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The Development of Cross-linguistic Transfer: The Case of Word-External Repairs of Empty Onsets in Spanish Heritage Speakers

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by

Gemma Repiso-Puigdelliura

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ABSTRACT OF THE DISSERTATION

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Gemma Repiso-Puigdelliura
Doctor of Philosophy in Hispanic Languages and Literatures
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Professor Ji Young Kim, Co-Chair
Professor Victoria Eugenia Mateu Martin, Co-Chair

This dissertation investigates the development of cross-linguistic transfer in the use of strategies to repair preconsonantal word-external empty onsets (i.e., /C#V/) in Spanish heritage speakers. The main focus of this work is to analyze the use of /ʔ/-epenthesis as a strategy to repair empty onsets, as its use is asymmetrical in the Spanish and English phonologies.

A total of 190 participants (i.e., monolingually raised Spanish speakers, monolingually raised English speakers and Spanish heritage speakers) took part in Spanish and/or English word production tasks that elicited function + content word sequences in real words (e.g., *un elefante* 'an elephant', *an umbrella*) and in phonotactically legal novel words (e.g., Sp. *un anbo*, En. *all embos*). Participants are divided in three main age groups: younger children, older children, and adults.

First, I examine whether the use of glottal phonation is a repair strategy employed more often in English than in Spanish, and whether it is conditioned by age. Overall, I find that in English glottal phonation is the preferred strategy to repair prosodically-prominent

onsetless syllables, whereas, in Spanish, the preferred repair strategy is modal phonation in both prosodically and non-prosodically prominent syllables. For the Spanish real words, I find no effects of language development in the experiments with real words. In the experiment with novel words, I show that older children and adult children produce a greater rate of glottal phonation than younger children, which I explain as an effect of the unpredictability of the novel words in the context. In English, the rate of glottal phonation in the real words is not affected by age. For the English novel words, older children produce greater rates of glottal phonation than the adults, demonstrating a U-shaped behaviour during language development.

Next, I formalize the Spanish and English results using MaxEnt grammars and accounting for three repair strategies: /ʔ/-epenthesis, no repair (i.e., coda consonant), and resyllabification/ambisyllabicity. I introduce the effect of prosodic prominence in the grammars using constraints on phonological enhancement.

I then compare the results of the Spanish heritage speakers to those of the monolingually raised Spanish and English speakers. For the Spanish real and novel words, I find that the younger and older child HS produce greater rates of glottal phonation than the monolingually-raised Spanish speakers, but no significant difference is observed between the adult monolingually raised Spanish speakers and the adult heritage speakers. To account for these results, I claim that child heritage grammars are more permeable to cross-linguistic transfer than adult heritage grammars. In addition, in the Spanish real words, my results show that heritage speakers with a higher amount of Spanish output glottalize less often than heritage speakers with a low amount of Spanish output, which brings to the forefront the importance of language use to control transfer from the majority language. In English, my results show that, overall, heritage speakers produce lower rates of glottal phonation than monolingually-raised English speakers (i.e., the dominant language may also suffer from negative transfer from the heritage language).

Finally, I argue that the results for the heritage grammars can be formalized using a model of language coactivation during input evaluation à la Goldrick et al. (2016). The two sets of language-specific constraints are scaled by the speaker-specific activation scores, which set the intended language and reflect the speaker's language dominance. To account for the apparent development of language control during language maturation (i.e., greater permeability of language transfer during adulthood), I posit the existence of a prior applied to the constraint weights during input evaluation.

The dissertation of Gemma Repiso-Puigdelliura is approved.

Claire Moore-Cantwell

Kie Ross Zuraw

Antonio C. Quícoli

Victoria Eugenia Mateu Martin, Committee Co-Chair

Ji Young Kim, Committee Co-Chair

University of California, Los Angeles

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Als meus avis . . .

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VITA

2008-2012	B.A. Translation and Interpretation, Universitat Autònoma de Barcelona.
2014–2015	M.A. Applied Linguistics and Second Language Acquisition, Universitat de Barcelona.
2015-2018	Lecturer at the Spanish and Portuguese Department, UCLA.
2018-2020	Teaching Assistant at the Spanish and Portuguese Department, UCLA
Spring 2021	Mellon Foundation Pre-dissertation Fellowship
2021-2022	Dissertation Year Fellowship, University of California, Los Angeles
2021-2022	National Science Foundation (NSF) Doctoral Dissertation Research Improvement Grant- Award Number BCS-2116801

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CHAPTER 1

First and heritage language acquisition

1.1 Introduction

Heritage speakers (HS) are early bilinguals that have acquired their first language, a minority language in the society, simultaneously or sequentially with the majority language. These developmental circumstances often result in situations of unbalanced bilingualism in detriment to the heritage language, as HS often shift their language dominance when they gain systematic exposure to the majority language (Benmamoun et al., 2013; Polinsky & Scontras, 2020; Valdés, 2014). That is, the exposure to the heritage language often diminishes or is interrupted as the speakers gain contact with the societal language, for instance with school teachers, school peers, internet, or television, and they might become more dominant in the majority language (Benmamoun et al., 2013). Interest in heritage language outcomes was initially more prominent in the morphosyntactic domain (Montrul, 2002, 2004; Montrul et al., 2012; Montrul & Sánchez-Walker, 2013; Polinsky, 2006; Polinsky & Kagan, 2007), arguably because early research on heritage language phonology showed advantages for HS over second language (L2) speakers in speech production (Au et al., 2002; Knightly et al., 2003, among others). However, recent studies have found that, despite the benefits of being exposed to the heritage language as a child, HS demonstrate a 'heritage accent' when compared to non-HS (Kupisch et al., 2015; Lein et al., 2016; Lloyd-Smith et al., 2020). This 'heritage accent' could be a result of cross-linguistic interaction from the majority to the heritage language. That is, the HS' two grammars may share at least some cognitive space and interact during language production (see (Putnam, 2020) for heritage grammars and

(Flege, 1995; Flege et al., 2020) for bilingual grammars). This 'heritage accent' is far from being uniform among the HS, as research on heritage grammars has documented a great deal of individual differences in speech production (Rao, 2016; Repiso-Puigdelliura & Kim, 2021). This variability is likely to stem from the unique linguistic trajectories during the speakers' lifespan (i.e., quantity and type of input, language use, interrupted exposure to the heritage grammar). However, there are few cross-sectional studies that have examined the development of the heritage language as these speakers become systematically exposed to the majority language (i.e., school years). To this purpose, the main goal of this dissertation is to examine heritage language speech production during late childhood and to compare it to that during adulthood.

Moreover, even though HS are bilinguals and, as such, are believed to share one phonological space (Flege, 1995; Flege et al., 2020), few studies have focused on the potential bidirectionality of the cross-linguistic influences observed in these grammars. For this reason, the second aim of this dissertation is to better understand to what extent the majority language influences the heritage language and vice versa. Understanding how the majority language and the heritage language interact in both directions is essential to build the phonological structure of these speakers.

Lastly, reduced exposure to the heritage language has been assumed to play an important role in the heritage grammars' outcomes. However, it is unclear how much input is necessary to produce target-like linguistic properties in the heritage language (Meisel, 2019). While the roles of input and output have been examined in relationship to early vocabulary acquisition and proficiency in morphosyntactic properties (Bohman et al., 2010; Correia & Flores, 2017; Gathercole, 2002a; Gathercole, 2002c; Thordardottir, 2011), less is known about the influence of input and output in the bilingual phonological system (Kim & Repiso Puigdelliura, 2020; Rao, 2014; Ruiz-Felter et al., 2016; Shea, 2019). Thus, the third goal is to investigate whether the amount of input and output in the heritage language (i.e., percentage of interactions in the two language with the caregivers, siblings, other relatives) predicts cross-linguistic influence on the heritage and majority language phonologies.

In the remainder of this chapter, I review the literature on first language speech production, as it will be relevant to compare the phonology of monolingual speakers to that of bilingual speakers. In particular, I focus on the acquisition of segments, the early production of the syllable and the prosodic word and the production of word-external phonological sequences. I then turn to summarize main findings in the literature of child bilingualism —both in cases of balanced and unbalanced bilingualism —, the evidence pointing to cross-linguistic influence in heritage language speech production. Finally, I discuss the roles of input and output in the development of bilingual grammars.

1.2 First language acquisition of phonology

Understanding the stages of first language development (i.e., heritage language in this study) is crucial to examine how learning a second first language (i.e., simultaneously or sequentially acquired during childhood) can alter the typical developmental paths and rhythms of a first language. In the following sections, I review the stages of first language acquisition of phonology, paying special attention to the acquisition of the segments, the syllable, the prosodic word, and word-external processes.

1.2.1 The acquisition of vowels and consonants

Children start to develop their linguistic system, presumably before birth. Initial research found that newborns prefer to listen to their mother's voice than to that of a stranger (Mehler et al., 1978), and later DeCasper and Spence (1986) found that infants prefer to listen to a story heard prenatally than to a story never heard before. During the first year of age, children language-specific sensitivity to the sounds in their native language. Young infants as early as 2 months of age discriminate categorically between lateral consonants (i.e., [ra] and [la]) (Eimas, 1975), nasal consonants (i.e., [ma] and [na]) (Eimas & Miller, 1980) and vowel contrasts (Swoboda et al., 1976). Later on, between 2-months and 8-months of age, infants have the capacity to discriminate between sounds from their native language and from foreign languages. Werker and Tees (1984) tested English-speaking Canadian infants' abilities to discriminate sound contrasts in English (/ba/ vs. /ga/), Hindi (/ ta/ vs. /ta/) and Nthlkampx (/k'i/ vs. /q'i/). Younger infants (between 6-8 months) could discriminate the three consonant contrasts, but only some older infants (between 8-10 months) could discriminate the Hindi and Nthlkampx sounds, indicating an early awareness of the sounds in their native language.

In regard to the acquisition of vowels, there is a general agreement that children acquire the vowels in their native language by age 3 (Bankson and Bernthal, 1998). However, some studies have also provided evidence of the continued development of vowels after this age. Allen and Hawkins (1980) found that, while stressed vowels are mastered by age 3, reduced vowels continue to develop up to the age of 5. Similarly, Young (1991) showed that between two and 4;3 years, children produce longer vowels in weak syllables (e.g., [dʒəraf] produced as [dʒɪraf]).

Unlike vowels, consonants have been widely researched in studies on speech development and speech pathology, as they display varying rates of acquisition Shriberg (1993), Smit et al. (1990), and Wellman et al. (1931, among others). A common finding among these studies is that the consonants /m, n, p, b, d, w/ are among the first acquired consonants. On the contrary, the liquids /l r/, the fricatives /ɹ ð θ/ and the affricates /dʒ tʃ / are frequently classified as late-acquired sounds. Some sounds also display a great deal of variation. Smit et al. (1990) found that their data for /l/, /f/, /s/ and postvocalic /ɚ/ was not uniform across their group of children. Shriberg (1993) examined that speech from 64 English-speaking children with speech sound disorders (3 to 6 years old) and classified consonants in the early-8 consonants were /m, b, j, n, w, d, p, h/, the middle-8 consonants /t, ŋ, k, , f, v,dʒ tʃ/, and the late-8 consonants /ɹ, ð, θ, ʃ, ʒ, l, s, z/. While first classified for children with speech disorders, this classification has been later used for typical sound development (Fabiano-Smith & Barlow, 2010). In a recent review of 27 languages, McLeod & Crowe (2018) documented that, although variation occurs across consonants and languages, most consonants are acquired approximately by age 5;0. In general, stops, nasals and non-pulmonic consonants have a shorter rate of acquisition than trills, flaps, fricatives, and affricates.

A physiological explanation may be at the center of the varying rates of acquisition for each consonant, by which ease of production may universally favor certain consonants (Diver, 1979; Tobin, 1997). For instance, stop consonants are likely acquired early because they do not require an active involvement of the lips or the tongue (Davis & MacNeilage, 1990). Consonants involving narrow constriction (i.e., fricatives, liquids, affricates), on the contrary, require more control of the articulators to produce a graded muscle strength (Tobin, 1997). The two-rhythm development of the vocal tract can also provide an explanation for the late development of consonants requiring more than one lingual constriction. That is, while the size and shape of the oral cavity stabilize around the age of 2;0 and 3;0 years, the tongue continues to grow after 5;6 (Vorperian et al., 2005). This indicates that sounds that require two lingual articulations are more difficult to produce before the tongue completely matures (Lin & Demuth, 2015). For instance, Oh (2005) examined ultrasound images of /l/ in onset, coda and intervocalic position in children between 3;11 and 5;9 years and found that although children produced laterals with an anterior and posterior constriction, one of these occlusions was often weak or incomplete. Moreover, Lin & Demuth (2015) found asymmetric rates of acquisition of coda and onset /l/. Whereas almost all target onset /l/ were rated as accurate from age 3;0, only 5% of coda /l/ were rated as accurate in the 3-year-olds, and accuracy only reached 52% of accuracy at age 7.

Interestingly, even the early-acquired consonants continue to develop past the age of perceptually complete acquisition. Green et al. (2000) analyzed the articulatory production (i.e., lip and jaw coordination) of syllables containing bilabial consonants (i.e., early acquired sounds) and found that the articulatory gestures continue to adjust until at least the age of

6.

1.2.2 The acquisition of the syllable

Babbling, which is prevalent between 4 and 12 months, is considered the first step of speech production (Jusczyk, 2000). In fact, there is a continuity between the sounds used in late babbling and in early word production (Stoel-Gammon & Cooper, 1984). Early word production starts around 1 year of age. As one of the initial steps in word production, the child has to acquire the syllable structure.

The assumption that CV is the universally unmarked syllable (Jakobson, 1968; Prince & Smolensky, 1993, 2004) has been supported by findings in language acquisition. Fikkert (1994a) and Fikkert et al. (2004) collected longitudinal data from 12 children acquiring Dutch and found an initial restriction against onsetless syllables and onset identity. First, syllables without onsets are produced with obstruent consonants (e.g., *appel* 'apple' /ɑpəl/ [ˈpaːpuː]). In the second stage, onsetless syllables are allowed in the child's grammar (e.g., *aap* 'monkey' /ɑːp/ [ˈɑːp]). In the third stage, the restriction on the type of onset is overcome and children produce onsets with obstruents or sonorants (e.g., *maan* 'man' /maːn/ [mɔm] or [maːm]). Codas are first disallowed in the child's grammars (e.g., *boek* 'book' /bu:k/ [tu:]), and they are later allowed but only produced as obstruents. At a fourth stage, sonorants are allowed in the output (e.g., *banaan* 'banana' /baː'naːna/ [naːn]) and, finally, consonant clusters appear (e.g., *hand* 'hand' /hant/ — [hant]). Complex onset clusters (i.e., binary branching) are acquired during later stages of development (Freitas, 2003; Kehoe et al., 2008; Levelt et al., 2000). Freitas (2003) showed that Portuguese-acquiring children undergo a stage in which they insert an epenthetic vowel between the first and the second consonant (/C1 V C2/). Levelt, Schiller and Levelt (2000) found that a markedness constraint against complex onsets and codas (*COMPLEX) remains highly ranked until the third stage (out of four) during word-internal syllabic development. Schwa-epenthesis (e.g., g[ə]lasses for glasses) has been reported in the speech of 2-3 year-olds (Dyson & Paden, 1983) and children between the ages of 5;8 to 9;5 (i.e., 44.1% during Grade 2, 28.1% during Grade 3 and 12.9% during Grade 4 (Ingram, 1974).

The stages of syllabic acquisition vary cross-linguistically. While onsetless syllables appear in early grammar stages in French and European Portuguese (Wauquier-Gravelines 2003, Freitas 1997), they appear later in English and Dutch (Fikkert, 1994b). Fikkert et al. (2004) suggests that asymmetries in constraint ranking (i.e., disallowing onsetless syllables for a longer time) might be rooted in language-specific rhythmic properties. While Germanic languages tend to be stress-timed, presenting only one full vowel per word and a syllabic structure involving more complex consonant clusters, Romance languages are often syllable-timed, showing more than one full vowel per word and less complex consonant clusters. This means that consonants play a greater role in Germanic languages than in Romance languages. Thus, the presence of consonants in the onset position (i.e., Onset) in required during a longer time in Germanic languages than in Romance languages. In other words, children acquiring Germanic languages disallow syllables without onsets and fill the onsets with segmental information (e.g., plosives, glottal stops) during later stages of development more often than children acquiring Romance languages.

1.2.3 The acquisition of the prosodic word

During the first years of word production, children present idiosyncratic rule-governed phonological processes which primarily contribute to simplifying the adult output (e.g., cluster reduction, deletion of final consonants, liquid gliding, fronting, stopping) (Dyson & Paden, 1983; Fey & Gandour, 1982; Ingram, 1974). These processes decline dramatically between the ages of 2.5 years and 4 years. After the age of 4, liquid gilding and cluster reduction occur very infrequently and deletion of final consonant, fronting and stopping are rarely found (Roberts et al., 1990). Despite these findings, specific examination of consonant reduction showed that this process varies across word length. Children master monosyllabic words by age 4;11, but disyllabic and polysyllabic words demonstrate consonant reduction up until 7;11 years of age (James et al., 2008). With regard to the inventory of consonant clusters, Smit et al. (1990) reported that by age 3;6 children produce clusters of stop + w (e.g., queen), and between the ages of 4;6 to 5;6 children produce clusters with /l/ (e.g., play) and clusters with /s/ (e.g., stop)).

The acquisition of adult-like word-internal phonological processes has also attracted the interest of developmental sociolinguists (Miller, 2013; Roberts, 1997; Smith et al., 2009). For t/d deletion (e.g., breakfas[∅]), Roberts (1997) and later Smith et al. (2009) found that as early as at the age of 3 years English-acquiring children had mastered this rule-governed sociolinguistic pattern. In a study on Spanish variation, Miller (2013) examined /s/-lenition in naturalistic speech from Chilean Spanish-speaking children and their caregivers and found that 4 and 5 year-olds pattern with adults in their /s/-lenition patterns. The findings of these studies suggest that the majority of non-adult-like phonological processes are very infrequent by the age of 4 years. Adult-like variation is also acquired around the ages of 3 and 4 years. However, children acquire complex structures later during development and polysyllabic words still show consonant reduction at the age of 7;11.

1.2.4 The acquisition of connected speech

Along with the mastery of the prosodic word structure, children must learn to connect speech in an adult-like manner, to display the intonational properties (e.g., pitch accent inventories, boundary tones, pitch scaling) and to produce the prominence-related features (e.g., placement of nuclear pitch accents) of their native language. Unlike the acquisition of the prosodic word, some of these processes have been found to continue developing during late childhood (**Repiso-Puigdelliura2020RepairingChildhood.**; Athanasopoulou, 2018; Shport & Redford, 2014) In this section, I focus in particular on the acquisition of processes related to connected speech.

Resolution of stress clash has been an area of interest in scholars examining the acquisition of connected speech and its integration with lexical and phrasal prominence. Stress clash in contexts in which sequences of two words result in contiguous lexically-stressed syllables. In English, stress clash can be resolved by shifting leftward the stress of the first stressed syllable (e.g., *thirtéen mén* to *thírteen mén* (Liberman & Prince, 1977)). Shport and Redford (2014) investigated the integration of word- and phrase level prominence in stress clash contexts, where misalignment between word-and phrasal-prominence occurs. They investigated the speech of 6;2 – 7;2 years old and adults in a counting task (e.g., thirtéen bárbeque), and found that children did not always integrate word-and phrasal-level prominence. But in both clash-and non-clash contexts, children shifted the phrasal prominence to the first syllable but maintained the word prominence in the second syllable. Thus, their results showed that 6-year-olds still show immature prosodic structures in cases of prominence integration.

In Greek, stress clash can be resolved by reducing the stress of the first prosodic word (i.e., rhythm rule) or by inserting a space between the two prosodic words (i.e., space insertion). Athanasopoulou (2018) analyzed the production of two-word sequences in clash- and non-clash contexts (e.g., xrisó dáxtilo 'gold finger' vs. mávri míti 'black nose') in 6-11 year old and adult Greek speakers. While the results of adult Greek speakers demonstrated that they use any of the two repair strategies to resolve stress clash (i.e., rhythm rule, space insertion), the data for children showed that both of the rules were acquired after the age of 7, albeit with different acquisitional patterns. Whereas children used the space insertion rule at age 8 and older, they only used the rhythm rule at age 11.

Despite the results for stress clash repair strategies suggesting a late development of connected speech, there is also evidence supporting an early acquisition of word-external phonological processes (Newton & Wells, 1999; Newton & Wells, 2002). Newton and Wells (2002) examined vowel-vowel word-external junctures (i.e., /V#V/) of an English-acquiring child (2;4-3;4). The authors examined production of glide /j w/ and /ɹ/ insertion in /V#V/ cases (e.g., tidy up [taɪdi^{j}ʌp]). Despite the fact that the child demonstrated glide insertion from the onset of two-word utterances (age 2;4), most junctures were produced with glottal phonation between the ages 2;7 and 2;9. The percentage of glide liaison increased to 80-

85% at 2;10 reaching adult-like patterns. /ɹ/ liaison (*painter in* [peɪntəɹɪn]) appeared at the age 2;11 and glottal stops were produced until the end of recording (3;4). In both cases, /ʔ/-insertion preceded adult-like segmental epenthesis (/ɹ/ and /j, w/). /ʔ/-insertion hence appears to be the favored juncture during language maturation. In an early study, Newton and Wells (1999) had not found any developmental trend between the ages of 3 to 7 in word-external assimilation, elision or liaison processes, suggesting that acquisition is complete by the age of 3. Lleó (2016b) analyzed percentage of resyllabification in data from two Spanish monolingual children residing in Madrid (1;1 – 2;8). The two children (i.e., Miguel and María) presented a high proportion of resyllabification appearing almost at the same time as they start producing two-word utterances. Resyllabified consonants reached a proportion of 98% (for Miguel) and 42% (for María) at the end of the examined age period (2;7). The use of glottalization in open junctures appears initially (40% for Miguel and 10% for María), but it becomes minimal at 2;6 (less than 10% for Miguel and 10% for María). That is, these results support an early acquisition of connected speech, showing that children go through an early stage in which glottalization is somewhat persistent, but that this is rapidly overcome by an adult-like production of word junctures. These findings are of particular importance for my study, as it also examines resyllabification and glottalization process across word junctures.

However, both Newton and Wells' (2002) and Lleó's (2016) studies are based on very few participants. On this domain, more data are needed to better understand the development of word junctures and directly compare it with adult speech.

As part of the discussion about the acquisition of word-external phonological processes, it is important to consider the effect that the intrinsic acquisitional properties of the segments involved in such process can have on their. Recall that Newton and Wells (2002) found that, while most between-word junctures (i.e., elision, liaison) appear from the beginning of two-word utterances, those junctures involving a rhotic consonant (i.e., /ɹ/-liaison) do not occur until the child is 2;11. It is possible that the late acquisition of /ɹ/-liaison is related to an overall late acquisition of the rhotic consonant. Aside from the acquisition rate of the consonants involved in the word-external phonological processes, the development of coarticulation between these consonants and their flanking vowels could also influence adult-like production of between-word junctures. For instance, Nittrouer (1993) found that children produced similar gestures to those of adults schwa-stop-vowel sequences (*a key*), but their movements were slower and demonstrated greater temporal variability. In particular, children did not show adult-like intergestural coordination at the age of 7 and consonant and vowel gestures overlapped during a longer time in children's productions than in adult's productions.

These studies suggest that the acquisition of word-external phonological processes could be dependent on the segments involved in such processes. More specifically, late-acquired consonants or coarticulatory processes could delay adult-like production of between-word junctures.

Moreover, lexical frequency has also been found to influence the production of connected speech (Bybee, 2001; Dugua et al., 2009). Dugua et al. (2009) investigated the acquisition of liaison consonants. French-speaking children (3;2-6;3) were asked to produce 8 singular and plural nouns and determiners, 4 of which were more frequent in the singular form (e.g., *un ours* 'a bear') and 4 were more frequent in the plural form (e.g., *deux arbres* 'two trees'). A correlation was found between how often a noun is produced as a singular or plural and how often the liaisons with /z/ or /n/ are produced correctly. In second language acquisition, Odette de Moras (2011) found that frequency of syntactic structures (e.g., monosyllabic determiner + noun vs. adjective + noun), frequency of co-occurrence of word 1 and word 2, and frequency of the liaison consonant (e.g., /z/ vs /v/) have an effect on the amount of liaison production of L1 English speakers learning French as an L2.

Within usage-based accounts, Bybee (2001) states that external sandhi phenomena are either stored as stable representations in the lexicon and retrieved as chunks, or they arise as a result of the implementation of a phonological rule on the two retrieved words. The two patterns can be found in the same phenomenon, and they are distinguished by lexical frequency. That is, words with a high transitional probability (e.g., highly frequent word sequences) will be robustly stored in the lexicon and will be retrieved as a chunk that has already undergone external sandhi. Phonological rules will apply to words with a low transitional probability (e.g., low frequency word sequences) for which no lexical representation is stored.

1.2.5 Conclusion

Spanish HS learn the heritage language and the majority language simultaneously or sequentially as two first languages. Thus, it is necessary to review the stages of first language acquisition to better predict early interaction between a child's two phonological grammars. Infants gain language-specific sensitivity to the sounds in their native language between 2 and 8 months of age, and first word production appears around one year of age. Vowels are mostly acquired by age 3, but consonants present varying rates of acquisition, which can be explained through physiological development. The path of syllabic acquisition supports the universal preference for CV syllables. In initial stages of syllabic acquisition, children insert segments in the onset position to resolve an early dispreference for onsetless syllables. Codas are also disallowed in the first steps of syllable development. These rule-governed processes (e.g., consonant dropping, consonant insertion) tend to disappear around the 4 years of age.

