, statistical analyses did not find differences in accuracy

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[15] Any subsequent sessions occurred within a month of the initial session.

between bilinguals' and monolinguals' coda cluster productions. This suggests that the increased target opportunities provided by higher completion rates on the Little PEEP (which has more coda cluster opportunities than the AEP) are more accurately assessing participants' production accuracy rates compared to lower completion rates on the AEP. Since bilinguals completing the AEP had fewer chances to produce coda cluster targets than bilinguals who completed the Little PEEP, each single unsuccessful production had a greater effect on their overall accuracy score. It's possible that, given more target production opportunities, BL01-BL05 would have obtained accuracy means resembling those of the remaining bilingual participants.

In either case, accuracy score means for bilinguals and monolinguals who completed the Little PEEP largely resembled each other. We therefore conclude that bilingual participants did not exhibit decelerated acquisition of English coda clusters relative to monolingual peers. Future research replicating these results should use data from larger numbers of participants who complete similar numbers of production attempts in order to ensure that there is sufficient statistical power to identify any differences that may exist between bilinguals' and monolinguals' production accuracy rates. It is additionally possible that socioeconomic status (SES) may have affected participants' performance. SES is known to affect children's vocabulary growth via features of maternal speech input (Hoff, 2003; Fernald, Marchman, & Weisleder, 2013), and children's vocabulary development is linked to their phonological development (review in Stoel-Gammon, 2011). While information regarding families' SES was not considered in the current study, future research should take this factor into account during between group comparisons (see further discussion regarding possible effects of SES in section 3.3 of Chapter 3).

Though bilingual participants' acquisition of English coda clusters was not decelerated, it did differ from monolingual participants' acquisition in a number of ways. First, unlike monolinguals, bilinguals were more advanced in their acquisition of onset clusters compared to their acquisition of coda clusters. Bilinguals' onset cluster productions were more accurate than their coda cluster productions, while monolinguals produced each structure with similar accuracy rates. This is unexpected, since coda clusters occur more frequently than onset clusters in English (see Table 4.1). Research on monolinguals' acquisition of syllable structure suggests that frequency of occurrence of syllable types in the language influences their order of emergence (Levelt, Schiller, & Levelt 1999/2000; Jarosz, 2010) and the accuracy levels at which they are produced during acquisition (Kirk & Demuth, 2003).

Why, then, are bilinguals more advanced in their acquisition of the less frequent syllable structure? This pattern of results is less surprising when we consider that onset clusters exist in both Spanish and English, and occur with similar frequency in each language. Spanish and English also differ in terms of the dimensions along which they allow onset clusters to increase in complexity. The results in Chapter 3 showed that exposure to these different sources of complexity resulted in bilinguals' accelerated acquisition of onset clusters in each language compared to monolingual peers. Together, these findings support the hypotheses that a large degree of overlap for a given property between bilinguals' languages and exposure to linguistic complexity in each language will result in their accelerated acquisition of that property. Note, though, that there are more opportunities to produce onset clusters than coda clusters in both the AEP and the Little PEEP (See Tables 3.8, 3.9, 4.6, 4.7). It is possible that bilinguals are achieving higher accuracy rates for their onset cluster productions compared to coda cluster productions in part because of the increased opportunities to produce onset clusters. The same pattern does not hold for monolingual participants, however, even though they completed the same assessments, which suggests that bilinguals' greater accuracy on onset clusters does indicate a real difference. Future research on the relative acquisition of onset and coda clusters in bilinguals or monolinguals should be designed to collect similar numbers of productions of each kind of cluster.