With regard to the acquisition of processes above the prosodic word, the age of acquisition depends on the type of phenomenon at hand. For instance, studies that examine processes involving the mastery of suprasemgmental features show that the acquisition of such processes extend in time (i.e., acquired during late childhood). On the other hand, studies that explore the acquisition of adult-like between-word junctures show that children master connected speech by age 3. To better understand the rates of acquisition of word-external processes, further research should examine the interplay between the acquisition of between-word junctures and that of suprasegmental features.

1.3 Language interaction in child bilinguals' grammars

Research on early bilinguals shows that a child's two grammars interact during language development. During childhood, the pressure from the majority language can result in differential acquisition patterns (i.e., acceleration, deceleration) or transfer of sounds from the dominant language into the heritage language. Paradis and Genesee's (1996) canonical work describes three types of interaction that can arise during the process of language acquisition: acceleration, deceleration and transfer. Acceleration occurs when a linguistic property is acquired faster in bilinguals than in age-matched monolinguals. Delay or deceleration indicates that a linguistic property is acquired at a slower rate in bilinguals than in age-matched monolinguals. Transfer is the third hypothesis in the bilingual interactionist model. Unlike acceleration and deceleration, transfer does not refer to the rate of acquisition, but rather to the incorporation of a linguistic property from language A into language B, which may be present up until the child grammars mature (Lleó, 2016a). Most of the literature predicting interaction between a child's two grammars examines child bilinguals in situations in which these speakers acquire a family language that is different from the majority language (Fabiano-Smith & Barlow, 2010; Kehoe, 2000; Lleó, 2002, 2003, 2018; Tamburelli et al., 2015), and fewer studies have dealt with bilingual acquisition in more or less balanced contexts (Paradis, 2001). For this reason, the results of child bilingual studies are very relevant to understand the linguistic trajectories of adult HS.

Acceleration has been a rare finding across studies on child bilinguals. Lleó et al. (2003) found that German-Spanish bilingual children (i.e., between 1;1 and 2;4 years) were faster at acquiring Spanish codas than age-matched Spanish monolinguals, possibly due to the fact that the bilinguals had been exposed to a higher frequency of complex syllabic structures in German. Tamburelli et al. (2015) found similar results in the acquisition of complex consonant clusters in Polish-English bilinguals. Polish-English bilinguals outperform English monolinguals (7;0-8;11) when producing /s/ + obstruent clusters in English non-words. In other words, being exposed to a language with more complex onsets (Polish) facilitates the acquisition of a language with less complex onsets (English).

Unlike acceleration, delay, or deceleration has been more frequently found in research on child bilingualism. Fabiano-Smith and Goldstein (2010) compared Spanish-English bilinguals to their monolingual counterparts (3;0 – 4;0 years old). Bilinguals showed lower accuracy rates in the production of the Spanish trill, fricatives, and glides when compared to Spanish monolinguals and in the production of English stops and fricatives when compared to those of the English monolinguals. Kehoe (2002) investigated the acquisition of German and Spanish vowels in 1;1-to-2;6-year-olds. While Spanish has a five vowel system with no length distinction, German has seven pairs of vowels differing in their length. German-Spanish bilinguals showed delay in the acquisition of vowel length distinctions compared to German monolinguals. However, the bilingual group acquired the Spanish vowel system at the same rate as Spanish monolinguals. This asymmetry in acquisition is explained through markedness. Unmarked vowel systems (viz. Spanish) are less likely to be delayed in acquisition than more marked vowel systems (viz. German).

Language transfer is probably the type of interaction that has attracted the most interest. Language transfer has been found to occur as early as two years of age. In a situation of societal bilingualism (i.e., French in Quebec), Paradis (2001) examined sensitivity to word stress and syllable weight in bilinguals (25-35 months) acquiring English, a quantity sensitive-language (i.e., feet are sensitive to syllable weight), and French, a quantity-insensitive language (i.e., feet are insensitive to syllable weight) and compared them to English and French monolinguals. Children were asked to repeat nonce words with alternating stress patterns. The syllables that they preserved by position (i.e., weak, strong) were taken as the dependent variable. In French, monolinguals and bilinguals showed the same pattern of not preserving syllables by weight. In English, monolinguals preserved heavy syllables more often than light syllables, but bilinguals did not show an effect of weight in syllable preservation. These results indicate a transfer from a quantity-insensitive language (i.e., French) to a quantity-sensitive language (i.e., English). Transfer has also been found in the consonant inventories of a child's two languages. Turning to a situation in which children are mostly exposed to the heritage language at home, Fabiano-Smith and Barlow (2010) showed that the speech of Spanish-English bilingual children (3-4 years) showed evidence of Spanish-like spirantized stops (e.g., [β]) in English (i.e, in one child), Spanish-like taps in English (i.e., in five children) and English-like voiced postalveolar fricatives (viz. [ʒ]) in Spanish (i.e., in one child). Similarly, Meziane and MacLeod (2021) compared sound inventories for Arabic-French bilinguals and found that, even though bilinguals had a different consonant inventory for each language, shared sounds between languages were produced with high accuracy (i.e., positive interaction) and unshared sounds were produced with lower accuracy (i.e., negative interaction). Language transfer also appears as children develop phonological rules in their two languages. For instance, Lleó (2018) examines the acquisition of Spanish spirantization (e.g., la [β]olsa "the bag") and assimilation of place of articulation of nasals (e.g., un perro [um pero] "a dog"), both considered marked properties of Spanish that are restricted to fast speech and informal registers in German. German stops and nasals are unmarked because they lack the spirantization rule and nasal place of assimilation rule. Results revealed that Spanish spirants and place of articulation of nasals are incompletely acquired by German-Spanish bilinguals (1;4 – 7 years), probably due to the influence from German. These findings point to the fact that marked properties in the heritage language (i.e., spirantization, place of articulation assimilation) show lower rates of acquisition when the ambient language presents the unmarked feature.

Of the processes described, transfer is the type of interaction that can persist in adult grammars, as it is not necessarily overcome during adulthood (Lleó, 2016a). As a matter of fact, research on adult heritage grammars has documented instances of transfer from the majority language into the heritage language.

1.4 Language transfer in adult heritage grammars

Language transfer has provided an explanation for the divergent outcomes in adult HS' grammars (Amengual, 2012, 2018; Bullock, 2009; Chang et al., 2011; Hrycyna et al., 2011; Kang & Nagy, 2016; Kim, 2019; Rao, 2014, among others). In the next sections, I summarize some of these findings in the segmental and suprasegmental domains.

1.4.0.1 Language transfer in the segmental domain

Voiced and voiceless stops have been probably the most frequently studied consonants in heritage language phonology. Au et al.'s (2002) early study on Spanish voiced /p t k/ and voiceless /b d g/ production compared childhood overhearers to L2 speakers and found that the former group produced voiced and voiceless stops in a more native-like manner than L2 speakers. Knightly et al. (2003) obtained similar results when comparing childhood overhearers, childhood speakers, and late L2 learners of Spanish in the phonetic realization of stops and native accent ratings. That is, childhood overhearers patterned similarly to Spanish HS. While these studies used HS as the baseline groups, later research has incorporated non-heritage native grammars in the designs. Kim (2011) compared English-dominant and Spanish-dominant HS to non-heritage Spanish speakers and found that English-dominant HS produced voiceless stops with shorter VOT values than those of monolingual Spanish controls, in order to distinguish them from English voiceless stops, which have longer VOTs (Kim, 2011). Amengual (2012) found that transfer was more likely to occur in the Spanish VOT values of /t/ in Spanish-English cognate words. Hrycyna et al. (2011) compared the voice onset time (VOT) of Russian and Ukrainian voiceless stops /p, t, k/ produced by Russian and Ukrainian immigrants in Toronto and found that their VOTs increased across generations, becoming more English-like (i.e., long-lag VOTs).

In other cases, the influence from the majority language triggers consonant lenition. For example, Repiso-Puigdelliura et al. (2021) examined the production of the Spanish palatal obstruent /ʝ/,[1] and found that the majority of the 15 participants favored English-like approximant realizations (i.e., /j/ as in 'mayor'). Interestingly, a great deal of variation was observed among the participants, and, more specifically, the speaker with the highest rate of fricative realization of the obstruent (i.e., more Spanish-like) (81.82%), was the only participant that lived in Mexico during the first 10 years of life. The authors argue that increased exposure to Spanish during childhood and access to education in the heritage language may explain the high fricative-rates in the production of the /ʝ/. Lenition has also been observed in geminate consonants. For instance, Rafat et al. (2017) investigated the maintenance of the Farsi geminate-singleton contrast in the speech of three generations of Farsi-English bilinguals (i.e., long-term immigrants, 1.5 generation, 2nd generation). While the geminate-singleton contrast is phonemically contrastive in Farsi (/æjɑr/ 'carat' contrasts with /ːɑr/ 'brave'), it is not contrastive in English. Although the participants across the three generations were able to produce the geminate consonants, results demonstrated that the percentage of degemination increased across generations (i.e., homeland < first generation < 1.5 generation < second generation).

The HS' vocalic space also shows pressure from the majority language. For instance, Spanish HS demonstrate a more asymmetrical vowel space than that of monolingual speakers. Studies have documented a greater dispersion in the front dimension, /u/- and /a/-fronting, and a lowering process of /o/ and /u/ (Ronquest, 2012; Willis, 2005). In addition, Spanish HS also show centralization of unstressed vowels, which could indicate that they apply English-like vowel reduction (Elias et al., 2017; Ronquest, 2013). Code-switching also has a pivotal role in explaining transfer from the majority language. Elias et al. (2017) examined HS' vowel production in a bilingual and a monolingual session. Unstressed vowels were more centralized in the session involving code-switching than in the monolingual session, which supports a view of transient transfer induced through code-switching. Godson (2004)

[1] The majority of the HS' primary caregivers were from central-west and central-east regions of Mexico. These regions favor fricative variants of the Spanish palatal obstruent /ʝ/.

found that HS of Western Armenian produced the Western Armenian vowels /a/, /ɛ/ and /i/ closer to monolingual English vowels (i.e., higher F1 and F2 values) than first-generation Armenian-dominant immigrants.

1.4.0.2 Language transfer at the suprasegmental level

Although less attention has been paid to the suprasegmental domain, recent research has found that HS transfer metrical and intonational properties from the majority language into the heritage language (Kim, 2015, 2020; Robles-Puente, 2014). Kim (2020) compared perception and production of lexical stress by HS, L2 speakers and non-heritage native speakers. The experimental design contained 60 minimal pairs of oxytones (i.e., stress in the ultimate) and paroxytones (i.e., stress in the penultimate syllable) (e.g., ***can***_to_ and _can_***tó***) in three prosodic contexts: nuclear position, prenuclear position, and unaccented context. HS showed Spanish-like patterns in perception (i.e., discrimination between oxytones and paroxytones), while L2 speakers showed more difficulties in differentiating between the two stress patterns. In production, HS patterned like L2, as they presented smaller differences in the duration between the first and the second vowels (V1-V2) in paroxytones than those found in the non-heritage native controls, which is probably a result of stress misplacement. It is possible that stress placement in verbs was affected by the fact that English minimal pairs occur between nouns, which are generally paroxytones (i.e., présent [ˈpɹɛ.zənt]) and verbs, which are generally oxytones (i.e., presént [ˈpɹə.ˈzɛnt]).[2]

With regards to syllabification, Shelton et al. (2017) investigated metalinguistic knowledge of diphthong syllabification using a paper and pencil task. While English has only one palatal rising diphthong (e.g., [ju] *hue*), Spanish has four palatal rising diphthongs (e.g., [ja] *sucia* 'dirty', [je] *Diego* 'Diego', [jo] *piojo* 'louse', [ju] *viuda* 'widow') and four velar rising diphthongs (e.g., [wa] *suave* 'smooth', [we] *huevo* 'egg', [wo] *acuoso* 'watery', [wi] *ruido*

[2]This is a suggestion made to me by Ji Young Kim.

‘noise’). The falling palatal diphthongs present no differences in Spanish and English (e.g., Eng. [aj] *high* Sp. *b<u>ai</u>le* ‘dance‘), and with regards to velar diphthongs, Spanish has one velar falling diphthong type more than English (e.g., [ew] *d<u>eu</u>da* ‘debt’). Shelton et al. (2017) showed that HS broke more diphthongs into hiatuses in rising than in falling diphthongs and more frequently when the rising diphthongs included a palatal rather than velar glide, which suggests transfer from the English syllabification patterns.

Intonation has also attracted the attention of scholars in heritage language phonology, who have compared pitch accents inventories (Rao, 2016; Robles-Puente, 2014), the phonetic realization of such pitch accents (Colantoni et al., 2016), and the expression of prosodic prominence (Bullock, 2009; Kim, 2019).

With respect to pitch accents inventories, Robles-Puente (2014) examined the prosodic production of broad declarative utterances in the speech of Spanish-English bilinguals in Los Angeles and divided them into five groups: L2 Spanish speakers (G1), early childhood Mexican immigrants (G2), LA –born bilinguals (G3), late adulthood Mexican immigrants (G4), and Mexican immigrants with less than one year in the US (G5). While Spanish prefers an L+>H* configuration in prenuclear pitch accents (Prieto & Roseano, 2010), English favors H* in prenuclear position (Girand, 2006). Robles-Puente (2014) found H* tones were only used by the groups with more English exposure (G1, G2 and G3), whereas L+H* was only produced by the groups with less exposure to English and LA born bilinguals (G3, G4 and G5). This suggests an influence of English pitch accent frequencies in Spanish intonation. Colantoni et al. (2016) also investigated prenuclear pitch accents in the speech of Spanish HS and long-term immigrants. While the most common pitch accent in both groups was the bitonal L+H*, long-term immigrants exhibited a higher proportion of L+H* than HS, and HS presented more H* than long-term immigrants. Again, this suggests that HS might transfer the English preference for H* pitch accents into the Spanish intonation. Colantoni et al. (2016) also examined the phonetic realization of these pitch accents. In a reading task, HS aligned the f0 peak of L+H* earlier than the long-term immigrants group. No difference was found in the narrative in terms of peak alignment, which indicates that both groups are more similar in more spontaneous speech. Staying with the phonetic realization of pitch accents, Mennen and Chousi (2018) examined the intonation of Greek HS living in Austria. Greek and Austrian German diverge in the timing of the prenuclear pitch accent. While Greek speaker align the onset of the rise at the start of the accented syllable, Austrian Germans show a later alignment of prenuclear pitch accents. The Greek HS in the study demonstrated an intermediate stage, in that their onset of the rise in prenuclear pitch accents occurred later than that of Greek monolinguals and earlier than that of German monolinguals

Regarding the expression of prosodic prominence, Kim (2019) found that Spanish HS use strategies that were used by both Spanish monolinguals (e.g., cleft construction) and English L2 learners of Spanish (e.g., prosodic prominence in situ) to mark focus structures in Spanish. Bullock (2009) also showed that HS of Frenchville French expressed contrastive or emphatic focus through left dislocation with LH% boundary tones and through prosodic prominence in situ. According to the author, these patterns are likely due to contact-induced transfer from English which can be interpreted as "the recruitment of additional strategies that enhance or expand native-language resources" (Bullock, 2009, p. 166).

Most of the findings reviewed in Section 1.4 provide evidence of transfer from the majority to the heritage language, confirming the prediction that language transfer is a type of cross-linguistic interaction that remains as heritage grammars mature. The question remains of whether transfer from the majority language is stronger during childhood —when HS are mainly exposed to the heritage language, but their grammars are still immature (i.e., presumable more permeable to language transfer) —or during adulthood —when HS tend to lose contact with the heritage language, but their grammars are more mature (i.e., arguably less permeable to language transfer). Another important question that has rarely been addressed in the literature is whether the heritage language has also an effect on the production of the majority language. If HS share the same phonological space, it is likely that the majority language will also show some degree of influence on the heritage language.

1.5 The roles of input and output in bilingual speech production

Although the pressure of the majority language offers an explanation to the divergent heritage language outcomes, the great deal of within-group variation suggests that there are more factors that predict heritage language production. More specifically, reduced input in the heritage language is frequently believed to account for the HS' patterns of divergent attainment (Benmamoun et al., 2010; Montrul, 2002; Montrul & Bowles, 2009; Montrul & Sánchez-Walker, 2013). That is, although HS' linguistic backgrounds are diverse, a commonality among these speakers is that they grow up in a country in which the majority language is not the home language. In these situations, input in the heritage language competes with input in the majority language, and the former is normally confined to the family environment. Of particular interest has been the child population of bilinguals, perhaps because their relative language exposure is more easily measured during early acquisition. Most studies on bilingual acquisition have used measures of lexical or morphosyntactic proficiency to examine the role of language input (e.g., Correira Flores, 2017; David 2004; Gathercole, 2002; Pearson et al. 1997; Thordardottir 2011). For example, Gathercole (2002a) and Gathercole (2002b, 2002c) examined grammaticality judgement tasks in Spanish-English bilinguals (i.e., Spanish HS) for mass/count noun distinction in quantifiers (i.e., only exists in English), grammatical gender (i.e., only exists in Spanish), and *that-trace* effect in embedded clauses (i.e., asymmetrical grammatical structures). For English, the results showed that the use of English at home had a small effect on the children's performance in English. For Spanish, however, language use at home was found to be a predictor in the children's outcomes in Spanish. Along the same lines, Paradis (2010) analyzed the acquisition of English verb morphology in French-English bilinguals (mean age = 6;10) and found that the groups of children that were mostly exposed to French at home had lower scores than the groups of children with more exposure to English at home.

Fewer studies have examined the effect of relative exposure to a speaker's two languages on the development of phonological skills. Ruiz-Felter et al. (2016) examined the production of vowels and consonants in 91 Spanish-English bilingual children (mean age = 5;6 years) and correlated accuracy with current input-output in Spanish and English. Results showed that English-dominant bilinguals (i.e., more input-output in English) were significantly more accurate in English than in Spanish on late developing sounds (i.e., Eng. /d ʃ ð θ s z l r/, Sp. /ð l r /) and Spanish-dominant bilinguals were more accurate in Spanish than in English in early developing sounds (i.e., Eng. /m b j n w d p h/, Sp. /ɲt m n k x/).

Researchers have also been interested in the quantity of input that is necessary for bilinguals to match their monolingual peers. For instance, Thordardottir (2011) showed that the amount of required input to match monolinguals changed depending on whether examining their receptive and productive vocabulary. Bilinguals matched monolinguals in their receptive vocabulary with 40 to 60% exposure, but needed exposure above 60% to match their peers in their productive vocabulary.

Compared to the research on language exposure in child bilinguals, lesser attention has been paid to language exposure in the adult heritage language phonology (Kim & Repiso Puigdelliura, 2020; Rao, 2014; Shea, 2019). In a study on rhotic production, Kim and Repiso Puigdelliura (2020) found that using (i.e., input and output) Spanish with the older generation.[3] predicted frequency of target-like production of the Spanish tap (i.e., taps with lingual constrictions visible in the spectrogram.) Rao (2014) examined the phonological process of spirantization of voiced stops in intervocalic position and found that /b/ was spirantized (i.e., pronounced as an approximant [β]) more often by HS with more experience of Spanish at home than by those with less exposure to Spanish. Finally, Shea (2019) measured Spanish and English Pillai scores to calculate the degree of overlap between heritage and non-HS' vowel distributions and examined the effects of Spanish and English dominance and proficiency. The dominance construct included the factors of language use at home, language use outside of home, amount of code switching and age of English acquisition. Findings

[3]Input and use were collected from self-reported responses to a linguistic background questionnaire

revealed that the use of Spanish outside the home made the greatest unique contribution to the Spanish dominance model, and that this factor was followed by the shared variance between Spanish inside the home and outside the home. For the English model, the results indicated that the greatest contributor to explaining variance in the Pillai scores was age of English acquisition, followed by use of Spanish outside of home. That is, the measures of language use had a greater explanatory power than code switching and age of English acquisition. Despite these findings, Shea (2019) also documented that the models for proficiency explained a higher amount of variability than language dominance. [4] The author argues that capturing language dominance using self-reported measures is less reliable than using proficiency measures. Moreover, research on adult speakers may have more difficulties tracing language input during the speakers' lifespan than studies that focus on child bilingualism.

Apart from the quantity of input, the type of input also explains variation in bilingual speakers. Place and Hoff (2011) demonstrated that specific properties of their English input, such as the variety of sources of English input, number of English-speaking interlocutors. Correia and Flores (2017) found that home input and the quantity of European Portuguese-speaking parents were the input-related factors that significantly correlated with lexical performance in European Portuguese HS. Along the same lines, Ishizawa (2004) showed that living with non-English-speaking grandparents influences children's minority language use.

Type of input also refers to the specific properties found in the input that bilinguals receive. In other words, HS might show differences from the monolingual norms in a given linguistic property because the input to which they are exposed does not contain the target property in the first place (i.e., exposure to informal registers of the language, decline of the target feature in the first generation grammars (Domínguez, 2009; Rothman, 2009). Pires and Rothman (2009) and Rothman (2007) examined the production of inflected infinitives in Brazilian Portuguese (BP) and European Portuguese (EP). While the EP HS showed

[4] Proficiency was calculated using scores for fluency in monologues, picture naming tasks, and vocabulary.

full morphosyntactic and semantic command of inflected infinitives, the BP HS did not demonstrate proficient knowledge of this feature. Pires and Rothman (2009) argue that the asymmetry in the EP and BP grammars can be attributed to the fact that inflected infinitives are disappearing in colloquial registers of BP, which are often the only registers to which HS have access.

Aside from language input, a bilingual's own language output has also been found to affect rates of language acquisition (Bohman et al., 2010; Cohen, 2016; Ribot et al., 2018). Bohman et al. (2010) found that language output and input had differential effects on performance on tests of semantic and morphosyntactic knowledge, and concluded that 'using a language forces the learner to process the language in a way that only hearing it does not' (2010, 339). Asymmetric influence from input-output has also been found in vocabulary development. Cohen (2016) showed that current and cumulative exposure to each language (i.e., English or French) is a significant predictor for receptive vocabulary and oral language proficiency in French-English bilinguals, and that stronger correlations are found between English output and proficiency than between input and proficiency measures. Similarly, Ribot et al. (2018) demonstrated that in Spanish-English bilingual toddlers, output predicts the development of expressive vocabulary. In addition, they found that children whose English output scores were higher than their input scores grew their expressive vocabulary at a faster rate than the children who spoke English less than they heard it. Hammer et al. (2012) showed that the main individuals with which children use the language also plays a role on bilingual language development. For US Spanish-English bilinguals, Hammer et al. (2012) found that, while children who used more English than Spanish when talking to their teachers or fathers showed higher English vocabulary, children who used more Spanish than English when speaking to their mother showed higher Spanish vocabularies. Hammer et al. (2012) argue that the school and fathers represent the larger speech community, which tends to value more the societally majority language. Mothers, on the other hand, convey the family language and culture, which can reinforce the use of Spanish in the household.

There are different possible explanations to account for the differential effect of language output. Following the output hypothesis in second language research (Swain, 2005), producing speech confronts speakers with what they do not know about the language, and this may promote linguistic analysis. That is, at the time of speech production, second language speakers are aware of the gap existing between their current knowledge and their intended speech act. Another possibility is that speech production connects lexical representations to articulatory instructions, in a way that language input does not (Menn & Matthei, 1992). A child's own language output would then strengthen the connection between articulation and language representations.

Besides creating connections between articulation and linguistic representations, producing output in a language may reinforce other cognitive processes that, in turn, benefit language acquisition. For instance, as suggested by Ribot et al. (2018), studies on learning and memory have shown that the process of retrieval is advantageous for learning, as it is a powerful mnemonic enhance (Roediger & Butler, 2011). Applied specifically to language, retrieving linguistic structures may help to retain those structures to a greater extent than just being exposed to them. Related in particular to bilingual speech production, inhibition is also a cognitive function that can be developed during language production. When choosing to retrieve candidates from one language, bilinguals use inhibitory control to inhibit the candidates of the non-selected language (Bialystok & Martin, 2004; Philipp et al., 2007). Inhibition processes have asymmetrical processing costs in the more dominant (i.e., lesser processing costs) and the less dominant language (i.e., higher processing costs) (Meuter & Allport, 1999). From a processing perspective, Putnam (2020) that weaker representations in the heritage language will be harder to activate in online production and might be substituted by the more dominant language as a result of insufficient inhibition. This means that the heritage grammar does not shrink in cases of attrition, but rather fails to be separated from the dominant language. To this respect, language output could strengthen the inhibitory skills of HS when producing speech in the less dominant language.

Despite the importance of understanding the type of exposure to the heritage language, Meisel (2019) argues that there is a lack of evidence supporting or rejecting the claim that reduced input affects heritage language outcomes. Most importantly, except for a few studies (Thordardottir, 2011), input is rarely quantified, which means that we cannot answer the question of how reduced the input must be in order to have an effect on heritage language grammars. In particular, Meisel (2019) calls scholars to examine input from a cross-sectional or longitudinal perspective when the target property of the grammar is still being developed.

1.6 Coactivation in the grammars and the role of bilingual language control

Besides understanding how individual factors influence language interaction, research on heritage language speech production should also engage with the loci of such interaction and the processes by which language transfer appears. These questions have been mainly addressed by research on bilingual language processing. Early studies on bilingual language comprehension demonstrated that the bilinguals' two languages are active to a degree when accessing the lexicon (Colomé, 2001; Spivey & Marian, 1999; Van Heuven et al., 1998). Evidence from word recognition, however, does not necessarily predict that coactivation will also be present during language production. Language comprehension is a bottom-up process, in which parallel activity of the two languages resolves in an eventual selection of the target language (Dijkstra & van Heuven, 2002). Speech production, to the contrary, is characterized by being a top-down process, in that speaking starts with a concept that is mapped into lexical information. As argued in Kroll et al. (2008), one would assume that the top-down nature of language production implies that language selection occurs early on in the speech planning process, and that parallel activation of the bilinguals' two language does not occur during speech production. Nevertheless, evidence of the contrary has been gathered in speech processing studies. The pioneer work of Meuter and Allport

(1999) showed that, in code-switch tasks, bilinguals incur greater costs in the switch-trials than in the non-switch trials, and these costs are greater when switching to the dominant language from the weaker language, than vice-versa. This suggests parallel competition of the two languages during speech production and a carry-over effect of the inhibition of the dominant language when switching to a dominant-language trial. Similar conclusions have been reached by researchers examining the role of cognates during speech production. These studies found that bilinguals are faster at naming words in the target language that are cognates with the non-target language than words that are non-cognates, arguably due to parallel activation of the two languages during speech production (Costa et al., 2000; Hoshino & Kroll, 2008; Kroll et al., 2000). Language coactivation is modulated by the amount of cognitive resources that are available to the speaker during speech production. For instance, Linck et al. (2008) found that the degree of cognate facilitation in a reading task (i.e., language comprehension) was regulated by working memory (i.e., less cognate facilitation in bilinguals with high working memory), and that the strength of cognate facilitation in a picture naming task (i.e., language production) was modulated by enhanced inhibitory control (i.e., less cognate facilitation in bilinguals with enhanced inhibitory control).

Despite parallel language activation, a common observation in bilingual speech production is that bilinguals' speech is better than what researchers would expect, assuming constant competition for selection (Kroll et al., 2006). In other words, bilinguals are equipped with language control networks that allow them to choose a target item in the lexicon, or to activate the target phonology. As summarized in Branzi et al. (2016), language control involves the intention to speak in a language, the selection of the words in the target language, the inhibition of the words in the non-target language, the process of action monitoring to avoid interference from the non-target language, and the ability to switch from one language to another. In addition, two types of language control are at work during language production: reactive control, which appears when the non-target language is activated during the selection of lexical items in the target language, and proactive language control, which appears as an anticipation of any disruption of the non-target language during target language speech production (Declerck, 2020; Seo & Prat, 2019). In addition, the language control network is believed to adapt to the demands of the interactional context in which speakers engage (Green & Abutalebi, 2013). For instance, in the specific interactional context of code-switching, as opposed to dual-language activation (i.e., two languages are active, but there is one intended language), the need for suppression of alternatives may be bypassed, as the two languages do not compete for selection, but rather co-operate.

Language control is associated with domain-general cognitive control, the set of mental functions engaged in goal-directed behaviors. In fact, the critical and subcoortical regions active in language control (i.e., dorsal anterior cingulate cortex/pre-supplementary motor area, the left prefrontal cortex, the left caudate, and the inferior parietal lobules bilaterally) are closely related to executive control (Abutalebi & Green, 2007, 2016). The relationship between language control and the domain-general executive function has generated a great deal of interest in the literature, as some behavioral studies have found positive correlations between task-switching costs (i.e., domain general control) and language-switching costs (i.e., language-specific control) (Branzi et al., 2016; Kubota et al., 2020) and others have not (Calabria et al., 2015; Declerck et al., 2017). In the area of acquisition and attrition, Kubota et al. (2020) examined Japanese-English bilingual children (7-13 years old) and found that development in executive control over one year predicted changes in language control in bilingual speakers. In spite of Kubota et al.'s (2020) findings, language control has been found to be affected by the development of the domain-general executive functions, it may, conversely, not be affected by its decline. Calabria et al. (2015) compared three groups of speakers from different ages (i.e., young, middle-aged, elderly) and found an age-related change in the domain-general executive control and none in the linguistic switching task.

Provided that the two languages are active in parallel during speech production and that language control has the role of suppressing the irrelevant language, a question that necessarily arises is at what point is the language selected. To answer this question, researchers have also engaged with the mechanisms that allow for language selection. As observed in Kroll et al. (2006), two main types of models have been proposed. The first type of model posit that there is a language-specific mechanism that regulates language selection within the lexicon. The second type of model propose that language selection is carried out by a general-purpose mechanism that restricts the lexical output. Examples of the former are language-selectivity models, in which the two languages are active during speech planning but do not compete for selection, because the intention to speak a language alone limits the selection mechanism to the target language (Costa et al., 1999). An example of the latter are competition-for-selection models, in which the intention to speak a language alone does not suffice to block cross-language competition (Green, 1998). Rather, the language cue helps to identify the language candidates without eliminating competition.

Critically, for this study, non-selective lexical access models have proposed that competition for selection is active also at the level of the L1 and L2 phonologies. For example, Colomé (2001) performed a phoneme-monitoring task in Catalan and asked participants to decide whether the target phoneme was present in the Catalan name of the picture presented. If the picture was a table, the target phonemes were /t/ for 'taula', Catalan, /m/ for its translation in Spanish 'mesa', and /f/ as a control. Participants were slower at identifying that the phoneme /m/ was not present in the picture's name than at deciding that the control phoneme (i.e., /f/) was not part of the picture's name. In a similar vein, Jared and Szucs (2002) investigated whether bilinguals activate the non-target language (French) when reading homographs in the target language (English). English-dominant bilinguals showed similar naming latencies for both the homographs and the English-only control words, whereas French-dominant bilinguals presented homograph interference in the naming latencies. Jared and Szucs's (2002) results support the claim that bilinguals activate their first language (French) when producing in their second language (English), but not vice-versa. In turn, this shows that parallel language activation depends on the speakers' proficiency in each language.

To sum up, the findings in the bilingual language processing literature indicate that there is coactivation of the bilinguals' two languages during language production, presumably at the phonological level, and that language control plays an important role in inhibiting the competing language. The extent to which language control recruits domain-general cognitive control is still debated in the literature.

1.7 Conclusion

Heritage grammars present output variation and systematic divergences from monolingual norms, arguably due to their unique learning trajectories, as exposure to their first language (i.e., heritage language) is often reduced or interrupted when these speakers gain systematic contact with the majority language (i.e., school years). Studies on early child bilinguals suggest that these speakers already demonstrate linguistic transfer from their most dominant language during childhood (Fabiano-Smith & Barlow, 2010; Kehoe, 2015; Lleó, 2016a, 2018; Lleó & Kehoe, 2002, among others). Majority-language transfer, in addition, has also been documented in several heritage languages at the segmental and suprasegmental levels (Amengual, 2012; Kim, 2019; Rao, 2014; Repiso-Puigdelliura & Kim, 2021; Ronquest, 2013, among others). Research comparing adults to children during the period in which exposure to the majority language becomes systematic (i.e., school age children) could shed some light on the HS' divergent outcomes and the strength of the majority language as the heritage grammars mature.

Moreover, it has been assumed that the development of heritage grammars is affected by a reduced input in the heritage language. On the domain of child bilingualism, studies have found an effect of input and output on the development of the bilingual child's lexical proficiency (Correia & Flores, 2017; Thordardottir, 2011), semantic and morpho-syntactic skills (Bohman et al., 2010), and production of consonantal sounds (Ruiz-Felter et al., 2016). Incipient evidence also shows that adult HS with more exposure to the heritage language (i.e., overall exposure [Rao, 2014], or language use with older generation [Kim & Repiso-Puigdelliura, 2020]) show more target-like patterns in their speech production. Nonetheless, empirical evidence showing the approximate amount of input necessary to fully master the heritage language is missing (Meisel, 2019).

Lastly, the studies reviewed on bilingual language processing have shown that parallel activation of the two languages is likely to occur at the phonological level and that language control is at the core of speech production. Thus, language transfer is presumably a result of the parallel activation of the HS' two languages during speech production and language control is the suppression mechanism by which the phonological features of the non-target language are blocked during speech production.

CHAPTER 2

Constraint-based approaches to model word-external repairs of empty onsets

2.1 Introduction

As reviewed in the previous chapter, researchers have found evidence of language transfer in the speech production of heritage speakers (Amengual, 2012; Elias et al., 2017; Kim, 2019; Kim & Repiso-Puigdelliura, 2021; Ronquest, 2012, 2013, among others). While some of these instances of transfer may come from a simultaneous activation of the majority-language grammar when these speakers are tested in bilingual mode (Amengual, 2018), or in code-switching situations (Elias et al., 2017), it is possible that, in other cases, majority-language-like transfer in the heritage language stems from an interaction between the two grammars at the phonological level. For this reason, modeling the phonological structure of heritage speakers' grammars can help investigators determine which parts of the grammar are more permeable to language transfer. More specifically, using gradient models of language production (i.e., weighted constraint-based approaches) to build heritage language phonologies can shed light on the manner and extent to which each grammar influences the other in the bilinguals' minds. In order to lay the groundwork for these models, in the first part of this chapter, I review constraint-based proposals seeking to explain the paths of first language acquisition, and I then evaluate alternatives to formalize bilingual speech production.

In the second part of this chapter, I introduce the literature on repairs of word-external empty onsets in Spanish and English, the phonological phenomenon that I examine in the course of this dissertation. Word-external phonological processes have received comparatively less attention than word-internal phonological processes (e.g., phonemic contrasts such as trills/tap contrast [Henrisken, 2015; Amengual, 2012], geminate consonants [Einfeldt at al., 2019], allophonic rules such as assimilation of place of articulation [Lleó, 2018] or spirantization [Rao, 2014]). The former processes are hence still an understudied area in heritage language phonology. Repairs of word-external empty onsets, in particular, can be of interest in this field as they present asymmetries in their surface realization. In Spanish, repairs of word-external empty onsets in postconsonantal position (i.e., /C#V/) are commonly resolved with a misalignment that appears between the prosodic word and the syllabic structure (i.e., resyllabification), and they surface with modal phonation. In English, speakers may produce an ambisyllabic consonant (i.e., multiply linked to the coda or the onset) or they may resort to glottal stop epenthesis to fill the empty onset (Davidson & Erker, 2014; Pak, 2014, 2016).

2.2 Modeling first language acquisition

2.2.1 The Constraint Demotion Algorithm

Early models of first language phonological acquisition data relied on parallel Optimality Theory (OT) (Prince & Smolensky, 1993, 2004) and correspondence theory (McCarthy, 1995) and stipulated a relationship between input (i.e., target form) and output (i.e., child's form) in the child's grammar, by which faithfulness to the adult input (i.e., faithfulness) interact with early preference for markedness constraints that allows unmarked speech productions to emerge in the grammars (Demuth & Fee, 1995; Gnanadesikan, 1995). For instance, complex onsets, which are marked but faithful structures in the adult grammars, are initially banned in the child's grammars through a highly ranked markedness constraint (i.e., *Complex) (Fikkert, 1994b; Freitas, 2003). For learning to occur, the child has the task to promote the faithfulness constraints so that their output resembles to that of adults (Gnanadesikan, 1995)

In Optimality Theory (Prince & Smolensky, 1993, 2004), a hierarchy of violable constraints evaluates a set of candidates generated by a universal function (i.e., GEN) given a lexical input. In Tableau 2.1, Candidate 1 is the losing candidate because it violates the highest ranked constraint.

	Constraint 1	**Constraint 2**
a. Candidate	*!	
b. Candidate		*

Table 2.1: OT Tableau showing ranking between two constraints

Learning occurs when the constraints are reranked in the grammars. In order to account for constraint learning, Tesar and Smolensky (1998) put forth the Constraint Demotion Algorithm (CDA) (Tesar & Smolensky, 1998). The CDA assumes that the child evaluates their initial grammar when exposed with a correct input-output pair from the adult output. The algorithm selects the losing candidate (i.e., initially the winner in the child's grammar), evaluates the constraints, and demotes the losing-preferring constraint. Through this process, the child demotes the initially preferred markedness constraints, which results in faithful outputs in the grammar. However, in some cases, the effects of a markedness constraint apply only in certain environments. To illustrate this example, Pater et al. (2007) report data on Québécois French (Rose, 2000), in which a child goes through a stage that allows clusters in stressed (1a) but not in unstressed syllables (1b).

1. Example from Rose (2000)

   klɪs *glisse* 'she slides' (1;10.04)

   biˈle *brulé* 'burned' (1;9.29)

In cases such as 2.2.1, the intermediate stage of consonant cluster reduction could be modeled by the demotion of the markedness constraint (*Complex) below a Positional Faithfulness constraint (Beckman, 1998) (*Max-Stress), but not below its general counterpart (Max) (i.e., *Max-Stress >> *Complex >> Max).

Although the CDA is able to capture faithfulness to the input at different stages of the child's grammar, and can model intermediate stages as shown above, the learning process is sudden. That is, once the constraint is demoted, the optimal output will always favor the new constraint ranking. Thus, the CDA is not suited to model the variation or gradual learning that characterizes early child grammars.

2.2.2 The Gradual Learning Algorithm

Stochastic frameworks in phonology are equipped to account for gradual learning. Fikkert and De Hoop (2009) applied Stochastic OT in conjunction with the Gradual Learning Algorithm (GLA) (Boersma, 1997; Boersma & Hayes, 2001) to model the observed flexible stages of acquisition in children's grammars. Stochastic OT assumes that the constraints are ranked along a continuous numerical scale. Each constraint is given a value on the ranking scale. That is, constraints can be more or less separated from each other. During constraint evaluation, noise is added to the ranking value and the new value (i.e., the selection point) evaluates the candidates. This noise is a Gaussian-distributed random variable with a mean of 0 and standard deviation of 1. This means that, when two constraints (e.g., C_1 and C_2) are close enough on the scale, the relative ranking of C_1 over C_2 becomes optional and variation appears in the output.

The Gradual Learning Algorithm (GLA) (Boersma & Hayes, 2001) is a learning algorithm that takes as input an initial set of constraints ranked on a continuous scale and returns slightly perturbed constraint rankings. The GLA is error driven, which means that changes occur when the algorithm identifies an output in the target grammar that mismatches the optimal output in the learner's grammar. At this point, the algorithm reevaluates the position on the scale. The value of the target output-preferring constraint (viz. the winner) is slightly demoted, and the value of the learner's output-preferring constraint (viz. the loser) is slightly promoted. While the perturbations might not change the relative ranking between the two constraints, the slight perturbations might bring the constraints close to each other. As mentioned above, the closer two constraints are, the higher the probability that variation arises in the output. Finally, the amount of constraint demotion or promotion depends on plasticity, which is a constant value that refers to the learner's speed. Unlike a sudden reranking of constraints, the GLA predicts that learning is gradual, that output variation can occur between 'stage of acquisition', and that the speaker can learn the variation in the grammar (Pater et al., 2007, p. 247). For instance, Curtin and Zuraw (2001) simulate Dutch word truncation data (Fikkert, 1994a) using the GLA, and identified intermediate stages in which the speaker produced output variation between monosyllabic stages and disyllabic outputs. Further, their simulation confirmed that the initial state has to be Markedness >> Faithfulness, as it provides outputs ranging from truncation to non-truncation. Moreover, the GLA is sensitive to frequency, as it needs enough data to reverse the constraints on the numerical scale.

In sum, the GLA resolves the problem of gradual learning during first language development by implementing a probabilistic model of OT and learning algorithms that allows for slight perturbations of the constraints at every mismatch between the child and the adult grammars. However, a general limitation of the GLA related to first language acquisition is that it cannot predict intermediate stages in which a positional constraint is ranked over its general counterpart (Pater et al., 2007). Taking the example above from Rose (2000), a stage in which deletion does not appear in stressed syllables (Max-Stress), but it appears elsewhere (Max) could not be modeled using the GLA because the general constraint will always be promoted more quickly than the more specific one. The general constraint will be violated by all cases in which a consonant is deleted and, consequently, it will be promoted more quickly than the specific constraint (i.e., Max will be positioned higher on the numerical scale than MAX-STRESS).

2.3 Modeling bilingual language acquisition and production

As in the case of monolingual phonological acquisition, bilingual acquisition also requires a model that allows for stochastic learning, as some areas of the phonological system are more vulnerable than others (Lleó, 2016a). However, to my knowledge, models engaging with child bilingual phonology are lacking. Instead, in this section, I review two constraint-based models with the acquisition and the of bilingual phonology.

2.3.1 The Gradual Learning Algorithm in bilingual language acquisition

A possible approach to model second language acquisition is to take the first language as a departing point and assume that L2 speakers will update the constraint weights of their second language based on the values of their first language. For instance, Cardoso (2007) models adult sequential acquisition (L2) of English word-final stops produced by Brazilian Portuguese native speakers. While Brazilian Portuguese bans final obstruents in the coda and repairs them by means of epenthesis (e.g., in the borrowing /hɑt dɑg/ → [hɔtʃi dɔgi] 'hot dog'), English allows obstruents in the coda (e.g., [hɑt dɑg]).

2. Constraints for Brazilian Portuguese

(a) NOCODA(OBS): syllables do not have obstruent codas (e.g., Broselow etal, [1998] as cited in (Cardoso, 2007))

(b) MAX-IO : every element of the input has a correspondent in the output

(c) DEP-IO : every element of the output has a correspondent in the input

The Brazilian Portuguese grammar will have an undominated NOCODA(OBS) to prevent obstruent codas to surface in the output and an undominated MAX-IO to disallow deletion as a repair strategy. Dep-IO, however, will be crucially dominated. Cardoso (2007) assumes that the initial stage in the L2 grammar is the L1 grammar (Figure 2.1).

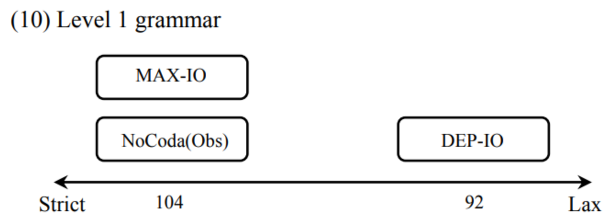


Figure 2.1: Initial Stage for L2 (Cardoso, 2007, pg. 7)

In order for Brazilian Portuguese speakers to acquire English codas, they will have to demote NoCoda(Obs) below Dep-IO. Cardoso (2007) trained OT Soft (Hayes et al., 2003) with five grammars according to the proficiency level and formal/informal register (i.e., grammar 1: beginners level, grammar 2: formal style and intermediate level, grammar 3: informal style and intermediate level, grammar 4: formal style and advanced level, grammar 5: informal style and advanced level) using one million input data. The GLA was able to predict output frequencies that were almost identical or the same frequencies that were observed in the data. The algorithm learned five different grammars corresponding to the grammars of beginner learners, intermediate learners, and advanced learners in formal and informal registers. For instance, while in the initial stage NoCoda(Obs) and Dep-IO had a ranking distance of 12 points, the distance was reduced by 2.6 in the intermediate stage, and was eventually reversed in the English-like production stage.

In Cardoso's (2007) proposal, the L2 grammars take the constraint of the L1 as an initial state. The learning algorithm updates these constraints as a function of exposure to the L2. Thus, this model can successfully predict transfer from the L1 at different stages of L2 acquisition. An important limitation of this approach is that it predicts that, once the grammar is learned, the L2 phonology will be stable and will not be affected by the L1 phonology. Similarly, at no point of the analysis, the L1 is predicted to be affected by the

L2, which means that it cannot account for the findings reviewed in the literature of adult heritage phonology.

2.3.2 Coactivation in the Gradient Symbolic Computation

More recent proposals have captured the findings in the bilingual speech processing literature (see chapter 1), showing parallel activation of the two languages during language evaluation. In particular Goldrick et al. (2016) proposes a model of coactivation in bilingual grammars for code-mixing grammars that is based on the Gradient Symbolic Computation framework (GSC) (Smolensky et al., 2014; Smolensky et al., 2020).

GSC is a grammar-based formalism that accounts for the interaction between discrete phonological structure and continuous structure representations (e.g., psycholinguistic effects produced by structural similarity, partial activation of alternative candidates). At the core of this interaction, there are two processes that operate in parallel: *optimization* and *quantization*. Optimization refers to the preference for well-formedness and quantization favors discrete symbolic structures. Partial activation of alternative structures during language production is one of the findings for which the GSC accounts. The activation levels of alternative structures form a continuum, and the activation of structure X at time t represents the amount of evidence gained by the grammar showing that structure X is the optimal output. The process of computing the activation values is carried out by optimization. During the computing of activation values, mental representations are formed with partially activated structures, or *blends*. At that point, the grammar has to settle for a discrete interpretable unit from the array of alternatives (i.e., blended structures). In other words, the grammar selects discrete units and disprefers blends as the output of the evaluation process. This process is carried out by *quantization*.

The GSC captures a grammar containing symbolic representations, which can be associated with continuous structures, such as activation values. Goldrick et al. (2016) formalize an account of the GSC to capture coactivation in bilingual grammars, and apply their model to doubling constructions in Tamil-English code-mixing.[1] In bilingual speech production, *blend representations* arise when the spread of activation results in partial activation of the non-target languages at different levels of speech processing. Blend representations are supported by evidence from cognate facilitation effects (Costa et al., 2000), phonetic transfer in cognates (Amengual, 2012) or in speech production in bilingual mode (Amengual, 2018; Elias et al., 2017). In a weighted grammar, Goldrick et al. (2016) propose that bilingual speakers have two sets of language-specific weights, which contribute, to a degree, to input evaluation. A given input is evaluated by the sum of the grammar resulting from the two partially-active constraint weights and the source-language specific constraint weights. This means that the strength of activation of each language will result in different degrees of language interaction. The dispreference for blend representations in the grammar, is captured by a QUANTIZATION constraint, which is language-independent and requires representations to be discrete symbolic structures. For instance, in their analysis of doubling constructions, candidates with two V projecting from the head of VP (i.e., blend representation) violate the QUANT constraint.

Goldrick et al.'s (2016) model provides a unified account of grammatical constraints and parallel activation during speech production. However, as noted by Bobb and Hoshino (2016), future extensions of this proposal would benefit from shedding some light into the mechanisms by which the language-specific weightings change over time (i.e., language proficiency, exposure, use). Green2018LanguageCode-switching also mentions that the coactivation model lacks an explicit integration of the processes by which language control regulates bilingual production. That is, in the coactivation model, parallel activation enters the phonology to evaluate the output, but no mechanism specific to language control is proposed to suppress such activation.

[1] Although this model does not strictly examine bilingual phonology, Goldrick et al.'s (2016) proposal uses a weighted constraint-based approach to model code-mixing in syntactic structures that is flexible enough to be applied to bilingual phonology.

2.3.3 Conclusion

Theoretical models of phonology acquisition initially relied on parallel OT (Prince & Smolensky, 1993, 2004) and the CDA (Tesar, 1998) to explain constraint reranking in early grammars (Demuth, 1996; Fikkert, 1995). Children start with an initial stage of highly ranked markedness constraints, which allow the emergence of unmarked structure in their grammars, and subsequently demote them under the faithfulness constraints in the grammar. The CDA can explain intermediate stages by resorting to Position Faithfulness (Beckman, 1998). However, the CDA is not equipped to model gradual learning and variation during phonology acquisition. Instead, a stochastic OT grammar coupled with the GLA (Boersma, 1997; Boersma & Hayes, 2001), in which the constraints are gradually reranked can successfully model the observed output variation between stages of acquisition (Curtin & Zuraw, 2001), the variation found in the input grammars. The GLA has been used to model second language acquisition (Cardoso, 2007). In such analyses, the second language learner reranks their existing constraints for their first language as they gain exposure to the second language. While the GLA accounts for first language to second language transfer (i.e., first language is the initial state), it cannot predict transfer from the second to the first language (i.e., majority to heritage language transfer), or between two first languages). Unlike the GLA, the GSC-based model of bilingual coactivation proposed in Goldrick et al. (2016) incorporates the findings in the psycholinguistic literature showing parallel activation of the two languages during speech production. In particular, Goldrick et al.'s (2016) propose that the bilinguals' two grammars are simultaneously active during language evaluation and that the resulting blend representations are penalized by a tendency in the grammar to prefer discrete phonological representations. This last account establishes a formal relationship between generative approaches to grammar and bilingual language processing.

2.4 Word-external repairs of empty onsets in Spanish and English

Universally, syllables favor onsets (i.e., CV) and tend to disprefer codas (i.e., VC) (Kahn, 1976; Selkirk, 1982). This preference is captured in the rule-based analysis of syllabification proposed by Steriade (1982), positing that codas are affiliated to the syllable at the end of the syllabification process. First, the nucleus is identified, after that, the pre-nuclear consonants are associated with the onset position and, finally, the rest of the consonants are affiliated with the coda. This means that /VCV/ sequences will be segmented as /V.CV/, instead of /VC.V/. Similarly, the Maximal Onset Principle (Blevins, 1995) also references this universal preference by requiring to maximize the onset with as many pre-nuclear consonants as possible. Empty onsets are also dispreferred in word-external sequences, and language employ different repair strategies to prevent them from appearing in the output.

2.4.1 Word-external empty onsets in Spanish

In postconsonantal and word-external position (i.e., C#VC), Spanish speakers affiliate the coda consonant to the subsequent word by a process of resyllabification. That is, the minimal pair *las alas* 'the wings' and *las salas* 'the rooms' are homophonous in Spanish (Hualde & Prieto, 2014).[2] Resyllabification was first explained using rule-based analyses. Harris (1983) put forth a resyllabification rule that changes the affiliation of the coda consonant to become an onset of a subsequent vowel-initial word. From an OT account (Prince & Smolensky, 1993, 2004) Colina (1997) posits that ONSET (i.e., every syllable has to have an onset) dominates ALIGN-L (i.e., every initial stem-edge has to match to an initial syllable edge) in the Spanish grammar. ONSET disallows candidates with external empty onsets, while the repair strategy of resyllabification is allowed through a crucially dominated ALIGN-L (See Tableau 2.2).

[2]Durational differences of the coda [s] might differentiate the two word sequences.

/las#a.las/	Onset	Align-L
→a. la.sa.las		*
b. las.a.las	*!	