Interestingly, Kehoe & Lleó (2003), found that coda clusters emerged before onset clusters in the acquisition of Spanish-German bilingual children. Importantly, German is similar to English in terms of the frequency of occurrence of closed syllables. Note, however, that onset clusters may be less frequent in German than in English (Delattre & Olsen, 1969, reported that onset clusters occur in 5.9% of German syllables and in 10.5% of English syllables). Additionally, while the current study and the study in Chapter 3 measured production accuracy, Kehoe & Lleó measured the age of emergence of each syllable structure. Spanish-English bilinguals might also acquire English coda clusters earlier than English onset clusters, but proceed more quickly in their subsequent onset cluster development supported by their exposure to this structure in both languages. Likewise, exposure to branching structure in onsets could help promote bilinguals' acquisition of branching structure in codas. These possibilities should be investigated in future research, ideally using longitudinal data.

Finally, in both the structural and segmental analyses, bilinguals and monolinguals demonstrated generally high accuracy levels in their productions of coda clusters. Closed syllables are common in English, and coda clusters occur with relatively high frequency, ending approximately 9% of words and syllables overall (see Table 4.1). Perhaps the high frequency of closed syllables in English supports acquisition of syllable-final consonants by bilinguals despite the lower frequency of occurrence of Spanish codas. It is possible that detection of any potential deceleration in bilinguals' acquisition of coda clusters will need to rely on data from younger speakers, and that preschool aged bilinguals have already 'caught up' to their monolingual peers in terms of coda cluster production accuracy. Future research should additionally address this potential issue.

4.4 Chapter Appendix

This appendix contains target words with coda clusters from the Assessment of English Phonology (AEP, Barlow, 2003a) and the Shorter Protocol for the Evaluation of English Phonotactics (Little PEEP, Barlow, 2012).

Table 4.6 AEP word-final coda clusters

behind	grape-s	shark	their-s
crayon-s	~~light~~/lamp	six	twelve
elephant	popcorn	skunk	twin-s
ghost	present	slipper-s	vest

Table 4.7 Little PEEP word-final coda clusters

airport	drink	grape-s	planet-s	slipper-s
beard	drum-s	horse	plant	sprinkle-s
behind	earmuff-s	iceberg	playground	stamp
block-s	elephant	inchworm	present	stripe-s
cat-s	fork	mask	rabbit-s	third
church	friend	milk	scarf	trunk
corn	front	moth-s	shark	twin-s
crab-s	game-s	nest	shrank	twist
crayon-s	ghost	oink	shrimp	vest
desk	gold	park	six	

4.5 Acknowledgements

Chapter 4 is a revised version of a paper that is currently in preparation for submission for publication [Keffala, Barlow, & Rose (in prep.) "Interaction in bilingual phonological acquisition: Spanish-English bilinguals' acquisition of English coda clusters"]. The dissertation author was the primary investigator and author of this paper.

Chapter 5

Conclusions and Future Directions

The series of studies presented here have provided evidence of transfer and acceleration in Spanish-English bilinguals' acquisition of aspects of their phonological systems. Furthermore, the language-specific factors of frequency and complexity were shown to impact both monolinguals' and bilinguals' phonological acquisition. In bilinguals specifically, differences between languages in frequency of occurrence and linguistic complexity of phonological properties gave rise to interaction in the forms of transfer and acceleration during acquisition of each phonological system. Differences between languages in the frequency of occurrence of syllable types were shown to influence acquisition patterns in bilinguals' positional acquisition of liquids (Chapter 2), as well as the order of acquisition of onset versus coda clusters in English (Chapter 4). Exposure to sources of complexity in one language also promoted bilinguals' acquisition of related properties in the other language (Chapter 3). These findings improve understanding of factors that influence language acquisition in bilingual children, and help us better predict where and how interaction will occur during their acquisition of each phonological system.

Chapter 2 examined Spanish and English mono- and bilinguals' acquisition of liquid segments between different syllabic positions (singleton onset, singleton coda, and C2). Participants exhibited only a subset of all possible semi-complete positional inventory types. Inventories with a liquid in one position had it in singleton onset or singleton coda, but not in C2. Inventories with a liquid in two positions had it in singleton onset and C2, or singleton onset and singleton coda, but not singleton coda and C2. The acquisition of liquids in singleton onset either first or second, but not last, suggested that structural markedness exerted a strong influence on acquisition order for monolinguals and bilinguals. At the same time, liquids could be acquired first in singleton coda, indicating that positional sonority preferences also affected the positional acquisition order of segments. The dual influences of structural markedness and sonority-based markedness on acquisition are therefore a source of variation during phonological development.