Table 2.2: Constraint-based account of resyllabification of *las alas* ('the wings')

The phonological account of resyllabification predicts that derived onsets will acoustically pattern with canonical onsets and will differ from codas. Reliable acoustic evidence of resyllabification has been found in the alignment of the f0 in rising pitch accents (Torreira, 2007). That is, the pair *mi lana* [mi.la.na] 'my wool' and *el ama* [e.la.ma] 'the landlady' both display f0 rise in onset /l/, which indicates that the start of the f0 rise coincides with the resyllabified onset.

However, recent phonetic studies on durational properties of canonical and derived onsets have proposed that resyllabification might not be complete (Hualde & Prieto, 2014; Strycharczuk & Kohlberger, 2016). Hualde and Prieto (2014) analyzed Spanish spontaneous speech elicited from a map task and compared the duration of intervocalic /s/ in canonical onsets (V#sV e.g., *como si* 'as if') and derived onsets (Vs#V e.g., *más abajo* 'lower'). Derived onsets (Vs#V) were found significantly shorter than canonical onsets (V#sV). These results provide evidence in favor of an account of partial resyllabification. On a similar line, Strycharczuk and Kohlberger (2016) tested [s]- duration in the conditions of word-initial onset (i.e., /V#sV/), word-final coda (i.e., Vs#C), derived onset (i.e., /Vs#V/), word-medial onset (i.e., /V.sV/), word-medial coda (i.e., /Vs.C/) and fake geminate (i.e., /Vs#sV/). Significant differences in duration were found across all the conditions, and sibilant duration fell within a continuum: word-medial codas < word-final codas < derived onsets < word-medial onsets < word-initial onsets < fake geminate consonants. The takeaway from these findings is that derived onsets present shorter duration than word-initial (i.e., canonical) onsets.

In order to account for the gradient variation found in the phonetic results, Bradley

(2020) has suggested the possibility of bidirectional coupling, by which derived onsets would be coupled in-phase with the following vowel and in anti-phase with the preceding vowel.[3] In Figure 2.2, the winner satisfies a requirement of onsets to be coupled in-phase with the following vowel (C—V) and vowels to be coupled in anti-phase with the following consonant before the right edge of a morphological word (V⇢ C).

⟦redes⟧⟦atadas⟧ 'tied nets'		C—V	V⇢C⟧	*V⇢C
a. (⟦...e_⟧)(⟦a…⟧)	e s — a		*!	
☞ b.	e ⇢ s — a			*
c.	e ⇢ s a	*!		*

Figure 2.2: (Bradley, 2020, pg.9)

Bradley's (2020) proposal successfully models the behavior of intervocalic consonants across word-boundaries and explains the gradient variation on consonant duration reported in recent studies on /s/ (Hualde & Prieto, 2014; Strycharczuk & Kohlberger, 2016). However, Bradley's (2020) account is based on the surface structure, the candidates that the learner encounters during learning, but it omits the representation of the hidden structure (i.e., syllabification). In other words, the grammar doesn't provide a syllabification structure for the bidirectionally coupled candidates. Bidirectionally coupled consonants could still be phonologized as onsets, codas or ambisyllabic segments by the learner. In addition, it is unclear whether the same account can be generalized across consonants. To this respect, articulatory studies should investigate the coupling relationships for each consonant that can be found at a word juncture. A more comprehensive model would include consonant-dependent articulatory representations for /C#VC/ sequences and syllabification candidates (i.e., hidden structure) for each articulatory representation (i.e., surface structure).

[3] In *in-phase* gestural coordination, Gesture 1 and Gesture 2 begin simultaneously. In *anti-phase* gestural coordination, Gesture 2 begins at halfway of Gesture 1.

/sought#Ed/	ALIGN-R	ONSET	ALIGN-L
a. sɔt.ɛd		*!	
→ b. sɔ.[ɾ]ɛd			*
c. sɔ.ɛd	*!		*

Table 2.3: English ambisyllabicity, adapted from (Itô & Mester, 2009)

2.4.2 Word-external empty onsets in English

Traditional phonological approaches posit that, at /C#V/-junctures, the word-final consonant affiliates both with the coda and the onset position, resulting in an ambisyllabic consonant (Gussenhoven, 1986; Hayes, 2009; Kahn, 1976). However, recent corpus and phonetic studies have shown that English speakers can epenthesize a glottal stop in prevocalic position to repair the empty onset (Pak, 2016; Scarpace, 2017; Scobbie & Pouplier, 2010).

Evidence for ambisyllabicity is provided by allophonic processes, such as flapping (e.g., *atom* [ˈæɾəm])(Kahn, 1976), or /l/-darkening (Hayes, 2009; Rubach, 1996). Itô and Mester (2009) formalize the Kahnian approach from a perspective of syllable well-formedness using strictly-ranked OT (Prince & Smolensky, 1993, 2004). Under their account (see Tableau), an undominated ONSET interacts with ALIGN-L (STEM, ω) (i.e., the left edge of the stem has to be aligned with the left edge of the prosodic word). Complete resyllabification is prevented by an undominated ALIGN-R (STEM, ω) (i.e., the right edge of the stem has to be aligned with the right edge of the prosodic word).

The lack of clear acoustic correlates for ambisyllabic consonants has raised concerns about the physical reality of multiple linking. Initially, Gick (2003) found that in word-external position the [l] in ‘hall otter’ (ambisyllabic) has a longer duration than that of ‘hall hotter’ (coda) and a shorter duration than that of ‘ha lotter’ (onset), suggesting that ambisyllabic consonants pattern between onsets and codas. Despite these findings, studies examining the durational properties of word-internal ambisyllabic consonants have shown that American

English speakers have a coda representation for these segments (Durvasula & Huang, 2017; Durvasula et al., 2013; Nesbitt, 2018). Other than duration, Gao and Xu (2007) examined pitch anchoring and found that the onset (e.g., *Nola Niles*) and ambisyllabic positions (e.g., *Norman Evens*) present similar F0 alignment patterns. These results show that the status of ambisyllabic consonants in English phonology is still inconclusive.

In spite of the quite extensive literature on ambisyllabicity, this syllabification process might not be the sole manner to repair empty onsets in English. Instead, studies have reported the use of glottal stops in consonant-to-vowel word-junctures. Cruttenden (1994, p.183) (as cited in Scobbie and Pouplier [2010]) suggests that glottalization might occur around the word-initial vowel in the absence of a resyllabification process. Pak (2016) reports that in a CHILDES corpus study, 23% of the adult production of *an + V* sequences contained glottal stops at the word-juncture. Similarly, Gick et al. (2006) posit that prosodically prominent syllables prevent resyllabification processes. Along the same lines, Scobbie and Pouplier (2010) analyzed L-sandhi in Scottish Standard English in different contexts: onset position (e.g., *pee Lima's and Rio's*), ambisyllabic position (e.g., *peel Eve*), fake geminates (e.g., *peel lemurs*), before [b] (e.g., *peel beavers*) and before [h] (e.g., *peel heaving*). Although [l] was found to be more onset-like (e.g., less tongue tip contact) in prevocalic conditions and more coda-like in consonantal conditions (e.g., more tongue tip contact), resyllabification did not consistently appear in all the tokens. Specifically, five speakers presented glottalization in every ambisyllabic token, which supports the idea that there might be more than one strategy to repair empty onsets. Scarpace (2017) examined the oral production of English native speakers. Rate of glottalization was investigated in preconsonantal stressed onsets (e.g., *Brendan Evans, Caine Evans, Karen Orris*). English speakers glottalized 92.48% of the tokens.

The optionality of epenthesizing a glottal stop is likely to arise as a result of prosodic prominence. For instance, Pak (2016) proposes that glottal stop insertion occurs in emphatic environments (i.e., emphatic glottal stop), and that glottal stop insertion is a rule that is applied before resyllabification / flapping (e.g., wha[t ʔ]ever). The proposal of emphatic glottal stop insertion aligns with findings on glottal phonation showing that prosodically prominent vowels are more often glottalized than unaccented and unstressed vowels (Dilley et al., 1996; Garellek, 2013, 2014; Redi & Shattuck-Hufnagel, 2001). For example, Garellek (2013, 2014) examined electroglottographic (EGG) contact in stressed and unstressed word-initial vowels across phrasal positions.[4] Stressed vowels showed an increase in EGG contact, while unstressed vowels presented a decrease in EGG contact.

To sum up, Spanish and English phonologies disprefer syllables without an onset, such as *oso* 'bear' for Spanish or *elephant* for English. Across word-boundaries, empty onsets (e.g., Sp. *un oso* 'a bear' or Eng. *an elephant*) are often repaired, yet each language uses slightly different strategies. Spanish has a consistent process of consonant resyllabification, by which speakers change the affiliation of the coda consonant and attach it to the onset (e.g., [un.ˈoso] becomes [u.ˈnoso]). For English, phonetic studies show that English speakers optionally incorporate a glottal stop /ʔ/ before the initial vowel (e.g., [an.[ˈʔe]lephant) and that this strategy is mediated by lexical stress. Thus, if transfer occurs from the majority language into the heritage language, there will be glottalization of word-initial vowels when preceded by coda consonants (e.g., [un.ʔoso]).

2.4.3 Transfer of glottal phonation in vowel-initial positions

Previous research supports the prediction that the production of glottal phonation at word-boundaries constitutes a site for cross-linguistic transfer. In Spanish, glottal stop epenthesis at word-junctures has been found to be susceptible to cross-linguistic transfer both during language learning (i.e., individual level) (González & Weissglass, 2017; Lleó, 2016b; Mohamed et al., 2019; Scarpace, 2017) and in instances of language contact (i.e., societal level)

[4]Similar results were found in this study for Spanish. However, the Spanish population in the study consisted of 12 UCLA Spanish-English bilinguals, 7 of which were born in Los Angeles. That is, proficiency in English might have been a confounding factor in the results.

(Gynan & López Almada, 2020, see for Paraguayan Spanish). Such instances of transfer have been found in lieu of Spanish resyllabification (Lleó, 2016b; Scarpace, 2017), as a strategy to resolve word-external hiatus (González & Weissglass, 2017; Mohamed et al., 2019), or in both word-internal and word-external position (Gynan & López Almada, 2020).

With regard to language transfer in L2 learning, Scarpace (2017) used a reading task to examine the rate and acoustic properties of glottal phonation in /V#CV/ (i.e.,*las alas* 'the wings') sequences and found that L2 Spanish speakers (i.e., English native speakers) produced instances of glottal phonation more often (/n/ = 53.65%, /s/ = 56.62%, /r/ = 77.88%) than the Spanish native speakers' control group (/n/ = 4.16%, /s/ = 4.16%, /r/ = 11.47%). Still in the L2 literature, González and Weissglass (2017) examined glottal stop epenthesis in word-external hiatus resolutions (i.e., /V#V/) and finds evidence of an initial stage of L1 English transfer in which L2 speakers produce glottalization across the board to repair /V#V/ sequences (38% for unstressed V_2 in the content words, 62% for stressed V_2 in the content words). After 16 weeks of Spanish instruction (i.e., interlanguage) L2 speakers reduced the use of glottal phonation only in unstressed content words (i.e.,18% for unstressed V_2 in the content words, 74% for stressed V_2 in the content words), and produced hiatuses or diphthongs instead. It is possible that 16 weeks of training is not enough time to acquire Spanish-like repairs of hiatus resolution.

Turning to heritage speakers, Mohamed et al. (2019) analyzed the speech of 5 Arabic heritage speakers residing in Puerto Rico using results from a reading task containing instances of /V#V/ sequences (i.e., *hacha amarilla* 'yellow ax'). Despite not finding a significant difference in rate of glottal phonation between Spanish monolinguals (M = 33%) and Spanish-Arabic bilinguals (M = 34%), their results showed that dominance in Arabic favored presence of glottalization. Arabic dominant heritage speakers produced 60% of glottal phonation, whereas Spanish dominant heritage speakers demonstrates 28% of glottal phonation.

As for the study of child heritage speakers, Lleó (2016b) is, to my knowledge, the only study to examine production glottal phonation during language maturation. In particular, Lleó (2016b) examined /C#V/ sequences in child Spanish heritage speakers in contact with German. Using a constraint-based approach Lleó (2016b) posited that, unlike Spanish (see example 2.4), DEP-IO (i.e., every segment in the output has to have a correspondent in the input) has a crucial role in the language, as it is dominated by ALIGN(PW,L, FT,L (i.e., the left edge of the foot has to be aligned with the left edge of the prosodic word). This allows for a repair of the empty onset using glottal stop insertion.

/das#aw.to/	ONSET	ALIGN-L	DEP
→ a. das.ˈʔaw.to			*
b. das.ˈaw.to	*!		
c. da.ˈsaw.to		*!	

Table 2.4: Glottal stop epenthesis in German

Lleó (2016b) examined longitudinal corpus data from 2 Spanish monolingual children from Madrid (i.e., from 1;1 to 2;8 years old), 1 German monolingual child (i.e., from 1;1 to 2;5 years old), 3 young Spanish-German bilinguals (i.e., from 2 to 5;7 years old) and compared their productions to data from 16 older Spanish-German bilinguals (i.e., from 7 to 8 years old). As presented in the previous chapter, Spanish monolinguals exhibited a high proportion of resyllabification from the start of two-word production. The German monolingual child presented glottal stop insertion at a rate of approximately 50% between the years of 1;1 and 2;5. In their turn, Spanish-German bilinguals showed a higher percentage of glottal stops than that of Spanish monolinguals, with curves presenting a growing tendency (2 to 5;7). When compared to older bilingual children (7), resyllabification was applied in a very restricted manner. This indicated that older children continued to have non-target-like productions of two word utterances. These findings suggest majority-to-heritage language transfer in German-Spanish bilinguals.

2.4.4 Conclusion

In Spanish and English connected speech, word-initial syllables without an onset are repaired. Both languages have a process of resyllabification by which the coda consonant gains affiliation to the following syllable and either detaches from its initial syllable (i.e., Spanish resyllabification) or maintains its attachment to it (i.e., English ambisyllabicity). Aside from the resyllabification process, English speakers optionally epenthesize a glottal stop to repair the empty onset, a process which appears to be mediated by prosodic prominence. Since the use of glottal phonation affects the surface structure, transfer of glottal stop insertion has been analyzed in the speech of L2 Spanish speakers who are L1 speakers of English. Scarpace (2017) has shown that these learners produce higher rates of glottal phonation than their monolingual peers. Transfer of glottal phonation has also been documented in other linguistic circumstances (i.e., heritage speakers of German-Spanish [Lleó, 2016], Arabic Spanish [Mohamed et al., 2019]). Thus, the use of glottal phonation to repair empty onsets is likely to appear in the speech of Spanish heritage speakers, from whom English is their dominant language.

CHAPTER 3

Monolingually raised Spanish and English speakers' production of glottal phonation in repairs of empty onsets

3.1 Introduction

The main goal of this chapter is to examine the development of word-external junctures (i.e., /C#V/) in non-heritage child and adult American English and Mexican Spanish grammars. In the first part of this chapter, I use four experiments to analyze the degree to which American English and Mexican Spanish speakers produce modal phonation (i.e., resyllabification or coda consonants) or glottal phonation (i.e., /ʔ/-epenthesis at the word juncture) to repair word-external empty onsets (i.e., /C#V/), and to explore whether these tendencies change over the course of language acquisition. In particular, I analyze the effects of prosodic prominence, consonant type, and the lexicon on the production of glottal phonation. In the second part of this chapter, I formalize base grammars for child and adult American English and Mexican Spanish speakers. Aside from the analysis of glottal phonation, I include phonetic data to determine the phonological candidates competing in the proposed grammars.

3.2 Research questions

In this chapter I examine how the rate of glottal phonation and consonant duration develop during childhood in a group of younger children (i.e., between the ages of 5 to 8) and a group of older children (i.e., between the ages of 8 to 11) and I compare them to a group of adults. I ask the following questions:

1. Does age predict the rate of glottal phonation as a repair of word-external empty onsets?

    - If repairs of word-external empty onsets are still developing during late childhood, the rate of glottal phonation will be higher during childhood than during adulthood (i.e., younger child > older child > adults)

2. Will the rate of glottal phonation show similar patterns across consonants /n/, /s/, /l/ during language development?

    - I predict that, in late-acquired consonants, children will resort for a longer time to glottal-stop insertion. Children may need a longer time to learn to coarticulate late-acquired consonants with the following vowel than to coarticulate early-acquired consonants. During this learning period, children may employ glottal stop epenthesis more often in late-acquired consonants in order to satisfy the onset condition. In addition, glottal stop gestures are transparent to coarticulation (Stemberger, 1993), which allows children to practice consonant-to-vowel coarticulation while satisfying the syllabic onset requirement.

        - **English:** Adult-like rates of glottal phonation will be acquired faster in early-acquired sounds (i.e., /n/) than in the late-acquired consonants (i.e., /l/, /s/). [1].

[1]While onset-/l/ has been shown to be acquired early by English-speaking children (2;0 to 4;6) (Dodd, Holm, Hua & Crosbie, 2003), coda-/l/ has been found to be acquired later, around the ages of 6;0 to 7;0. In addition, research has also found that /s/ shows to be developing up until the age of 7 (Williamson, 2010).

- **Spanish:** Adult-like rates of glottal phonation will be acquired faster when the word-juncture involves early-acquired sounds (i.e., /n/) than when it involves late (or later) acquired sounds (i.e., /l/, /s/)?.

3. Are words bearing initial primary stress more likely to be glottalized than those not bearing initial primary stress? Does age moderate the effect of primary stress on the rate of glottal phonation?

   - Vowel-initial words bearing initial primary stress will be more likely to present glottal phonation than those not bearing primary stress (Davidson & Erker, 2014; Dilley et al., 1996; Garellek, 2013). Moreover, recall that Newton and Wells (2002) report an initial stage in which children produce between-word junctures with non-adult-like rates of glottal stop phonation, suggesting that glottal phonation precedes the production of closed-junctures, ambisyllabic consonants in our case. If this is the case, it follows that glottal stop-epenthesis will be used to repair empty onsets regardless of the prosodic status of the vowel initial word. Thus, if children are still developing adult-like production of /C#V/ sequences, the difference in glottal phonation between content words bearing primary stress and content words not bearing primary stress will be smaller during childhood than during adulthood (i.e., interaction between primary stress and age).

4. Are novel words more likely to be produced with glottal phonation than real words? Does age moderate the effect of the lexicon?

   - If phonological constraints are sensitive to the lexicon, the rate of glottal phonation will be greater in novel words than in real words, since speakers will be more likely to be exposed to modal phonation in the real words.[2] Moreover, if the

[2]Here, I assume an initial stage, in which pairs of function and content words are likely to surface with glottal phonation, as reported in Newton and Wells (2002) and Lleó (2016a).

lexicon has an effect on the rate of glottal stop phonation, it is likely the effect of the lexicon is less robust in children than in adults, because their lexicons are still maturing, and they have not been presented with modal phonation with the same frequency as adults. Thus, I predict that the difference in the rate of glottal phonation between real and novel words will be smaller in children than in adults (i.e., interaction between type of word and age).

5. Are rates of glottal phonation greater in English than in Spanish?

    - Drawing from the phonological descriptions in Spanish and English, I predict that English speakers will produce greater rates of glottal phonation than Spanish speakers, as /ʔ/-epenthesis is a type of repair strategy included in the English phonological inventory, but not in that of Spanish.

3.3 Methods

3.3.1 Test materials

3.3.1.1 Experiment 1a Spanish

Stimuli. Eight Spanish vowel-initial words, 4 words with initial stress and (e.g., *ojo* 'eye') and 4 words with non-initial stress (e.g., *espejo* 'mirror'), were selected for this experiment. The words with initial stress and the words with non-initial stress were matched in frequency by consulting the CHILDES database (MacWhinney, 2000). In addition, I calculated the frequency of function word + content word co-occurrence divided by the overall occurrence of the content word, to ensure similar rates of consonant-vowel junctures in the input (i.e., Ratio C/V in Table 3.1).

Initial-stress				**Non-initial stress**			
Items	*Log Freq*	*Ratio C/V*	*Gloss*	*Items*	*Log Freq*	*Ratio C/V*	*Gloss*
ojo	1.79	0.78	eye	animal	1.92	0.71	animal
árbol	1.87	0.84	tree	elefante	1.71	0.78	elephant
hombre	1.69	0.29	man	espejo	1.49	0.90	mirror
ángel	0.73	0.71	angel	avión	1.00	1	plane

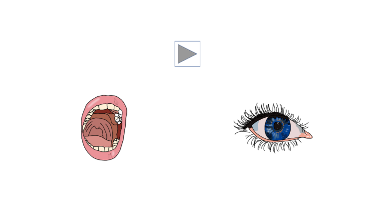
Table 3.1: Frequencies from CHILDES (MacWhinney, 2000) in Spanish words

Task. The task had 24 trials (4 item x 2 stress x 3 coda). The target sequence consisted of a function word (i.e., *el* 'the', *dos* 'two' and *un* 'a/an') and a vowel-initial content word. Participants were presented with two images side by side in a PowerPoint® presentation. Each item contained a consonant-initial support word and a target word. Participants were then presented with a sentence recorded by a female Mexican Spanish speaker to elicit the target sequence (see the elicitation sequence for Experiment 1). I tried to maintain a certain degree of pragmatic felicitousness in the elicitation sequences.

1. Elicitation sequence for Experiment 1a

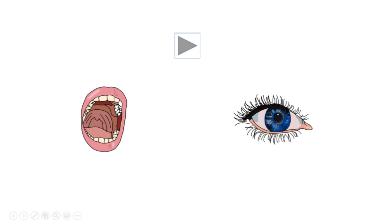
    - Coda /n/: Esto es una boca y esto es... 'This is a mouth and this is...'

      CH: un ojo 'an eye'

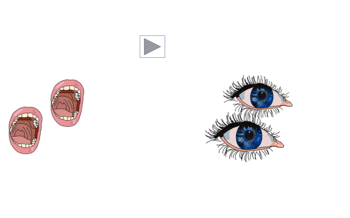
    - Coda /l/: ¿Cuál es azul? 'Which one is blue?'

      CH: el ojo 'the eye'



- Coda /s/: Aquí hay dos bocas y aquí hay... ‘There are two mouths here and here there are...’

  CH: dos ojos ‘two eyes’



3.3.1.2 Experiment 1b English

Stimuli. Eight English vowel-initial words, 4 words with initial stress (e.g., *octopus*) and 4 words with non-initial primary stress (e.g., *umbrella*), were selected for this experiment. The words with initial stress and the words with non-initial stress were matched in frequency by consulting the CHILDES database (MacWhinney, 2000).

Initial stress			**Non-initial stress**		
Items	*Log freq*	*Ratio C/V*	*Items*	*Log freq*	*Ratio C/V*
octopus	1.28	0.32	umbrella	1.77	0.36
island	0.95	0.11	aquarium	0.60	0.00
onion	0.90	0.25	iguana	0.90	0.50
olive	0.48	0.33	avocado [3]	0.00	0.00

Table 3.2: Frequencies from CHILDES (MacWhinney, 2000) in English words

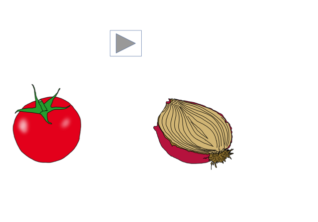
I ran t-tests to ensure comparable neighborhood frequencies (NFreq) and neighborhood densities (ND) across languages (real words in Spanish and real words in English). Independent samples t-tests indicated that the NDs for Spanish and English were not significantly different ($t(7)= 1.33$, $p = 0.22$) and that the NFreqs did not differ significantly between the two languages either ($t(7)=1.73$, $p = 0.12$).

Task. The task had 24 trials (4 items x 2 stress positions x 3 types of coda). The target sequence consisted of a function word (i.e., *all*, *this*, *an*) and a vowel-initial content word. The consonant-initial support words and pictures were used to elicit parallel structures (see the elicitation sequence for Experiment 1b).The audio stimuli were recorded by a female speaker of American English.

2. Elicitation sequence for Experiment 1b

- Coda /n/: This is a tomato and this is...

  CH: an onion



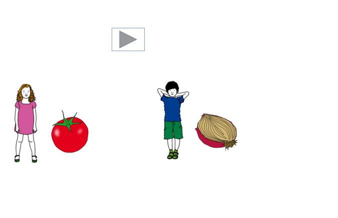
- Coda /l/: The girl likes all tomatoes and the boy likes...

  CH: all onions

[3]The selected corpora have transcriptions from families all over the US (e.g., Arizona, Southern California, Boston) and most of the recordings were conducted between 1975 and 2000. Thus, the current lexical frequency for *avocado*, which has been recently incorporated in the American cuisine, may not be reflected in the corpora. Note also that the first syllable of *avocado* bears secondary stress.

- Coda /s/: The girl likes this tomato and the boy likes..

  CH: this onion



Cognates. In order to create comparable designs in both languages in terms of lexical frequency, picture recognition, and location of primary stress, the use of cognates was inevitable in the two experiments. For the purpose of controlling for cognate effects, I calculated the NFreq of each set of words for both Spanish and English. An independent samples t-test between the NFreq in Spanish for English real words and the NFreq for English in Spanish real words do not differ significantly ($t(12.8)$ = -0.54, p = .59).

3.3.1.3 Experiment 2a Spanish

Stimuli. Twenty-four phonotactically-legal Spanish novel words have been created. 8 consonant-initial words (e.g., *mingo*), 8 vowel-initial words (e.g., *endo*) and, /l/-initial-words (e.g., *lamba*) (see Table 3.3). The target sequence was *el* [det. art. masc. sg. 'the'] + novel word for the /l#C/ condition (e.g., *el mingo*) and the /l#V/ condition (e.g., *el endo*). The target sequence for /V#l/ is *la* [det. art. fem. sg. 'the'] + novel (e.g., *la lamba*). Syllable weight was used to encourage initial and non-initial stress, as heavy syllables tend to attract stress for Spanish-learning infants (Pons & Bosch, 2010). The vowels are maintained across conditions for each different observation. An independent samples t-test showed that the NFreq means for Spanish and English are not significantly different ($t(45)$=-0.31, p = .75) and a second t-test indicated that the NDs are not significantly different between the two languages ($t(38.93)$ = 0.84, p = .40).

Task. This task had 24 trials (4 items x 2 stress positions x 3 consonant positions). To

Table 3.3: Spanish Novel Words

	/l#V/	/V#l/	/l#C/
Initial stress	el ingo [elˈiŋgo]	la lirba [laˈliɾβa]	el mingo [elˈmiŋgo]
	el anbo [elˈambo]	la lamba [laˈlamba]	el nanbo [elˈnambo]
	el endo [elˈen̪do]	la lenba [laˈlemba]	el belgo [elˈβelɣo]
	el onbo [elˈombo]	la londa [laˈlonda]	el borgo [elˈβoɾɣo]
Non-initial stress	el ilor [eliˈloɾ]	la lidul [laliˈðul]	el milor [elmiˈloɾ]
	el adol [elaˈðol]	la laned [lalaˈned]	el madín [elmaˈðin]
	el ebón [eleˈβon]	la leriz [laleˈɾis]	el berol [elβeˈɾol]
	el obín [eloˈβin]	la lodad [laloˈðad]	el bodín [elβoˈðin]

elicit the target sequence (e.g., *el madín*), participants were presented with a PowerPoint® presentation showing two images: a picture of a real word and a picture of a novel object (e.g., *el jarrón* 'the vase'- *el madín*). Participants then heard an audio recording that named the real and the novel word and asked them to identify the color of the target word (see the elicitation sequence for Experiment 2a). The audio was recorded by a male Spanish speaker and a female Spanish speaker. The target novel words were produced by the male speaker and cross-spliced in the carrier sentences, recorded by the female speaker, to avoid priming participants with typical word-external processes in Spanish. In order to prevent exposure to glottal phonation in the target stimuli, I removed visible glottalization at the beginning of the target vowel-initial word. I calculated the mean degree of glottalization of the first vowel in the vowel-initial words and the first vowel in the /l/-initial words (i.e., context where glottalization does not surface) using the difference between the first and the second harmonic of the f0 (H1*-H2*) (Garellek, 2014; Keating et al., 2015; Shue et al., 2011)[4]. A paired sample t-test indicated that the difference in degree of glottalization between the vowel-initial words (M = 3.52.12 dB, SD = 3.82 dB) and the /l/-initial words (M = 3.23

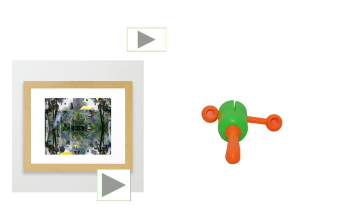
[4]H1*-H2* was calculated using VoiceSauce for Matlab (Shue et al., 2011)

dB, $SD = 1.93$ dB) was not significantly different ($t(7) = 0.22$, $p = 0.82$).

3. Elicitation sequence for Experiment 2a

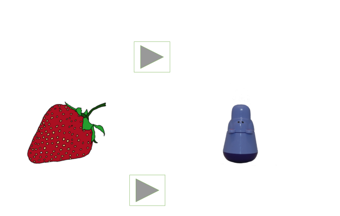
- Coda *el*: Esta cosa se llama *cuadro* y esta cosa se llama *anbo*[5]. ¿Cuál es verde? 'This thing is called *painting* and this thing is called *anbo*. Which one is green?'

  CH: el anbo



- Coda *la*: Esta cosa se llama *fresa* y esta cosa se llama *lenba*. ¿Cuál es azulada? 'This thing is called *strawberry* and this thing is called *lenba*. Which one is blue?'

  CH: la lenba



3.3.1.4 Experiment 2b English

Stimuli. Twenty-four English phonotactically-legal novel words were created. 8 consonant-initial words (e.g., *nadgy*), 8 vowel-initial words (e.g., *adgy*) and 8 /l/-initial-words (e.g., *lamby*) (see Table 3.4). The target sequence was *all* + novel word for the conditions of /l#C/ (i.e., *all nadgies*) and /l#V/ (e.g., *all adgies*) and *a* + novel words for the /V#l/ condition (e.g., *a lamby*). The words with initial stress have a closed initial-syllable. That

[5]The names in italics were produced by a different voice from that of the carrier phrase

is, they have a /VC.CV/ structure (e.g., *embo*) or a /CVC.VC/ structure (e.g., *lamby*). The words with non-initial stress have a closed ultima. That is, they follow a /V.CVC/ structure (e.g., *abeed*) or a /CV.CVC/ (e.g., *lemood*) structure. Syllable weight was used to attract stress, as it has been shown to influence stress placement in English. In particular, long vowels in open syllables are more likely to attract stress than closed syllables with short vowels (Guion et al., 2003). I ran t-tests to control for frequency differences across languages for neighborhood frequencies and neighborhood densities. An independent samples t-test showed that the NFreq means for Spanish and English are not significantly different between ($t(32)$=-1.42, p = .16) and a second independent samples t-test indicate that the NDs for Spanish and English are not significantly different ($t(45)$=-0.83, p = .42).

Table 3.4: English Novel Words

	/l#V/	**/V#l/**	**/l#C/**
Initial stress	all adgies [ɔɫˈædʒəz]	a lamby [əˈlæmbi]	all nadgies [ɔɫˈnædʒəz]
	all imbos [ɔɫˈɪmbəz]	a lidzo [əˈlɪdzow]	all ninzos [ɔɫˈnɪnzəz]
	all embos [ɔɫˈɛmbəz]	a lenzy [əlɛnzɪ]	all menzies [ɔɫˈmɛnziz]
	all ombies [ɔɫɔmbəz]	a lonzy [əˈlɔnzɪ]	all nombos [ɔɫˈnɔmbəz]
Non-initial stress	all abeeds [ɔɫəˈbidz]	a lameed [ələˈmid]	all nanoods [ɔɫnəˈnudz]
	all egoons [ɔɫəˈgunz]	a lemood [ələˈmud]	all megoons [ɔɫməˈgunz]
	all iboons [ɔɫɪˈbunz]	a linoon [əlɪˈnun]	all minoods [ɔɫmɪˈnuds]
	all ozeeds [ɔɫəˈzidz]	a lozeen [ələˈzin]	all nodeens [ɔɫnəˈdinz]

Task. The production task had 24 trials (4 items x 2 stress positions x 3 consonant positions). The same elicitation procedure as Experiment 2a was followed (see the elicitation sequence for Experiment 2b). All visible glottalization at the left edge of the target stimuli was manually removed from the audio. In addition, I compared the degree of glottalization between the vowel-initial words and the /l/-initial words. A paired sample t-test indicated that the difference in degree of glottalization between the vowel-initial words (M = 4.12 dB,

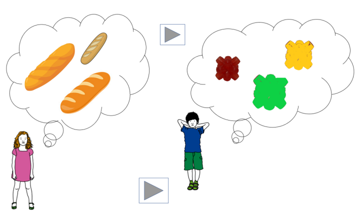
$SD = 2.24$ dB) and the /l/-initial words ($M = 3.07$ dB, $SD = 1.58$ dB) was not significantly different ($t(7) = 1.37$, $p = 0.21$).

4. Elicitation sequence for Experiment 2b

   - Coda *all*: These are some funny *baguettes* and these are some fancy *egoons*. The girl likes all *baguettes* and the boy loves.

     CH: all egoons

     [6].

   - Coda *a*: This is a *racoon* and this is a *lemood*. What is this?

     CH: a lemood

3.3.2 Experimental protocol

The four experiments were presented using a PowerPoint® presentation. The items were presented in random order and the order of the experiments were counter-balanced. Children were presented with the recorded stimuli once and were asked to complete the sentence. Non-target productions were those in which the participant did not include the functional

[6]The names in italics were produced by a different voice from that of the carrier phrase

element or those in which the picture was not correctly identified. In the former case, the experimenter reminded the participant that two words were needed to correctly complete the task. In the latter case, the experimenter produced the word in isolation and then the recording was played a second time. Under no circumstances, the experimenter produced the target word in connected speech (i.e., word + target word).

3.3.3 Adult participants

Monolingually raised adult Spanish speakers. Twenty-five monolingually raised Spanish speakers in Mexico (SpanMonoS) were recruited for this experiment. Data of three speakers were discarded due to clipping in the speech signal. Upon revising the questionnaire, two participants were further removed. One participant was discarded because their reported Spanish input and output values did not reach a threshold of 70%, and one participant was removed for having spent more than 6 weeks in an English-speaking country (i.e., 4 months). Data of the remaining 20 participants (14F, 6M, mean age = 20.87, *SD* = 1.99) residing in Mexico were analyzed in this study. None of the participants reported having lived outside of Mexico for more than 6 consecutive weeks. The adult Spanish speakers in Mexico had a mean Spanish input of 86.98% (SD = 0.08) and a mean Spanish output of 92.58% (SD = 0.07). Participants were compensated with a $15 gift card.

Monolingually raised adult English speakers. Twenty-four adult monolingually raised American English speakers (EngMonoS) were recruited for this study. Data of three speakers were not included due to noisy or weak speech signal. Upon examination of the participants' linguistic background, one participant was removed for having been exposed to Mandarin at home, which has a high rate of vowel-initial glottal phonation (Belotel-Grenié & Grenié, 1997; Yu & Lam, 2014). The data of 20 English monolinguals (14 F, 6 M, mean age = 20.2, *SD* = 1.06) with basic or no previous knowledge of Spanish were analyzed in this experiment. All the speakers were born in California. None of the participants used languages other than English on a regular basis or were exposed to Spanish at home. Participants were compensated with class credit.

3.3.4 Child participants

Monolingually raised child Spanish speakers. Fifty child Spanish speakers in Mexico were recruited for this study (i.e., child SpanMonoS). Data of one participant were removed due to non completion of the experiment. Data of two participants was excluded due to noisy speech signal. Upon revising the questionnaire, one participant was removed due to exposure to Hebrew at home and two participants were discarded due to exposure to Spanish less than 70% of the time. Data of the remaining 44 child Mexican speakers (19F, age range = 5;1 to 11;8 years, mean age = 8;6 years) were included in the analysis. The children were divided into a group of younger children (N = 21, age range = 5;1 to 8 years, mean age = 6;8 years) and a group of older children (N = 23, age range = 8 years to 11;8 years, mean age = 10;1 years). While participants were exposed to English at school to various degrees, all the participants were exposed to Spanish at least 70% of their awake weekly time (i.e., 98 hours). In addition, all the child Mexican speakers had been receiving online education for at least 6 months at the time of testing. The younger children group had a mean input of 91.52% (10.29%) of and a mean output of 97.93% (SD = 4.47%). The older children group had a mean input of 91.25% (SD = 9.75%) and a mean output of 98.50% (SD = 3.60%). [7] Participants were compensated with a $15 gift card.

Monolingually-raised child English speakers. Forty-seven child American English monolinguals participated in this study (i.e., child EngMonoS). Data of three participants were removed due to enrollment in a Spanish immersion program. Data of one participant were removed due to home exposure to British English, and data of one participant were

[7] Testing started in August 2020 and primary schools had been holding online classes since March 2020 due to Covid-19.

removed due to impossibility to obtain their demographic information. The remaining forty-two participants were included in the study. Participants were divided into a group of 20 younger children (8F, mean age = 7;1, age range = 5;7 to 8 years), and a group of 22 older children (15 F, 1 non-binary, mean age = 9;5 years, age range = 8;2 to 11;5 years). Twenty-five participants were recruited through the UCLA Lab School and were not compensated for their participation. The rest of the participants were recruited through social media and were compensated with a $15 gift card for their participation.

3.4 Data coding and segmentation

3.4.1 Categorical coding

I used a binary scheme to classify the tokens: glottal phonation or modal phonation. The former category included tokens realized with creaky phonation and tokens produced with full glottal stops. Full glottal stops were identified as a period of silence not exceeding 150 ms with possible evidence of creaky phonation in the flanking segments (Garellek, 2013; Scarpace, 2017) (see Figure 3.1 and 3.3 top for Spanish, and Figure 3.4 top for English). Following Scarpace (2017), the cut-off point for assuming the presence of a glottal stop was 150 ms. This means that pauses longer than 150 ms were considered to be speech disfluencies or hesitations. [8] An example of a token with disfluency can be seen in Figure 3.6.

Creaky phonation was coded when the consonant or the vowel presented aperiodicity (i.e., discontinuous duration of consecutive pulses), widening of pulses, diplophonia (i.e., changes in amplitude), or lowered f0 (Davidson & Erker, 2014; Dilley et al., 1996; Keating et al., 2015) (see Figure 3.1 and 3.3 left and Figure 3.4 left for English). As shown in Figure 3.5, the tokens were classified as creaky even in the cases in which creakiness was presented in a small portion of the sequence and less irregular pulses were visible (i.e., more difficult to

[8] For the complete data set (i.e., heritage speakers and monolinguals), 41 tokens were discarded for Spanish real words, 59 for Spanish novel words, 84 for English real words and 72 for English novel words.

segment). Modal phonation was coded when none of the above characteristics were present in the speech signal (see Figure 3.1 and 3.3 right and Figure 3.4 right for English).

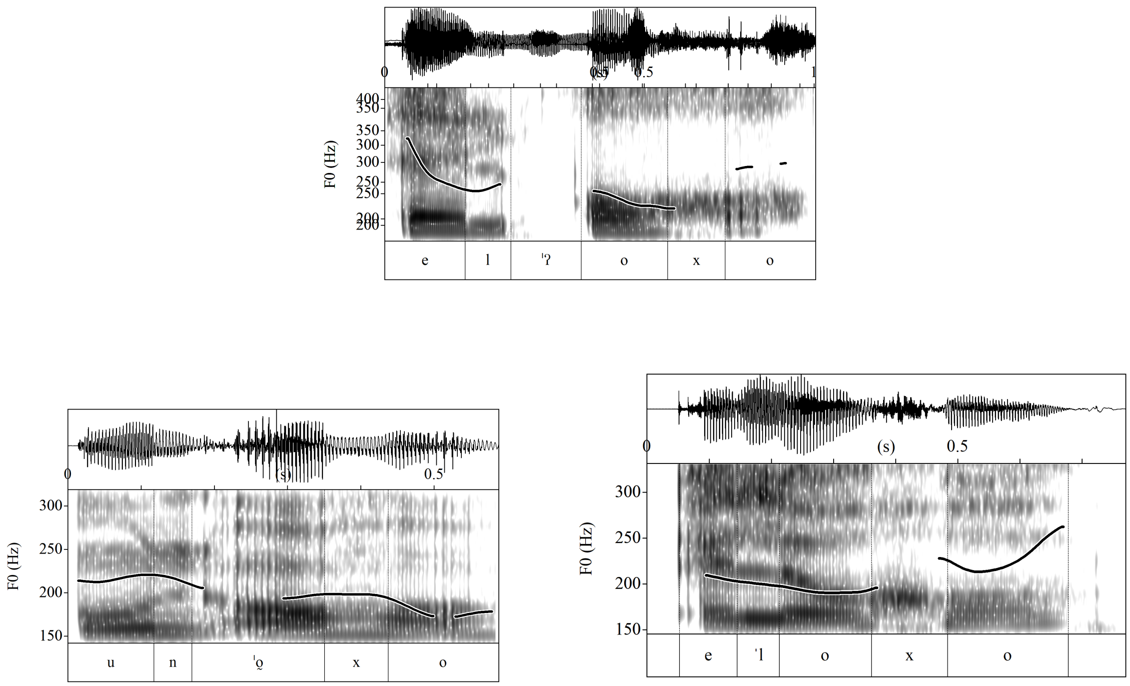


Figure 3.1: Types of phonation in real words ‘the eye’, glottal stop (top), creaky phonation (left), and modal phonation (right) for Spanish

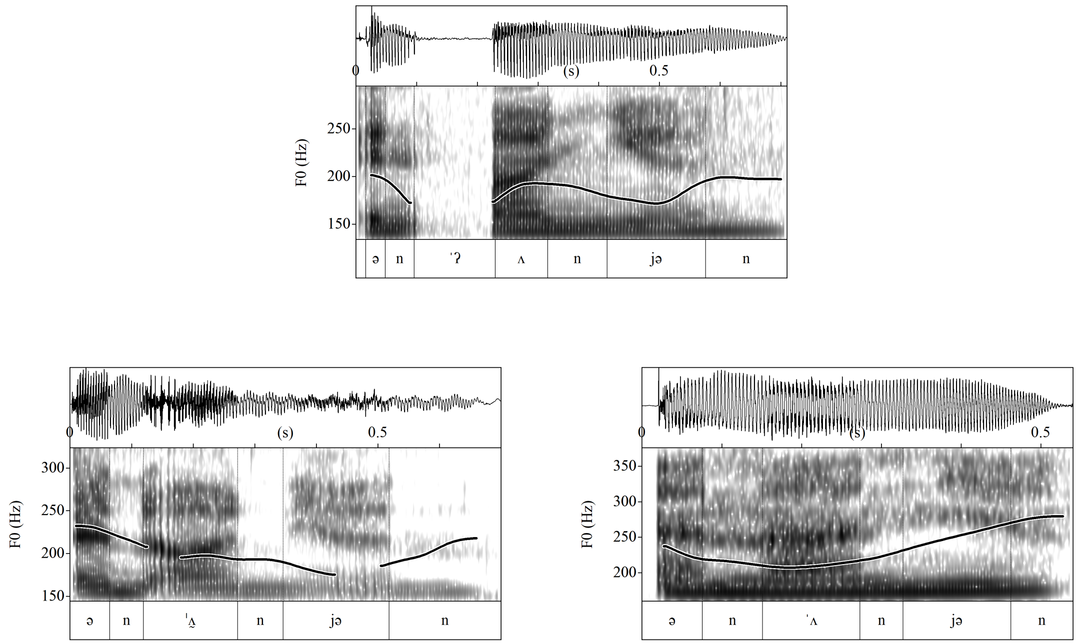


Figure 3.2: Types of phonation in real words 'an onion', glottal stop (top), creaky phonation (left), and modal phonation (right) for English

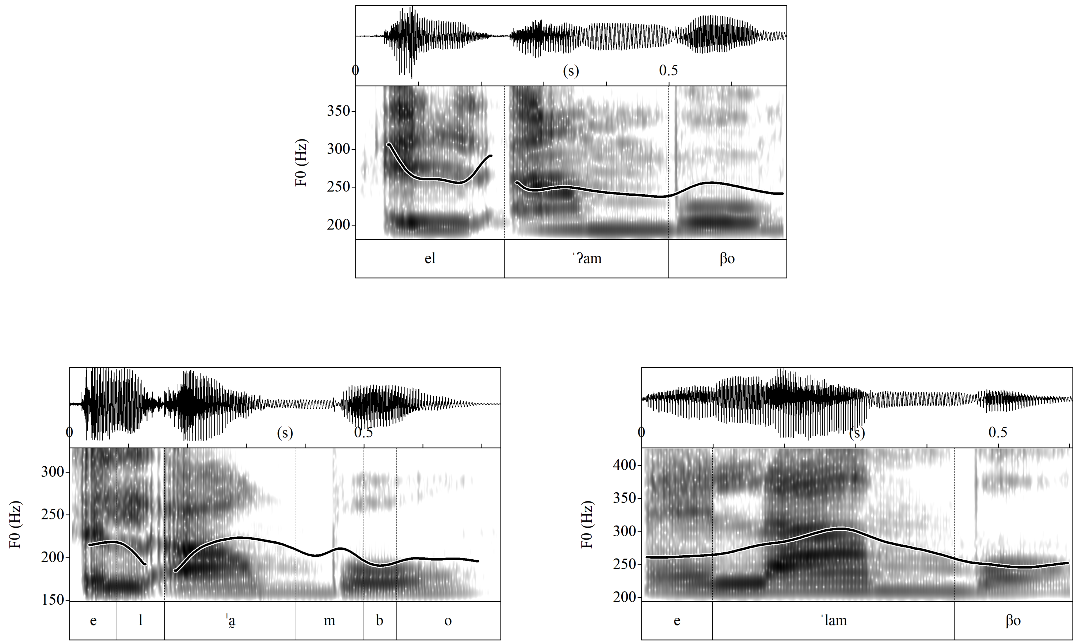


Figure 3.3: Types of phonation in novel words ‘el anbo’, glottal stop (top), creaky phonation (left), and modal phonation (right) for Spanish

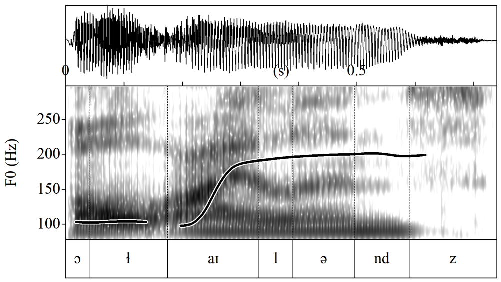


Figure 3.5: Example of token produced with a small portion of creaky phonation 'all islands'

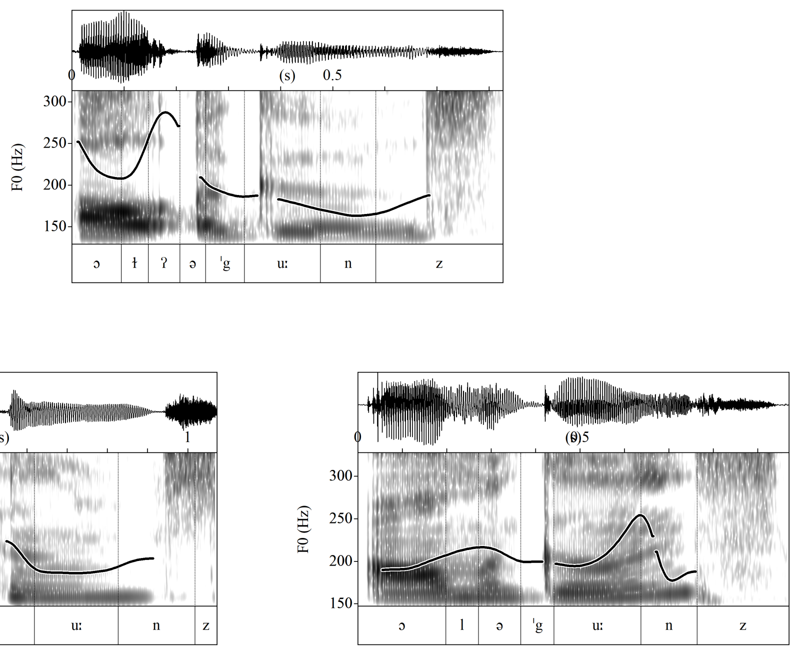


Figure 3.4: Types of phonation in novel words 'all egoons', glottal stop (top), creaky phonation (left), and modal phonation (right) for English

Two undergraduate research assistants were trained to perform the categorical coding along with the author of this dissertation. Each one of them performed a classification of a subset of the data in each language. With the subset of the data, I calculated inter-rater

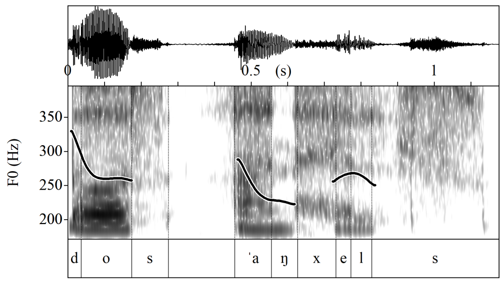


Figure 3.6: Example of disfluency in the sequence 'dos ángeles' *two angels*

reliability on the binary coding (i.e., modal phonation: 0, glottal phonation (creaky or glottal stop): 1) using Cohen's kappa (1960) and the function *cohen.kappa* from the package *psych* (Revelle, 2016) in R (R Development Core Team, 2020). The Cohen's kappa scores in Table 3.5 show substantial to almost perfect agreement for the four data sets [9] for each experiment and including the complete data set (i.e., monolinguals and heritage speakers).

	Spanish		**English**	
	N tokens[10]	Cohen's kappa estimate	N tokens	Cohen's kappa estimate
Real words	521	0.83 (CI:0.83,0.89)	329	0.74 (CI: 0.69, 0.80)
Novel words	122	0.79 (CI: 0.67, 0.91)	124	0.93 (CI: 0.86, 1)

Table 3.5: Cohen's kappa scores for each experiment on the complete data set

[9]According to Cohen (1960) the Kappa scores should be interpreted as following: 0 as indicates no agreement, 0.01–0.20 suggests none to slight agreement, 0.21–0.40 indicates fair agreement, 0.41– 0.60 is moderate agreement, 0.61–0.80 is substantial agreement, and 0.81–1.00 is as almost perfect agreement.

3.5 Results for Mexican Spanish

3.5.1 Real words

Out of the resulting 1624 tokens produced in Experiment 1a, 31 tokens were removed due to initial vowel deletion, creakiness throughout the complete function + content word, clipping or weak signal, pause longer than 150 ms between the consonant and the vowel, or productions missing the function word or with non-target content words (e.g., *angelito*). The remaining 1593 tokens were submitted to a generalized logistic regression using the *lme4* (Bates et al., 2015) and *lmerTest* packages (Kuznetsova et al., 2017) in R (R Development Core Team, 2020). The proportion of glottal phonation is shown in Figure 3.7. The variables age (i.e., younger CH, older CH, adults), initial primary stress (i.e., yes, no) and consonant (i.e., /n/, /l/, /s/) were entered as fixed effects. I ran separate models with two-way interactions for the three variables, but none of the interactions turned out to be significant. My data did not provide enough evidence to support a model with interaction terms. Thus, I can assume that the effects of stress, consonant, and age are independent of each other. A model allowing random intercepts for both participant and word showed singular fit, given a variance of close to 0 for the random effect of word. Thus, only participants were allowed random intercepts in the model.[11] For clarity, I report the descriptive statistics in my results, which include proportion of glottal phonation and standard error.