The semi-complete inventories examined in this study also indicated differences in the positional liquid acquisition patterns of English and Spanish monolinguals. There was a greater occurrence of singleton coda liquids in English positional inventories (either alone or in combination with other positions) compared to Spanish positional inventories. This suggests that syllable type frequency also influenced positional liquid acquisition patterns; the greater frequency of occurrence of codas in English syllables promoted acquisition of segments in singleton coda position, at least in the case of high sonority segments like liquids. At the same time, the high frequency of occurrence of onsets and low frequency of occurrence of codas in Spanish promoted acquisition of Spanish liquids in onsets before singleton codas. Past research has shown that the frequency of occurrence of syllable types in a language affects the order in which monolinguals acquire them, such that more frequently occurring syllable types are acquired earlier than less frequently occurring syllable types (Levelt, Schiller, & Levelt, 1999/2000; Jarosz, 2010; Kirk & Demuth, 2003). Monolinguals also acquire complex syllable structures earlier if the ambient language uses those structures frequently (e.g. German monolinguals acquire singleton codas earlier than Spanish monolinguals, as demonstrated in Lleó et al., 2003). I have shown here that, beyond affecting the acquisition of syllable structure, syllable type frequency also affects the positional order of acquisition of segments.

Like monolinguals, bilinguals were also affected by structural and sonority-based markedness, and by the frequency of occurrence of syllable types in Spanish and English. Their positional liquid acquisition patterns differed between languages, suggesting that they were acquiring two distinct phonological systems. Their positional liquid inventories were largely similar to those of monolinguals of the same language in most instances, except in the case of English /l/. Instead, bilinguals' acquisition of English /l/ more closely resembled bilinguals' and monolinguals' acquisition of Spanish /l/. This suggests that bilinguals were experiencing interaction during their acquisition of English /l/ in the form of transfer. Monolinguals learning Spanish acquire the lateral liquid earlier than monolinguals learning English (Cataño, Barlow, & Moyna, 2009). Research has also shown that Spanish-English bilinguals' acquisition of English /l/ is accelerated compared to English monolinguals (Goldstein

& Washington, 2001). Additionally, bilinguals transfer their knowledge of /l/ between their languages, producing prevocalic [l] in each language with categorical equivalence (Barlow, Branson, & Nip, 2013). The findings presented in Chapter 2 regarding bilinguals' acquisition of English /l/ provide further evidence that bilinguals transfer their earlier expertise with Spanish /l/ into English, where /l/ follows a positional acquisition pattern similar to that of Spanish /l/.

In Chapter 3, I presented evidence that differences between Spanish and English in the frequency of occurrence and linguistic complexity of syllable structures and phonotactic patterns within these positions promoted interaction in bilinguals' acquisition of syllable types. Bilinguals' acquisition of Spanish singleton codas was accelerated relative to Spanish monolinguals, due to their exposure to the greater frequency and complexity of codas in English. While onset clusters occur with similar frequency in both Spanish and English, each language allows onset clusters with increased linguistic complexity along different dimensions. English allows three-element clusters, which exhibit greater structural complexity than Spanish allows in this position. Spanish, on the other hand, allows approximant + liquid clusters, which are more complex than sequences allowed in English onset clusters in terms of the sonority distances between segments. As a result, bilinguals are exposed to increased complexity along both dimensions, whereas monolinguals only have exposure to increased complexity in one dimension. Bilinguals' exposure to these sources of complexity across their languages promotes their acquisition of onset clusters in each language, resulting in their accelerated acquisition of English and Spanish onset clusters relative to monolinguals.