The model showed a main effect of stress (β = -1.21, z = -2.76, p < 0.001), indicating that words with initial primary stress (i.e., reference level) were more likely to be glottalized (M = 2.89%, SE = 0.34) than words without initial primary stress (M = 0.95%, SE = 0.61). Age did not show a significant main effect in the model at any of the levels. Consonant type (i.e., reference level = /n/) demonstrated a main effect with /s/ (β = 2.24, z = 3.49, p < 0.001), indicating that vowel-initial words following /s/ were more likely to be glottalized

[11]The model had the following syntax: glmer(Glottal.rate ~ Consonant + Age.Group + Stress + (1|Participant).

(M = 3.99%, SE = 0.85) than vowel-initial words following the coda consonant /n/ (M = 0.54%, SE = 0.31). After releveling the model (i.e., reference level = /l/), a main effect of consonant was also found with /s/ ($\beta = 1.41$, $z = 2.88$, $p < 0.001$), suggesting higher rates of glottal phonation in vowel-initial words followed by /s/ than by /l/ (M = 1.15%, SE = 0.47). No difference was found between /n/ and /l/.

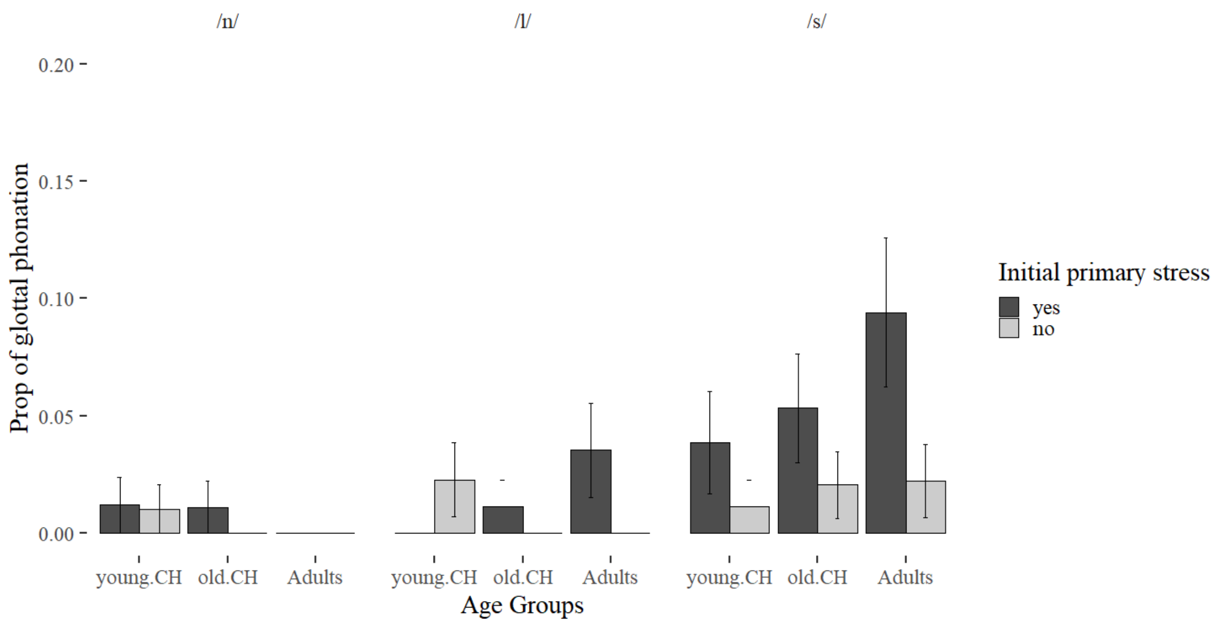


Figure 3.7: Spanish real words: Proportion of glottal phonation by consonant, stress and age

3.5.2 Novel words

Four hundred ninety-nine tokens were produced in the experiment 2a, 50 tokens were removed due to a pause between the function word and the content word (i.e., a silent gap longer than 150 ms). The remaining 449 /l#V/ tokens were submitted to a generalized linear model. The variables age (i.e., younger child SpanMonoS older child SpanMonoS, adult SpanMonoS), and initial primary stress (i.e., yes, no) and their interactions were entered as fixed variables and participant and content word were entered as random effects. [12] Consonant was not included as a fixed effect because all the novel words were elicited with the coda /l/. As demonstrated in Figure 3.8, results show that younger child SpanMonoS produced a lower rate of glottal phonation ($M = 11.45\%$, $SE = 2.79$) than older child SpanMonoS ($M = 23.52\%$, $SE = 3.26$) ($\beta = 1.63$, $z = 2.02$, $p = 0.04$) and adult SpanMonoS ($M = 28.38\%$, $SE = 3.72$) ($\beta = 2.01$, $z = 2.40$, $p = 0.01$). No differences were found between older child SpanMonoS and adult SpanMonoS. In addition, with age was set at the mean, initial primary stress was found to be a significant predictor of glottal phonation ($\beta = 2.01$, $z = 2.40$, $p = 0.01$), indicating that stressed syllables ($M = 25\%$, $SE = 2.85$) were more likely to show glottal phonation than unstressed syllables ($M = 17.97\%$, $SE = 2.61$). No significant interaction was found between age and stress.

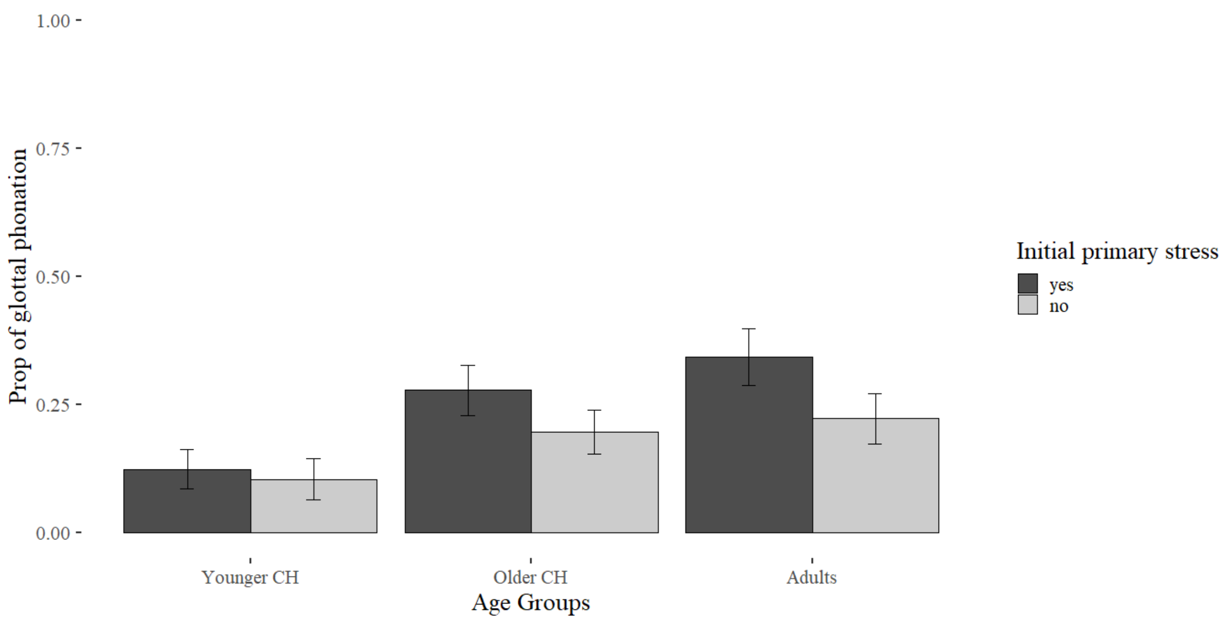


Figure 3.8: Spanish novel words elicited with the function word 'el': Proportion of glottal phonation by consonant, stress, and age

[12]The model had the following syntax: glmer(Glottal.rate ~ Primary Stress * Age.Group + (1|Participant) + (1|Word).

3.5.3 Comparing real words to novel words

Figure 5.6 shows the rate of glottal phonation for the real words (i.e., elicited with the coda consonant /l/) and the novel words (N = 975). I ran a generalized logistic regression was with the variables age (i.e., younger child SpanMonoS older child SpanMonoS, adult SpanMonoS), stress (i.e., stressed, unstressed), and type of word (i.e., real words, novel word) as fixed effects. Separate models with two-way interactions for each variable were fitted. Since the interactions turned out to be non-significant, I can assume that the effect of age, stress, and type of word was the same across each level of the other two variables. In addition, a model with random intercepts for word and participants resulted in a singular fit due to the variance close to 0 for word. Thus, the selected model only included random intercepts for participant. [13]

My findings showed that real words were less likely to be glottalized (M = 1.14%, SE = 0.46) than novel words (M = 21.60%, SE = 1.94) (β = -3.80, z = -7.97, p < 0.001). With type of word and age set at the mean, vowels bearing primary stress were more likely to be glottalized (M = 12.91%, SE = 1.53) than unstressed vowels (M = 8.28%, SE = 1.24) (β = -0.78, z = -2.86, p = 0.004). In addition, with type of word and stress set at the mean, a main effect of age demonstrated that adult SpanMonoS were more likely to glottalize (M = 13.88%, SE = 1.92) than younger child SpanMonoS (M = 5.80%, SE = 1.37) (β = 1.62, z = 2.27, p = 0.02). Younger child SpanMonoS did not significantly differ from older child SpanMonoS (M = 11.85%, SE = 1.68) (β = 0.88, z = 1.6, p = 0.11). Lastly, older child SpanMonoS did not significantly differ from adults (β = 0.57, z = 1.06 p = 0.28).

[13]The model had the following syntax: glmer(Glottal.rate ~ Type.of.word + Stress + Age.Group + (1|Participant).

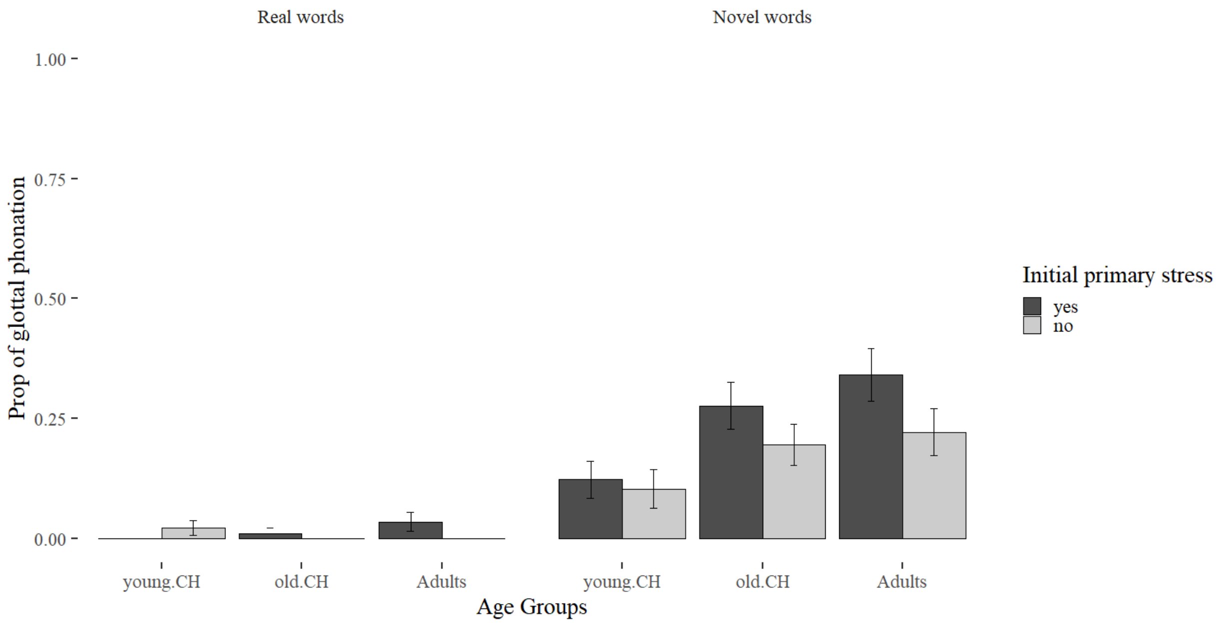


Figure 3.9: Spanish real and novel words elicited with the function word 'el': Proportion of glottal phonation by type of word, stress and age

3.6 Results for American English

3.6.1 Real words

Out of the 1478 tokens produced in the Experiment 1b, 115 were removed due to pauses longer than 150 ms between the function and the content word, failure to produce the a/an allophony, creakiness extended throughout the function and content word, and unclear speech signal. As in the model for Spanish, the remaining 1363 tokens were analyzed using a mixed effects logistic regression model. The variables age (i.e., younger child EngMonoS, older child EngMonoS, adult EngMonoS), initial primary stress (i.e., yes, no) and consonant (i.e., /n/, /l/, /s/) and their interactions were entered as fixed variables and participant and content word were entered as random effects.[14] The categorical variables were contrast coded using

[14] The model had the following syntax: glmer(Glottal.rate ~ Consonant * Age.Group * Stress + (1|Participant) +(1|Word).

simple coding. Figure 3.10 shows the proportion of glottal phonation by consonant, stress, and age.

The model showed that content words with initial primary stress were more likely to show glottal phonation (M = 85.75%, SE = 1.32), than consonant without initial primary stress (M = 34.42%, SE = 1.79) (β = -3.13, z = -5.16, $p < 0.001$). The effect of consonant type demonstrated that /n/ (i.e., reference level) (M = 45.90%, SE = 2.38) was less likely to show glottal phonation than /l/ (M = 65.95%, SE = 2.19) (β = 1.73, z = 7.73, $p <$ 0.001). In addition, /n/ also showed lower rates of glottal phonation than /s/ (M = 65.14%, SE = 2.22)(β = 1.56, z = 7.27, $p < 0.001$). After releveling the model (i.e., /s/ as reference level), /l/ and /s/ did not show a significant difference in rate of glottal phonation. Age was not found to be a significant predictor. In addition, no interactions with stress or consonant were found in the model.

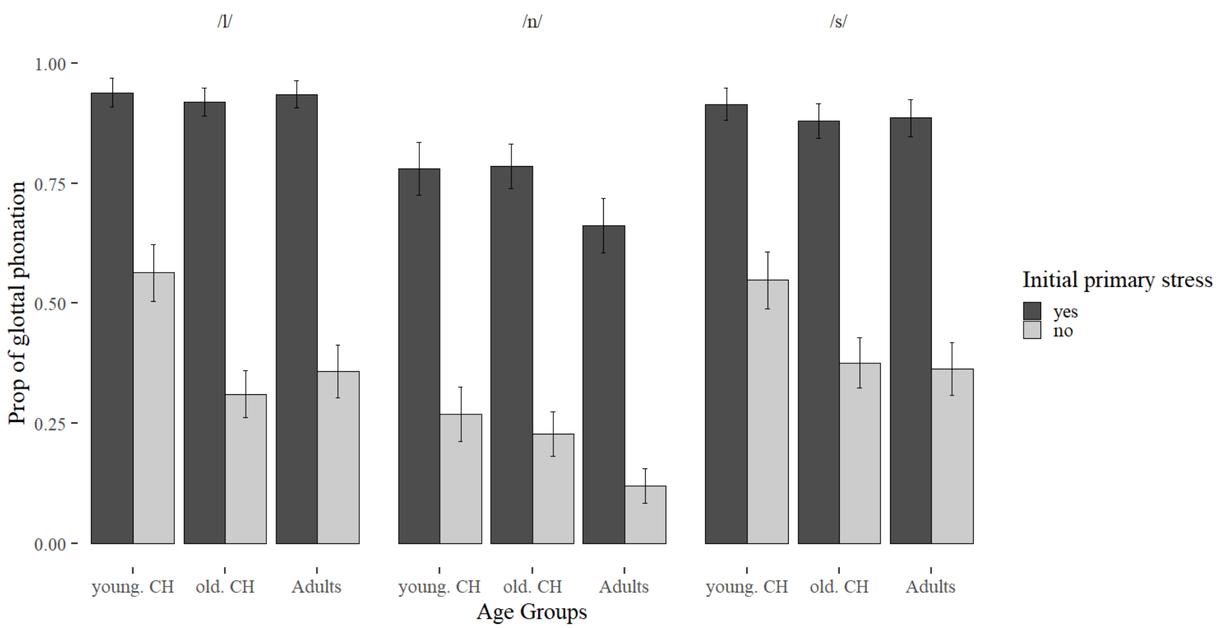


Figure 3.10: English real words: Proportion of glottal phonation by consonant, stress and age

3.6.2 Novel words

Out of the 537 tokens produced in the Experiment 2b, 54 tokens were removed due to pauses longer than 150 ms, consonants inserted as onsets of the vowel-initial words (e.g., baboons), or stress misplacement. The remaining 483 tokens were analyzed using a mixed effects logistics regression and entering the variables initial primary stress (i.e., yes, no), age (i.e., younger child EngMonoS, older child EngMonoS, adult EngMonoS) and their interactions as fixed effects and participant and content word as random effects. [15] Figure 3.11 shows the proportion of glottal phonation by age group and position of primary stress.

The model demonstrated an effect of age with adults (i.e., reference level = younger CH) (β = -1.34, z = -2.07, p = 0.03), showing that younger child EngMno produced higher rates of glottal phonation (M = 81.20%, SE = 3.4) than adults (M = 66.09%, SE = 3.59%). After releveling the model (i.e., older child EngMonoS), a main effect with adults was also found (β =-2.16, z = -3.22, $p < 0.001$), demonstrating that older child EngMonoS also produced a higher rate of glottal phonation (M = 88.71%, SE = 2.32) than that of adult EngMonoS. No interaction was found between age and the other variables. The results showed an effect of initial primary stress (β = -2.14, z = -4.71, $p < 0.001$), indicating that content words with primary stress in the initial syllable (M = 90.98%, SE = 1.88%) were more likely to be glottalized than content words without primary stress in the initial syllable (M = 67.69%, SE = 2.90%).

[15] The model had the following syntax: glmer(Glottal.rate ~ Age.Group * Stress (1|Participant) + (1|Word).

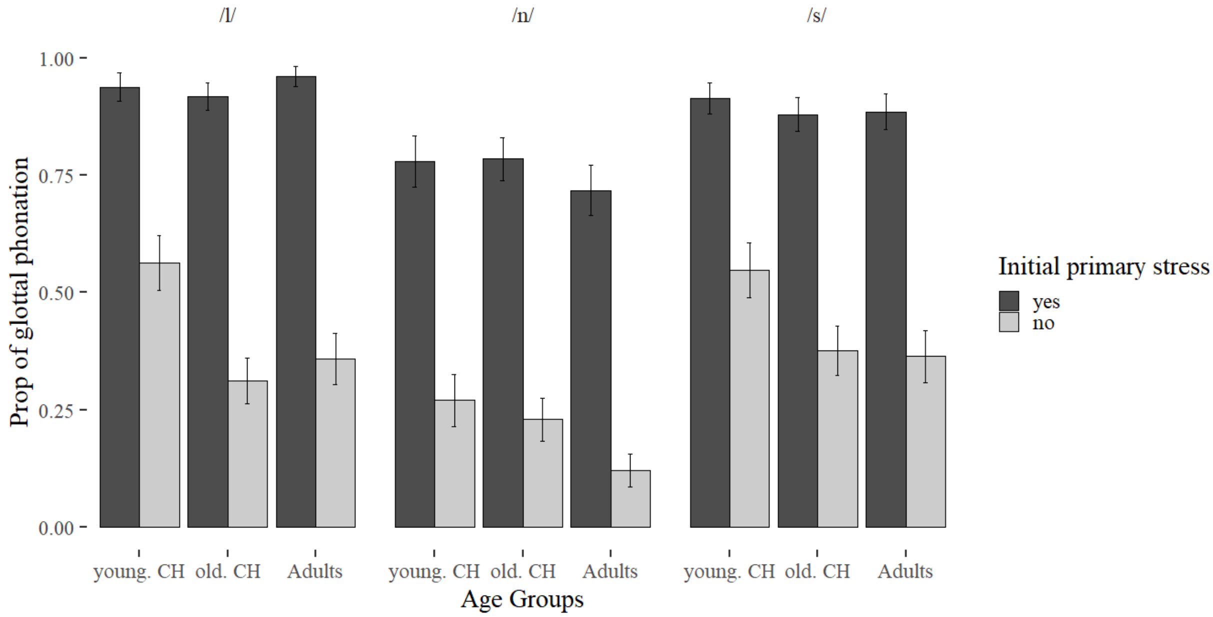


Figure 3.11: English novel words: Proportion of glottal phonation by stress and age group

3.6.3 Comparing real words to novel words

To compare the real words with the novel words, the /l/ real words were subset from the data (N = 467) and merged with the novel words (Total N = 962). Figure 3.12 shows the proportion of glottal phonation by type of word, age group, and initial primary stress. The variables type of word (i.e., real, novel), age (i.e, younger child EngMonoS, older child EngMonoS, adult EngMonoS), primary stress in the initial syllable (i.e., yes, no) and their interactions were entered as fixed effects in a logistic regression with participant and word as random effects.[16] The categorical variables were contrast coded using simple coding.

My results showed a main effect of type of word ($\beta = 0.69$, $z = 2.05$, $p = 0.04$) conditioned by stress ($\beta = 1.73$, $z = 2.58$, $p = 0.009$) and age ($\beta = 1.83$, $z = 2.90$, $p < 0.003$). That is, only words without initial primary stress showed a significant difference in the rate of

[16]The model had the following syntax: glmer(Glottal.rate ~ Primary Stress * Age.Group * Type of Word (1|Participant) + (1|Word).

glottal phonation across the two levels of type of word (non-initial primary stress real words = 40.16%, non-initial primary stress novel words = 67.69%, $p < 0.001$). As for age, only older child EngMonoS showed a significant difference across the two levels of type of word (older child EngMonoS real words = 60.79%, older child EngMonoS novel words = 88.71%, $p < 0.001$). In addition, adult EngMonoS demonstrated a higher rate of glottal phonation than the younger child EngMonoS (β = 0.93, z = 2.00, p = 0.04). After releveling the model (i.e., reference level = older CH), age also showed a main effect with age (i.e., adult EngMonoS) (β = -0.97, z = -2.18, p = 0.02), which was conditioned by type of word (β = -2.33, z = -3.93, $p < 0.001$), confirming that the difference in rate of glottal phonation between the younger child EngMonoS and the adult EngMonoS was greater in the novel words (β = 2.14, z = 3.79, $p < 0.001$), than in the real words (β = 0.66, z = 1.19, $p < 0.001$). No further differences were found between age groups.

Age also demonstrated a first order effect (i.e., adults). Younger child EngMonoS glottalized more often (M = 77.69%, SE = 2.54) than adult EngMonoS (M = 65.35%, SE = 2.63) (β = -0.90, z = -2.00, p = 0.04). After releveling the model (i.e., older CH), older child EngMonoS were also found to produce a greater rate of glottal phonation (M = 75.14%, SE = 2.27) than that of adult EngMonoS (β = -0.97, z = -2.18, p = 0.02). In addition, the model also demonstrated an interaction between type of word and age with older child EngMonoS (β = 1.83, z = 2.90, p = 0.003) (see Table 3.12). Post-hoc tests showed that, while the difference in rate of glottal phonation between real and novel words was not significant in younger child EngMonoS, older child EngMonoS produced a significantly higher rate of glottal phonation in novel words than in real words (β = -2.08, z = -3.98, $p < 0.001$).

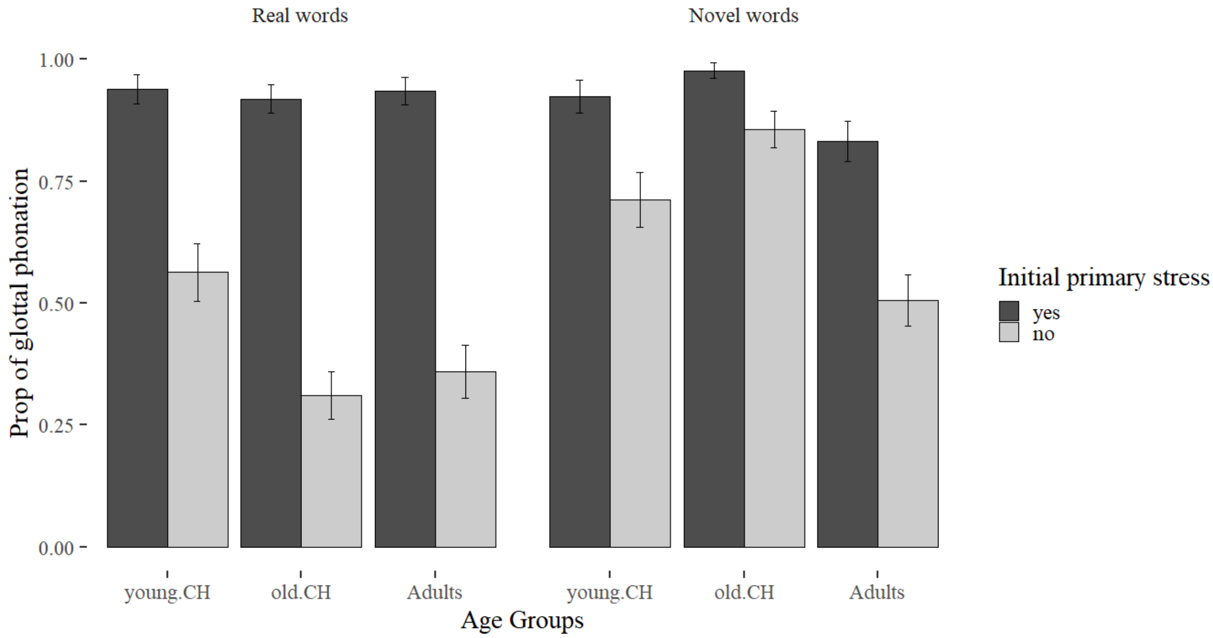


Figure 3.12: English real and novel words elicited with the function word 'all': Proportion of glottal phonation by type of word, stress and age

The main effect of stress was replicated in this model, syllables with primary stress (M = 92.42%, SE = 1.23) were more likely to be glottalized than syllables without primary stress (M = 54.73%, SE = 2.26) (β = -2.93, z = -7.74, $p < 0.001$). Finally, younger child EngMonoS produced higher rates of glottal phonation than adult EngMonoS (β = -1.19, z = -2.32, p = 0.02).

3.7 Discussion

3.7.1 Mexican Spanish: Predictors of glottal phonation

The first research question asked whether age predicts rate of glottal phonation in the repairs of preconsonantal word-external empty onsets. My results for real words suggest that, by the age of 5 years, children demonstrate adult-like rates of glottal phonation. The results of this study align with Lleó's (2016) findings showing that two Spanish-speaking children produced resyllabified consonants from the onset of two-word utterances and that glottal phonation is reduced to approximately 0% and 10%[17] for each child at 2:6 years of age.

With respect to the second question asking whether there is a differential effect of consonant across age group, my empirical results did not support a model that included consonant as a moderating variable of rate of glottal phonation. At least from the age of 5, the production of glottal phonation is independent of coda type (i.e., /s/, /n/, /l/). However, type of consonant showed a main effect in the model, indicating that vowel-initial words preceded by /s/ were glottalized more often than vowel-initial words preceded by /n/ or /l/. A lack of interaction due to low power is unlikely because vowel-initial words preceded by /s/ are more often glottalized in the adult SpanMonoS (5.71%), than in the older SpanMonoS (3.80%) and the younger SpanMonoS (2.39%). I turn to Garellek's (2012) study to account for these results. Garellek (2012) found that glottalization was more likely to be realized in content words preceded by a function word than in content words preceded by another content word. He explains these results by arguing that, if there is no clear boundary at the word juncture, function words are more likely to become proclitics on the target words than other content words. In this work, 'dos' (*two*) has the semantic property of being a numeral and provides more semantic meaning in the two-word sequence than the indefinite article 'un' (*an*)[18] or definite article 'el' (*the*). Thus, speakers may be more likely to strengthen the boundary between 'dos' and the subsequent content word to avoid proclitization of the function and content word.

The third research question asked whether syllables bearing primary stress are more sensitive to glottal phonation than syllables not bearing primary stress, and whether this

[17]These percentages are based on Figure 1 is Lleó's (2016, p.199) book chapter.

[18]Although *un* has been commonly believed to be either an indefinite and a numeral, recent theoretical proposals and experimental findings suggest that, in Romance languages, *un* is only an indefinite (Barbiers, 2007; Kayne, 2009; Mateu & Hyams, 2016). For instance, Kayne (2009) argues that, like quantifiers, *un* agrees in gender and number with the noun (e.g., una chica '$a_{[Fem.\ Sg.]}$ girl'), a pattern that is not observed in numerals.

effect interacts with age. My results demonstrate that both real words and novel words are sensitive to primary stress. These findings contribute with cross-linguistic evidence to the relevance of prosodic prominence in promoting vowel-initial glottalization (Bissiri et al., 2011; Garellek, 2014; Pompino-Marschall & Żygis, 2010).

The fourth research question asked whether the lexicon predicts rate of glottal phonation. Based on Bybee's (2001) approach on the usage-based acquisition of external sandhi, frequency of co-occurrence should moderate the rate at which Spanish speakers produce glottal phonation in /C#V/ sequences. If phonology is sensitive to the lexicon, speakers should produce highly frequent with lower rates of glottal phonation than words that are not stored in the lexicon. This prediction is supported by my findings, since they show that novel words are more likely to present glottal phonation than real words. My original hypothesis, nevertheless, did not predict rate of glottal phonation to vary across age periods, because the novel words would be newly encountered by the three groups of speakers. But my findings demonstrate that the younger children produced a lower rate of glottal phonation in the novel words than the adults. This means that lexical frequency cannot be the sole explanation to my findings. Instead, I rely on the concept of *predictability*, a language user's belief of the probability of a word occurring in a certain context (Hall et al., 2018), to argue that the initial syllable of the novel words are more likely to be glottalized by the older children and adults because they recognize the unpredictability of these words in their speech stream. The concept of predictability, as described in Hall et al. (2018), refers to the context-dependent probability of an element X to occur in a situation Y. An important difference between lexical frequency and predictability is that lexical frequency is context-independent (i.e., as much as possible) and simply counts the number of occurrences of X. The speaker may judge this predictability also with respect to the listener. Turnbull (2015) presents a listener-oriented account of predictability, by which speakers guide phonetic effort by considering the listener's needs. Speakers will use the least effort possible in those elements that are deemed easy to be retrieved by the listener, and greater phonetic effort will be employed in those elements that speakers consider that the listener will be less likely to retrieve from the context. I argue, that this step may be one that is still in development between the ages of 5 to 8 years.

Studies have shown that phonetic reduction increases with word predictability (Baker & Bradlow, 2009; Lowe & Altmann, 1989; Galati & Grenan, 2010). Predictable words in natural speech are more likely to be shorter (Bell et al., 2009; Moore-Cantwell, 2013; Pluymaekers et al., 2005) and undergo more assimilation processes (Turnbull et al., 2020), or more phonemic deletion (Turnbull, 2018) than non-predictable words. Low predictability, to the other hand, is associated to phonetic enhancement. Moreover, as suggested in Hall et al. (2018, p.19), initial syllables are a site for enhancement because early segments in a lexical item play the most important role to disambiguation from other words. Crucially, glottalization enhances the prominence of the initial syllable and eases word recognition. For instance, Crowhurst (2018) showed that creak is perceptually salient for Mexican Spanish speakers and that it can be used to segment sequences into foot or word-sized units.

I argue that older children and adults consider novel words to be less predictable and choose to enhance these words' prosodic boundaries to render them more perceptually salient. 5-to-8 year-olds, on the contrary, may not be able to take a listener-oriented perspective to recognize that the novel words are less predictable than the highly frequent real words. Immature theory of mind skills may be at the center of this asymmetry between younger children and children up to the age of 8.[19] Although first order theory of mind skills develop around 4 to 5 years old, it is possible that, between 5 and 8 years old, children are still learning to incorporate theory of mind in their phonology, as it is a process at the pragmatics-phonology interface.

Overall, monolingually raised Spanish speakers produce word-junctures with modal phonation. In addition, since the rates of glottal phonation in the real words do not show a sig-

[19]The link between theory of mind and listeners' oriented predictability in adult phonetic reduction has been proposed in Turnbull (2019).

nificant trend over time, I conclude that Mexican Spanish children by the age of 5 produce adult-like connected speech. Unexpectedly, in the novel words, adults produced a higher rate of glottal phonation than children. I argue that adult phonological grammars are more inclined to increase the perception of psycholinguistically salient positions.

3.7.2 American English: Predictors of glottal phonation

My first research question examined whether age is a significant predictor of rate of glottal phonation. Age did not turn out to predict the rate of glottal phonation in the real words, or to interact with the variables of consonant or stress. These results support previous findings in word-external junctures, pointing to an early development of connected speech (Newton and Wells, 1999, 2003). However, it is noteworthy to comment on the fact that, while the proportion of glottal phonation is similar across groups in words with initial primary stress (younger child = 88.14%, older child = 86.29%, adults = 83.02 %), the rate of glottal phonation in words without initial primary stress shows a moderate decrease between the younger children, and the adults compared to the older children and the adults (younger child = 46.86%, older child = 30.62%, adults = 27.73%). To this respect, it is possible that a larger sample size would have supported a significant interaction.

My second research question asked whether consonant type shows different rates of glottal phonation across ages. I did not find an interaction was found between age and consonant, which indicates that adult-like production of glottal phonation is likely to be independent of consonant type (i.e., late-acquired or early-acquired consonants). However the interaction between age and consonant being insignificant, my results demonstrate that /l/ and /s/ are produced with a greater rate of glottal phonation than the consonant /n/. As in the case of Spanish, it is possible that the low rates of glottal phonation in /n/ could be attributed to the specific function word used in the experiment (i.e., 'an'). Unlike 'all' and 'this', 'an' has the semantic property of being indefinite or non-specific, and thus, less salient in the grammar than the demonstrative ('this') or the quantifier ('all'). Following an account in which speakers may strengthen the boundary between a function word and a content word to avoid proclitization (Garellek, 2012), the semantic content of the function words ‘all’ and ‘this’ may increase the likeliness of speakers’ inclination to avoid proclitic structures.

With regard to the effect of the lexicon, when examining only the novel words, the younger and older children presented significantly higher rates of glottal phonation than the adults. When comparing the novel words to the subset of real words elicited with /l/, only the older children showed a significant difference between the real and the novel words. In other words, the younger children presented an equally higher rate of glottal phonation for the real words (M = 74.26%) than for the novel words (M = 81.20%), the older children showed a higher rate of glottal phonation in novel words (M = 88.70%) than in real words (M = 60.79%), and the adults demonstrated as lower rates of glottal phonation in the real words (M = 64.51%) as in the novel words (M = 66.09%).

These findings indicate that the effect of the lexicon is greater in the older children than in the younger children and the adults. That is, there is probably an initial stage in the grammar in which children produce overall high rates of glottal phonation. Then, as children gain exposure to two-word sequences, they update their grammars and increase the penalties for low-frequency candidates with glottal phonation. At this point, during late childhood, words that are stored in the lexicon are more likely to be evaluated with the updated grammar than newly encountered words. This could be a result of an increase in the robustness of the lexicon or a reorganization of the lexicon promoted by new knowledge. In fact, Storkel (2002) found that children restructure their representation of words in the lexicon as they add new knowledge. Phonologically, it is possible that the degree of activation of the lexicon during input evaluation increases between the younger children and the older children. The more active the lexicon is during input evaluation, the more likely it is that real words are evaluated with a newly updated grammar.

From 8 to 11 years, children evaluate the real words with the new grammar, and the novel words with a grammar that still favors glottal stop epenthesis. Under this account, the new grammar could consist of lexically indexed constraints, for the words stored in the lexicon, and general constraints, for the new words. The general constraints would be updated more slowly, but, by adulthood, newly encountered words would be evaluated with similar constraint weights to those that evaluate real words.

This scenario would be more strongly supported by the data, if the complete set of real words demonstrated an effect of age. It is possible that updates in the grammar are not a uniform process during childhood, and that they are rather correlated with vocabulary growth (Beckman et al., 2007). That is, it is likely that some children by the age of 6 already evaluate the tested real words with a grammar that assigns greater penalties to glottal stop epenthesis. In future studies, a post-test on word familiarity would help to determine whether knowing a word decreases the chances of repairing empty onsets with glottal phonation. To this respect, my study underlines the importance of using novel words to understand phonological patterns during language acquisition, because children's varying rates of vocabulary knowledge could mask the effects of those phonological processes that are not completely independent of the lexicon.

With respect to the research question asking whether prosodic prominence affects rate of glottal phonation in preconsonantal empty onsets, the results of this study demonstrate that, both in real words and novel words, primary stress in the initial syllable predicts rate of glottal phonation. These results were expected and contribute to the existing literature showing that glottal phonation is mediated by prosodic prominence (i.e., stress and/or pitch accents) (Dilley et al., 1996; Garellek, 2012; Pierrehumbert, 1995; Redi & Shattuck-Hufnagel, 2001). However, one should be cautious to conclude that primary stress is the only contributor to rate of glottal phonation in my data. The two-word sequences in my experimental data composed an intonational phrase in which a nuclear accent was likely to be produced on the content word. Thus, the content words with initial primary stress were also targets of a pitch accent. Thus, those words had an added layer of prosodic prominence that could have impacted on the rate of glottal phonation. Moreover, the type of pitch accent could also have a differential effect on such rate. Pierrehumbert & Frisch (1994) noted that low targets (i.e., L* or L*+H pitch accents) may be more conducive to glottalization. For this reason, further exploration of my data will include pitch accent coding and future research should elicit data in pitch accented and unaccented positions to isolate the role of primary stress in preconsonantal vowel-initial words.

Now I want to turn to the possibility of secondary stress affecting glottal phonation, as the item *avocado* in the set of real words in the condition of non-initial primary stress bears secondary stress in the initial position. Table 3.6 shows that glottal phonation was produced before *avocado* 28.58% more frequently than in the other three items in the same condition, and 30.77% less frequently than before the item of the initial primary stress condition. This suggests that syllables with initial secondary stress may be more likely to present glottal phonation than unstressed syllables (i.e., iguana [ɪ.ˈgwa.nə]). In turn, the difference between the words with primary stress and *avocado* could be explained by the stronger prominence granted by primary stress when compared to secondary stress.

Item	N	%	SE	CI
aquárium	175	21.71	3.12	6.17
àvocádo	176	55.68	3.75	7.41
iguána	173	29.48	3.75	6.86
umbrélla	176	30.11	3.47	6.84
ísland	171	86.55	2.62	5.16
óctopus	162	83.33	2.94	5.80
ónion	174	86.78	2.57	5.08
ólive	157	89.17	2.49	4.91

Table 3.6: Rate of glottal phonation per item in English real words

3.7.3 Comparing English to Spanish

The fifth research question in this study asks whether American English monolingual speakers glottalize to a greater extent than Mexican Spanish speakers in Mexico. For experiment 1, EngMonoS demonstrate a preference for resolving empty onsets with /ʔ/-epenthesis over modal phonation in words with initial primary stress in the three groups of speakers (younger child EngMonoS M = 88.14%, older child EngMonoS M = 86.29%, and adult EngMonoS M = 83.21%). In the words without initial stress, the preference of glottal phonation over modal phonation is still observed in the child EngMonoS (younger child EngMonoS M = 71.21%, older child EngMonoS M = 85.55%), but adults show approximately equal probabilities of producing glottal or modal phonation (M = 50.55%).

The same preference for glottal phonation is not observed in the grammars of the Mexican Spanish speakers. In vowel-initial words bearing initial primary stress, Spanish speakers prefer to resolve empty onset with modal phonation than with glottal phonation (younger child SpanMonoS M = 1.69%, older child SpanMonoS M = 2.67%, and adult SpanMonoS M = 4.19%). In the words without initial stress, the preferred repair strategy is modal phonation over glottal phonation for both language groups (English: younger child EngMonoS M = 46.86%, older child EngMonoS M = 30.62%, and adult EngMonoS M = 27.73%, and Spanish: younger child SpanMonoS M = 1.45%, older child SpanMonoS M = 0.70%, and adult SpanMonoS M = 0.72%). However, notice that, in all age groups, the rate of glottal phonation is significantly lower in Spanish than in English.

For Experiment 2 (novel words), American English speakers prefer to use glottal phonation over modal phonation in words with initial primary stress (younger child EngMonoS M = 92.31%, older child EngMonoS M = 97.67%, and adult EngMonoS M = 83.13%) and words without initial primary stress younger child EngMonoS M = 71.21%, older child EngMonoS M = 85.55%, and adult EngMonoS M = 50.55%). In the Mexican Spanish grammars, the same preference is not observed for the words with initial primary stress (younger child SpanMonoS M = 12.33%, older child SpanMonoS M = 27.71%, and adult SpanMonoS M = 34.21%), or for the words without initial primary stress (younger child SpanMonoS M = 10.34%, older child SpanMonoS M = 19.54%, and adult SpanMonoS M = 22.22%).

To sum up, when comparing the Mexican Spanish and American English /C#V/ productions, the findings for the two experiments demonstrate that /ʔ/-epenthesis is the preferred repair strategy when resolving empty onsets in prominent positions. Moreover, American English monolingual speakers also demonstrate this preference for unstressed initial syllables when evaluating novel words. In Spanish, despite the increase in the use of glottal phonation in words with initial primary stress and in novel words, the overall preference in the grammar is to resolve empty onsets using modal phonation. The asymmetry between the two languages can be explained from a prominence-based account of glottalization. Garellek (2014, p.112) claims that, in such an account, frequent word-initial glottalization would be found in languages in which prominence has an important role, and we can consider that the role of prosodic prominence is more relevant in English than in Spanish. For instance, pitch accents are more important in English than in Spanish in the expression of focus; as the former has nuclear stress flexibility and the latter has nuclear stress rigidity (Zubizarreta, 1998). Hence, my results align with the expected cross-linguistic patterns predicted by a prominence-based account of glottal phonation, in that glottal phonation is preferred over modal phonation in English, but not in Spanish.

3.8 Conclusion

In this chapter, I have experimentally examined the rate of glottal phonation in /C#V/ sequences as a proxy for the frequency of /ʔ/- epenthesis emerging as a repair of word-external empty onsets in Mexican Spanish and American English grammars. The purpose of this chapter was to better understand the development of non-heritage grammars so that they can serve as baselines of comparison for the heritage grammars.

In regard to language development, the findings for the real words in this study for Spanish and English did not show significant differences between the younger children, older children or adults, neither in Spanish nor in English, suggesting a complete acquisition of repairs of empty onsets by the age of testing (around 5 years of age). The results for the novel words, however, presented a more complex scenario. Contrary to my prediction, adult Mexican Spanish speakers and older children demonstrated higher rates of glottal phonation (adult SpanMonoS = M = 28.38%, older child SpanMonoS M = 23.52%) than younger child SpanMonoS (M = 11.45%). I argue that older child SpanMonoS and adult SpanMonoS are more likely to be sensitive to the unpredictability of the novel words. In this situation, older child SpanMonoS and adult SpanMonoS may use glottal phonation to increase the perceptability of the target novel word. The English results showed that the younger children produce a similar high rate of glottal phonation in the real and the novel words, the older children demonstrate a higher rate of glottal phonation in the novel words than in the real words, and adult present an equally low rate of glottal phonation for the real and the novel words. I have discussed the possibility of an acquisition path by which novel words are evaluated with constraints that update more slowly than those that evaluate real words, suggesting a grammar with lexically specific constraints. The weights for the lexically specific constraints and the general constraints would be maximally separated during late childhood, resulting in a significant difference between the rate of glottal phonation in real and novel words.

My findings also contribute to the growing body of literature showing the effect of prosodic prominence on word-initial glottalization (Dilley et al., 1996; Garellek, 2014; Pierrehumbert, 1995). Moreover, American English speakers prefer glottal phonation to modal phonation in prosodically prominent initial syllables (rate of glottal phonation in real words = 85.75%, rate of glottal phonation in novel words = 91.02%), whereas Spanish speakers favor modal phonation over glottal phonation in both stressed and unstressed syllables (rate of glottal phonation in real words = 7.01%, rate of glottal phonation in novel words = 21.48%). In light of these findings, I predict that, if transfer from the majority to the heritage language occurs, Spanish heritage speakers will produce higher rates of glottal phonation in stressed syllables in Spanish than their Spanish monolingual peers. If, instead, transfer from the heritage to the majority language arises, I predict that Spanish heritage speakers will produce lower rates of glottal phonation in English than their English monolingual peers.

CHAPTER 4

Modeling repairs of empty onsets in the grammars of monolingually raised Spanish and English speakers

4.1 Introduction

In this chapter, I use constraint-weighted grammars to fit my experimental data, with the aim of exploring the development of constraint-weights as the grammars of monolingually raised Spanish and English speakers mature. I take previous analyses of resyllabification (Colina, 1997; Lipski, 1999) and vowel-initial glottalization in connected speech phenomena (Alber, 2001; Davidson & Erker, 2014) as a departing point for my models. In my analysis, I consider three strategies to resolve empty onsets: syllabic misalignment (i.e., resyllabification in Spanish or ambisyllabicity in English), maintenance of the empty onset (i.e., consonant in the coda position), glottal stop epenthesis (i.e., /ʔ/-epenthesis). Moreover, I account for the role of primary stress in increasing the probabilities of empty onsets to be repaired with /ʔ/-epenthesis.

4.2 Fitting repairs of empty onsets with MaxEnt grammars

The phonological models were fitted using a Maximum Entropy Grammar (MaxEnt)(Goldwater & Johnson, 2003; Hayes & Wilson, 2008; Wilson & Hayes, 2008). MaxEnt operates under a constraint-based approach. That is, a set of constraints in the grammar evaluates output candidates. Distinctly from strictly-ranked OT accounts (Prince & Smolensky, 1993, 2004), in which constraints are ranked and allow a single winner for each input, constraints in MaxEnt grammars are numerically weighted and assign non-zero probabilities to all the possible candidates. That is, each output candidate has some probability to surface in the grammar. The value of the constraint weight is relative to the other constraints in the grammar. The higher the constraint weight, the more the probability of a candidate violating that constraint is lowered. Therefore, MaxEnt predicts output variation.

Probability distributions for each input are established as a function of the constraint violation profile and the constraint weights. First, each candidate is assigned a harmony score, which is the sum of the weighted constraint violations.

$$h(x) = \sum_{i=1}^{N} w_i C_i(x)$$

where,

- w_i is the weight of the i constraint
- $C_i(x)$ is the number of times x violates the ith constraint

Then, the MaxEnt value is calculated by negating the harmony score and raising e to the result.

$$P^*(x) = exp(-h(x))$$

Finally, the resulting value $P^*(x)$ is divided by the sum of all the candidates' previously exponentiated harmony values (Z). The result is a probability distribution summing to 1.

$$P(x) = P^*(x)/Z$$

In order to find the corresponding weight for each constraint, MaxEnt grammars use an objective function that minimizes the distance between the training data (observed data) and the predicted data. In this study, I fitted the grammar with the Solver function in Excel with a weak regularization term ($\mu = 0$, $\sigma = 1000$).

4.2.1 Candidates and the constraint set

Structural repairs of /C#V/ sequences are motivated in the grammar with the markedness constraint ONSET, which forbids initial syllables surfacing faithfully without onsets (candidate a in Tableau 4.1 and candidate a in Tableau 4.2).

5. ONSET σ_{Initial}: Initial syllables must have onsets.

I consider that ONSET can be satisfied with either a candidate showing misalignment in the syllabic structure, or a candidate surfacing with segmental epenthesis (i.e.,/ʔ/- epenthesis). Recall that, in the current study, we consider glottal phonation (i.e., full glottal stop, creaky phonation) as /ʔ/- epenthesis. As for the misalignments in the syllabic structure, Spanish and English are assumed to behave differently. In Spanish, the word-final consonant gains complete affiliation with the following syllable (i.e., complete resyllabification) (Colina, 1997; Harris, 1983; Hualde & Prieto, 2014) (candidate b in Tableau 4.1). In English, the coda consonant is believed to be linked both with the coda and the onset positions (i.e., ambisyllabicity) (Gussenhoven, 1986; Hayes, 2009; Kahn, 1976; Rubach, 1996) (candidate b in Tableau 4.2).

In order to propose parallel analyses for English and Spanish, I formalize the misalignment in the syllabic structure with an alignment constraint demanding sharp coincidence between the right edge of the stem and the right edge of the syllable (i.e., ALIGN-RIGHT [Stem, R, σ, R]).[1] Sharp coincidence is violated when the stem-final segment of the syllables is also parsed by another syllable (McCarthy & Prince, 1993, p.53).[2]

[1]Colina's (1997) seminal analyses proposed that resyllabified consonants violate an ALIGN-L(stem, σ). However, in this analysis, ALIGN-L(stem, σ) would also be violated by candidate c, as segmental material intervenes between the left edge of the stem and the left edge of the syllable. In this case, candidate c would be harmonically bounded by candidate b. To avoid harmonic bounding, I posit an activeALIGN-R(stem, σ) in the grammar.

[2]The right edge of the stem of the first prosodic word is marked using a vertical line.

6. Align-Right (Stem, R, σ, R):The right edge of every stem sharply coincides with the right edge of some syllable.

The constraint Onset can also be satisfied with segmental epenthesis. More specifically, the unfaithful candidates c in Tableaux 4.1 and 4.2 surface with glottal phonation at the word-juncture preceding the word-initial vowel. These candidates violate a Dep -ʔ constraint, which is formalized as requiring glottal stops in the output to have a correspondent in the input.

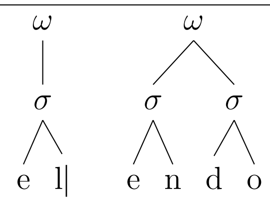
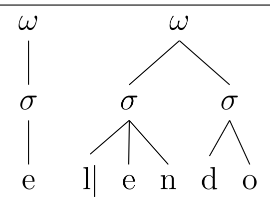
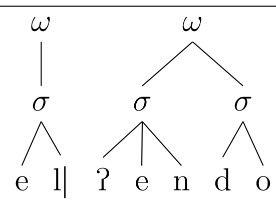
/ el endo/	Onset/σ_{Initial}	Align -R	Dep-ʔ
a. 	1		
b. 		1	
c. 			1

Table 4.1: Basic Tableau for *el endo* in Spanish

4.2.2 Stress-driven glottal stop epenthesis

My statistical results add to previous literature showing that prosodic prominence modulates the emergence of /ʔ/- epenthesis in /C#V/ sequences (Dilley et al., 1996; Fuchs, 2015; Garellek, 2014, among others), putting forth the need for prominence-driven constraints to

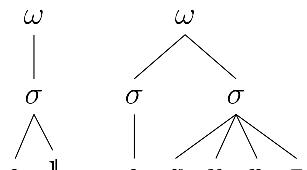
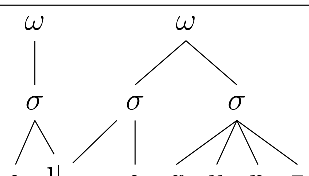
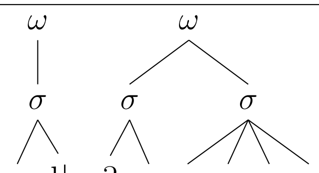
/ɔɬəˈgunz/	ONSET/σ_{Initial}	ALIGN -R	DEP-ʔ
a.  ɔ ɬ| ə g u n z	1		
b.  ɔ l| ə g u n z		1	
c.  ɔ ɬ| ʔ ə g u n z			1

Table 4.2: Basic Tableau for *all egoons* in English

model the stress-based asymmetry found in the data. The effects of prosodic prominence in the onsetless syllables can be formalized as a case of phonological augmentation, as proposed in Smith's (2005) theory of specific markedness constraints for strong positions (**M/str** or augmentation constraints). **M/str** license characteristics that enhance the perceptual salience of phonetically or psycholinguistically salient positions (i.e., prominence condition). Specifically for onsets, Smith (2005) proposes an ONSET/ˈσ constraint specific to stressed syllables and subhierarchy of onset constraints (i.e., *ONSET/X) that require syllable onsets to be low in sonority. *ONSET/X is justified by the fact that low-sonority elements between vowels enhance the perceptibility of the syllable nuclei.