Despite the existence of overlap between Spanish and English in terms of their allowance of singleton coda as a possible structure, bilinguals' acquisition of English singleton codas was not accelerated relative to monolinguals. This lack of acceleration similarly fails to support the notion of a general bilingual advantage. Neither did bilinguals' acquisition of English singleton exhibit deceleration relative to English monolinguals for the ages examined, which is consistent with the findings of Lleó et al. (2003) regarding Spanish-German bilinguals' acquisition of German singleton codas. This lack of deceleration suggests that linguistic complexity may exert greater influence on interaction than frequency of occurrence, at least in the acquisition of syllable structure.

Finally, in Chapter 4, I presented evidence that even an extreme difference between Spanish and English in the frequency of occurrence of coda clusters did not result in decelerated acquisition of that syllable structure in the language where it occurs with greater frequency. While coda clusters are exceedingly rare in Spanish, and may not even appear in the ambient language to which children are routinely exposed, bilinguals' productions of coda clusters in English achieved accuracy levels similar to those of their monolingual peers. However, interaction still occurred during bilinguals' acquisition of this structure. While monolinguals exhibited similar rates of accuracy in their productions of onset and coda clusters, bilinguals' productions of onset clusters were more accurate than their coda cluster productions, suggesting that, unlike monolinguals, their acquisition of onset clusters was more advanced than their acquisition of coda clusters.

All together, I have presented evidence that frequency and linguistic complexity influence the course of phonological acquisition in monolingual and bilingual children. Positional order of acquisition of segments was affected by language-specific frequency of occurrence of syllable types, and by structural and sonority-based markedness pressures. In the case of bilinguals, differences between languages in the complexity of the properties they allow promoted accelerated acquisition of related properties in the other language. The studies presented here have demonstrated the occurrence of interaction at both segmental and syllabic levels. Bilinguals' earlier expertise with Spanish /l/ provided a scaffold for their acquisition of English /l/, and their accelerated acquisition of syllable types extended to both structural and segmental accuracy. In other bilingual populations, we should expect earlier acquisition of some property in one language to promote acquisition of similar properties in the other language. Additionally, we should expect the existence of increased complexity for a given property in one language to promote acceleration of related properties in the other language.

While these studies found evidence of accelerated acquisition, more research is needed to explore cases in which bilinguals' acquisition is decelerated. Research that has found decelerated acquisition in bilingual learners has examined segmental accuracy more generally (e.g. Gildersleeve-Neumann et al., 2008; Kehoe, 2002), or has compared accuracy on shared versus unshared sounds (Fabiano-Smith &

Goldstein, 2010). Future research should investigate segmental accuracy in more depth, with special attention to the positional phonotactics of the languages involved. It is possible that deceleration may appear in terms of lower positional production accuracy for segments that are disallowed in that position by one of a bilinguals' languages. In the studies presented here, participants' accuracy scores were generally high. This suggests that future research should expand the age ranges under consideration to include younger children. It is possible that by 3-4 years of age, bilinguals may have 'caught up' to their monolingual peers, obscuring any deceleration that may have occurred at earlier stages of acquisition. Furthermore, longitudinal data would provide us with information regarding the order of emergence of syllable structures, and of sounds in different syllabic positions. Additionally, future research should consider potential effects of different levels of language input, dominance or proficiency on phonological acquisition in bilingual learners. This research might involve measurement of bilinguals' and monolinguals' proficiency, including vocabulary scores, parent and child language usage statistics, and parent-reported proficiency scores (Prezas, 2008; Goldstein, Bunta, Lange, Rodriguez, & Burrows, 2010; Scarpino, Lawrence, Davison, & Hammer, 2010). Whereas the bilinguals who participated in the studies presented here did not exhibit decelerated acquisition, it is possible that greater dominance in one language or the other might result in different manifestations of interaction during bilingual children's phonological development.

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