7. ONSET/ˈσ Initial: Stressed initial syllables must have an ONSET.

8. *ONSET/X: For every segment a that is the leftmost pre-moraic segment of some syllable x, $|a| < X$

where | y | is the sonority of segment y X is a particular step on the segmental sonority scale (Smith, 2005)

9. The *ONSET/X hierarchy (Smith, 2005)

   *ONSET/LOWV >> *ONSET/MIDV >> *ONSET/GLI >> *ONSET/RHO >> *ONSET/LAT >> *ONSET/NAS >> *ONSET/D >> *ONSET/T

In the analysis of word-external resyllabification/ambisyllabicity, the *ONSET/X hierarchy bans segments in the onset that are higher in sonority than glottal stops, arguably the least sonorous segments as they present the least marked place of articulation (Lombardi, 2002).[3] Crucially, *ONSET/X is specified in the domain of a stress initial syllable.

10. [*ONSET/LAT]/ˈ$\sigma_{\text{In.}}$: For every segment a that is the leftmost pre-moraic segment of some initial stressed syllable x, | a| < Lateral

As shown in the tableaux 4.3 and 4.4, candidates a violate ONSET/ˈσ_{Initial}, as they surface with an onsetless stressed syllable. Candidates b violate *ONSET/LAT for presenting an onset with a segment that is not the lowest in the sonority scale.

An important note on this analysis is that it captures the perceptual saliency of prosodically prominent positions, but it does not formalize a potential constraint blocking misalignments in the syllabic structure in stressed syllables. Although the effects of phonological enhancement and dispreference of syllabic misalignments in stressed syllables are conflated in this study, evidence for the latter has can be found in isolation. For instance, in an articulatory study on Korean, Cho et al. (2014) examined the articulation of across IP boundaries and across prosodic word boundaries consonant-to-vowel sequences in Korean (e.g., /[im]_IP[a]_IP/ and /im#a/), and found that the former showed less CV overlap than the latter, indicating that prosodic boundaries can block the temporal reorganization of

[3]In initial stressed syllables with an onset, IDENT-C constraints preserve the identity of the consonant.

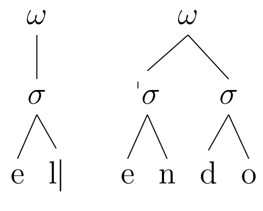
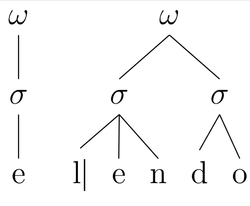
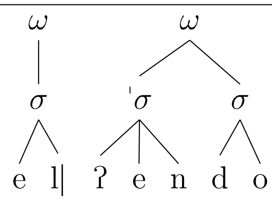
/el endo/	ONSET/σ_{Initial}	ALIGN -R	DEP-ʔ	ONSET/ˈσ	[*ONSET/LAT]/ˈ$\sigma_{\text{In.}}$
a. 	1			1	
b. 		1			1
c. 			1		

Table 4.3: Tableau for *el endo* in Spanish with phonological augmentation constraints

/C#V/ sequences. In such cases, an articulatory-based analysis could rely on a constraint banning temporal restructuring of C#V in strong positions.

Nevertheless, a strength of the current analysis is that it can be extended to account for glottal stop epenthesis in instances of hiatus resolution in which glides (Davidson & Erker, 2014) or intrusive /r/ Mompean2011Hiatus/r/-liaison are less likely to appear in front of stressed syllables. Glides in stressed positions would be prevented by [*ONSET/GLI]//ˈ$\sigma_{\text{In.}}$ and rhotic intrusion in stressed positions would be prevented by [*ONSET/RHO]//ˈ$\sigma_{\text{In.}}$, both universally ranked above [*ONSET/ʔ]//ˈ$\sigma_{\text{In.}}$[4]

[4]Davidson and Erker (2014) discuss the possibility of including a universally ranked *glide >> *ʔ, but opt for using a *MULTILINK constraint in order to account for homorganic glide insertion in Japanese, Czech, or Polish. In the current analysis, however, a prosodically-sensitive *MULTILINK would not prevent the resyllabified consonants in Spanish from surfacing in the output.

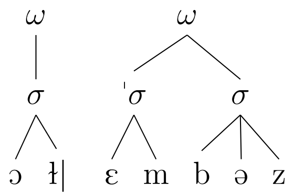
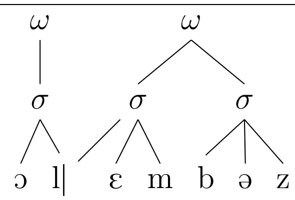
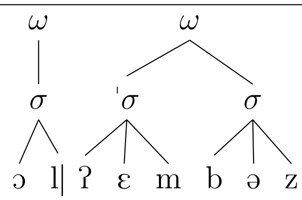
/ ɔɫˈɛmbəz/	ONSET/σ_{Initial}	ALIGN -R	DEP-ʔ	ONSET/ˈσ	[*ONSET/LAT]/ˈ$\sigma_{\text{In.}}$
a. 	1			1	
b. 		1			1
c. 			1		

Table 4.4: Tableau for *all embos* in English with phonological augmentation constraints

4.2.3 Candidates' probabilities

The models were created with the aggregated results of the novel words in Spanish and English (Experiments 2a and 2b). Recall that the lateral /l/ in the novel words was elicited in the conditions of /V#l/, /l#C/ and /l#V/, allowing for comparisons between the distributions. For Spanish, the duration of /l#V/ tokens is expected to fall within that of /V#l/, as laterals in /l#V/ acquire the canonical onset position. For English, the degree of darkness in laterals produced in /l#V/ position is expected to be different from that of laterals in /l#C/ position, as ambisyllabic laterals are predicted to be less dark than coda laterals (Hayes, 2009).[5]

[5]In this section of the study, the novel words were not used to determine the candidates' probabilities of the real words, because the number of syllables in the real words was not comparable to that of the novel words. In addition, novel words may have been produced more accurately, which could have result in slower speech rates in the novel words when compared to the real words.

The probabilities for the candidates with /ʔ/- epenthesis were extracted from the annotated data in experiments, which included the tokens with creaky phonation in the target /C#V/ sequence and the tokens with full glottal stop. The probabilities for the candidates in which the /l/ emerges as a coda or as resyllabified or ambisyllabic were estimated from the phonetic data gathered in this study. The process of labeling these candidates is explained in the following two subsections.

4.2.3.1 Resyllabified and coda candidates in Spanish

In Spanish, the tokens produced with modal phonation were further divided into coda candidates or resyllabified candidates using the duration of the target consonant.

Phonetics studies determining the status of resyllabified consonants have assumed that, if a consonant is resyllabified, it will absorb the phonetic properties of its new syllabic position (Hualde & Prieto, 2014; Strycharczuk & Kohlberger, 2016). Results for /s/ duration, for instance, have shown that, while the resyllabified consonant does not completely pattern with canonical onsets, it is significantly longer than coda consonants (Hualde & Prieto, 2014; Strycharczuk & Kohlberger, 2016). The durational properties of /l/ in /l#V/ position have been less explored. However, in a reading task, Repiso-Puigdelliura (2021a) showed that /l/ in /l#V/ positions (i.e., *mil hijos* ‘thousand sons’) patterns durationally with /l/ in /V#l/ positions (i.e., *mi lima* ‘my lime’), and the laterals in /l#V/ and /V#l/ sequences the laterals in /l#C/ position (i.e., *mil tigres* ‘thousand tigers’).

4.2.3.2 Segmentation of Spanish novel words

Speech was automatically segmented using Montreal Forced Aligner (McAuliffe et al., 2017). The boundaries of each lateral were manually corrected in Praat (Boersma & Weenink, 2020) by the principal investigator. The lateral was defined as a steady period of the F2 trajectory, with weak energy between the F3 and F5 region (Kirkham et al., 2019; Nance, 2014). Additionally, intensity displays were also used to segment the lateral. The target lateral was segmented in the sequences /V#l/, /l#V/ and /l#C/.

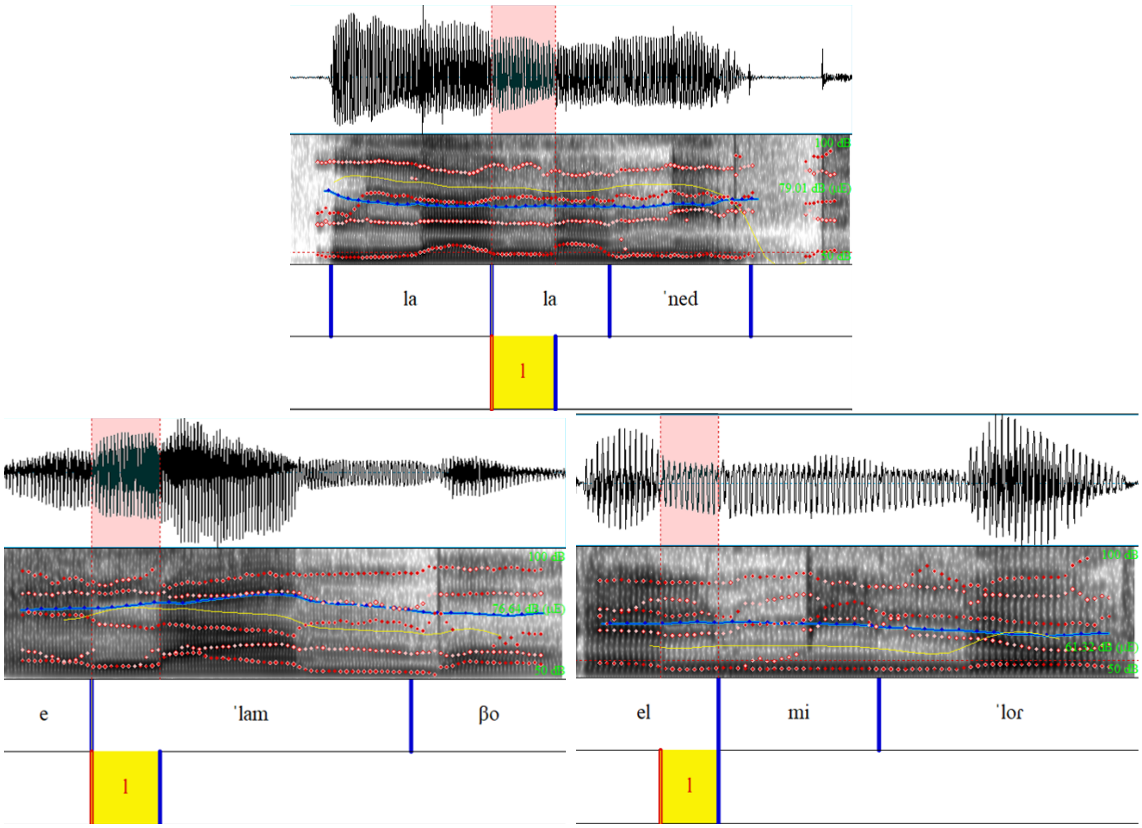


Figure 4.1: Segmentation of /l/ in /V#l/ position ‘la laned’ (top), in /l#V/ position ‘el anbo’ (left) and in /l#C/ position ‘el milor’ (right) in Spanish

The onset of the lateral was marked at the onset of amplitude drop in the waveform and at the onset of a decrease in intensity of F2 when compared to the preceding vowel. The offset of the lateral /l#V/ and /V#l/ positions was marked at a noticeable increase in amplitude of the waveform and intensity in F2 (Amengual, 2018) (see Figure 4.1 for Spanish). For /l#C/ position laterals, the offset of [l] was segmented at the onset of further formant weakening for stops and presence of anti-resonances for nasals.

4.2.3.3 Token labeling for resyllabified and coda candidates

To label the tokens, I first created two distributions with the durational data of the /V#l/ tokens (i.e., l̲amba) and the /l#C/ tokens (i.e., el̲ mingo). The two distributions were further divided into two equal-sample distributions of consonants produced by children (N = 286 for each distribution) and consonants produced by adults (N = 143 for each distribution). To maintain the same number of observations in each distribution, outliers were treated by replacing the values situated above the upper boundary and below the lower boundary of the interquartile range with the mean. Figure 4.2 shows density plots of the duration of /V#l/ and /l#C/ in ms for each group. Then, two one-samples t-test were conducted for each token produced with modal phonation in /l#V/ position (i.e., one for each distribution) in order to obtain two t-statistics for each token. The resulting t-statistics were compared, and each token was assigned to the distribution for which the t-statistic was closer to 0.

Table 4.5 shows that percentages of the tokens classified as resyllabified candidates, coda candidates, and candidates with glottal phonation (i.e., labeled based on existence of glottal phonation).

	[e.len.do]	**[el.en.do]**	**[el.ʔen.do]**
Younger children	58.77%	29.77%	11.43%
Older children	27.97%	49.40%	22.79%
Adults	29.09%	42.57%	28.08%

Table 4.5: Percentage of tokens classified as canonical onsets, codas and /ʔ/-epenthesis in the groups of monolingually raised Spanish speakers

4.2.3.4 Ambisyllabic and coda candidates in English

In English, the tokens produced with modal phonation were divided into coda consonants and ambisyllabic consonants. In the case of English, I relied on degree of consonant darkness

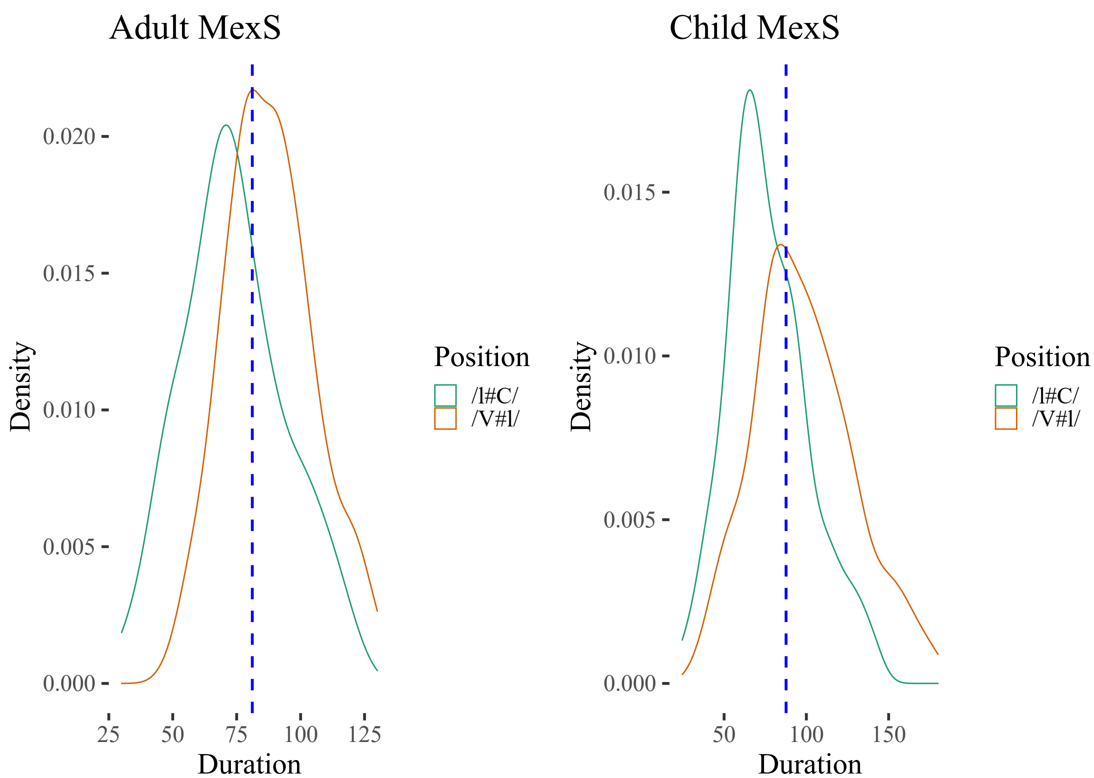


Figure 4.2: Density plots of target consonant duration in /V#l/ and /l#C/ position for the child and adult SpanMonoS

to categorize the /C#V/ tokens in each of the two bins. Whereas /l/ in coda position is produced as a dark lateral with relatively low F2 and high F1 (i.e., [ɫ], Bi[ɫ]), it is realized as a light lateral in onset position with relatively high F2 and low F1 (i.e., [l], [l]ips). From an articulatory perspective, the /l/ is produced with two gestural events: a primary oral constriction gesture or a consonantal gesture (i.e., apical gesture) and a secondary constriction or a vocalic gesture (e.g., vocalic dorsal gesture for [l]). Sproat and Fujimura (1993) explained the distribution of the dark and light realizations of the lateral as a function of a preference of these two gestures to be either close to the syllabic nucleus or at the margin of the syllable. In particular, vocalic gestures prefer to be closer to the syllabic nucleus and consonantal gestures have a tendency to be at the margins of the syllable. In onset position, hence, the primary constriction gesture precedes or is produced near- synchronously with the secondary constriction gesture, while in coda position, the two gestures are triggered sequentially with the secondary gesture preceding the principal gesture.

In ambisyllabic position, it has been argued that laterals are produced with a lighter realization, as they absorb some acoustic properties of the onset position Hayes (2009) and Rubach (1996). Articulatory studies have found that the tongue tip gesture in laterals produced in prevocalic position /l#V/ shows onset-like properties (Gick, 2003; Scobbie & Pouplier, 2010). For instance, Gick (2003) found that spatial magnitude of the tongue tip gesture showed a tendency to resyllabify (i.e., similar values for *hall otter* and *ha lotter*), whereas the tongue dorsum showed no such tendency.

4.2.3.5 Segmentation and formant extraction of English novel words

With regard to segmentation, as shown in Figure 4.3, the onset of the lateral was marked at the onset of amplitude drop in the waveform. The offset of the lateral before a vowel was segmented when an increase in the amplitude of the waveform was observed. In preconsonantal condition, the offset of [l] was segmented at the onset of presence of anti-resonances for nasals. Tokens in which no intensity drop was observed in the spectrogram between the preceding vowel and the lateral consonant were hand-annotated as vocalized and were not further segmented.

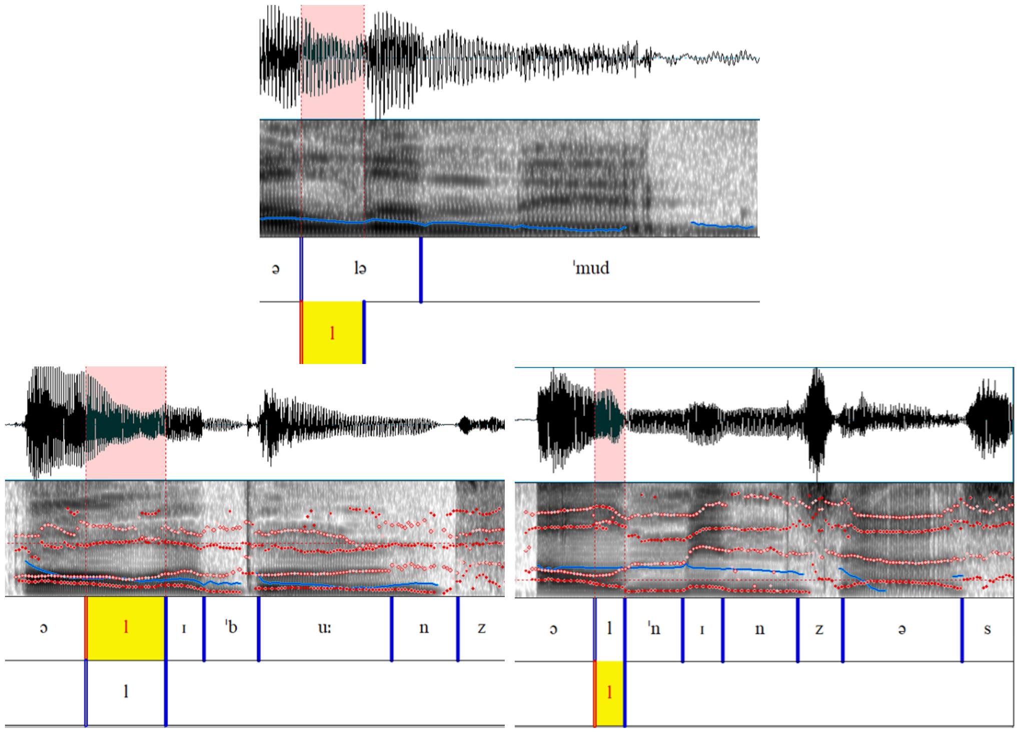


Figure 4.3: Segmentation of /l/ in /V#l/ position ‘a lemood’ (top), /l#V/ ‘all iboons’ (left) and /l#C/ ‘all ninzos’ (right) in English

Following Simonet (2010), I measured the degree of darkness using the F2-F1 distance in Bark units. F2 and F1 values were extracted at the midpoint of the annotated segments using McCloy (2011) script for Praat. The maximum formant set to 5000 Hz for males, 5500 Hz for females and 5500 Hz for children, and the number of formants was set to 5 for all the speakers. The formant values were transformed to Bark units using the *bark* function from the *emuR* (Winkelmann et al., 2021) package in R. Since lateral articulation has been shown to continue to develop between the ages of 3 and 7;11 (Lin & Demuth, 2015), I split the data into the tokens produced by children (N = 1701) and the tokens produced by adults (N = 939) to ensure comparability of the results. First, to explore whether the two groups show different F1-F2 patterns by syllabic position, I ran a linear mixed effects model for each group with position as an independent variable and allowing the intercept for each content word to vary. The models demonstrated that the group of adults and the group of children produced darker laterals in /l#C/ than in /V#l/ (adults $\beta = 1.83$, $t = 10.71$, $p < 0.001$, children = ($\beta = 1.93$, $t = 11.22$, $p < 0.001$)). These findings confirm that F2-F1 values can be used as a correlate for syllabic position, as the two groups distinguish between at least coda position and onset position. When compared to laterals in /l#C/, only the group of adults showed lighter laterals in /l#V/ (β = -0.38, t = -2.24, p = 0.03).

4.2.3.6 Token labeling for ambisyllabic and coda candidates

Since the prediction for the /l#V/ tokens is that their F2-F1 values will be higher than those of /l#C/, but also lower than those of /V#l/, I could not assume that the ambisyllabic /l#V/ tokens would be drawn from the /V#l/ distribution, as it was the case for the Spanish resyllabified candidates. Instead, I created two clusters using the scaled /l#C/ and /l#V/ F2-F1 distributions to determine the probabilities that a /l#V/ token would in the cluster with lower values of F2-F1 (coda-like) or the cluster with higher values of F2-F1 (ambisyllabic-like). More specifically, I used fuzzy clustering with the R package *cluster* to soft label the tokens. The model provides posterior probabilities of each token belonging to one of the clusters. Fuzzy clustering was run for each group on the /l#C/ and /l#V/ tokens specifying two clusters using the R package *ppclust*(Zeynel Cebeci et al., 2017).

For each group, the cluster with the lowest mean (adult EngMonoS M = -2.86, child EngMonoS M = -0.48) was considered to be coda-like and the cluster with the highest mean (adult M = 0.78, children M = 1.70) was considered to be ambisyllabic-like (Figure 6.2 shows the clusters for each group). The ambisyllabic tokens were assigned to the cluster for which they demonstrated higher probability. Table 4.6 shows that /l#V/ tokens were more likely to fall within the ambisyllabic-like cluster in the adult EngMonoS than in the child EngMonoS, which resulted in 39 tokens labeled as ambisyllabic and 20 as coda in the adult EngMonoS, and 18 tokens labeled as ambisyllabic and 28 as coda in the child EngMonoS. Recall that the overall number of tokens is due to the fact that the majority of /l#V/ productions were classified as containing glottal phonation.

F2-F1 in Bark	Cluster 1 M = 3.04	Cluster 2 M = 5.21	Cluster 3 M = 7.82
/V#l/	119 (14.2%)	555 (58.8%)	290 (79.5%)
/l#V/	136 (16.2%)	114 (12.1%)	26 (7.12%)
/l#C/	584 (69.6%)	275 (29.1%)	49 (13.4%)

Table 4.7: Means and number of tokens per cluster

Adult EngMonoS	M prob. coda-like cluster	M prob. ambisyllabic-like cluster	Fuzzy sil. index
/l#V/	0.37	0.62	0.73
/l#C/	0.62	0.38	
Child EngMonoS			
/l#V/	0.40	0.59	0.79
/l#C/	0.59	0.41	

Table 4.6: Mean probabilities for the tokens in each distribution to fall within each one of the clusters and fuzzy silhouette indices (scores from -1 to 1 to evaluate goodness of the clustering technique, a score of 1 denotes that the data point is very compact within the cluster and is far away from the other clusters)

4.3 Grammars of monolingually raised Spanish speakers

Three MaxEnt grammars were fitted using Excel Solver with the aggregated probabilities from the experimental design. As a recap, phonetic data were used to first classify the tokens into candidates with glottal phonation and candidates with modal phonation. The tokens containing modal phonation were further divided into coda candidates and resyllabified candidates using durational data. The MaxEnt grammars were fitted with weak priors

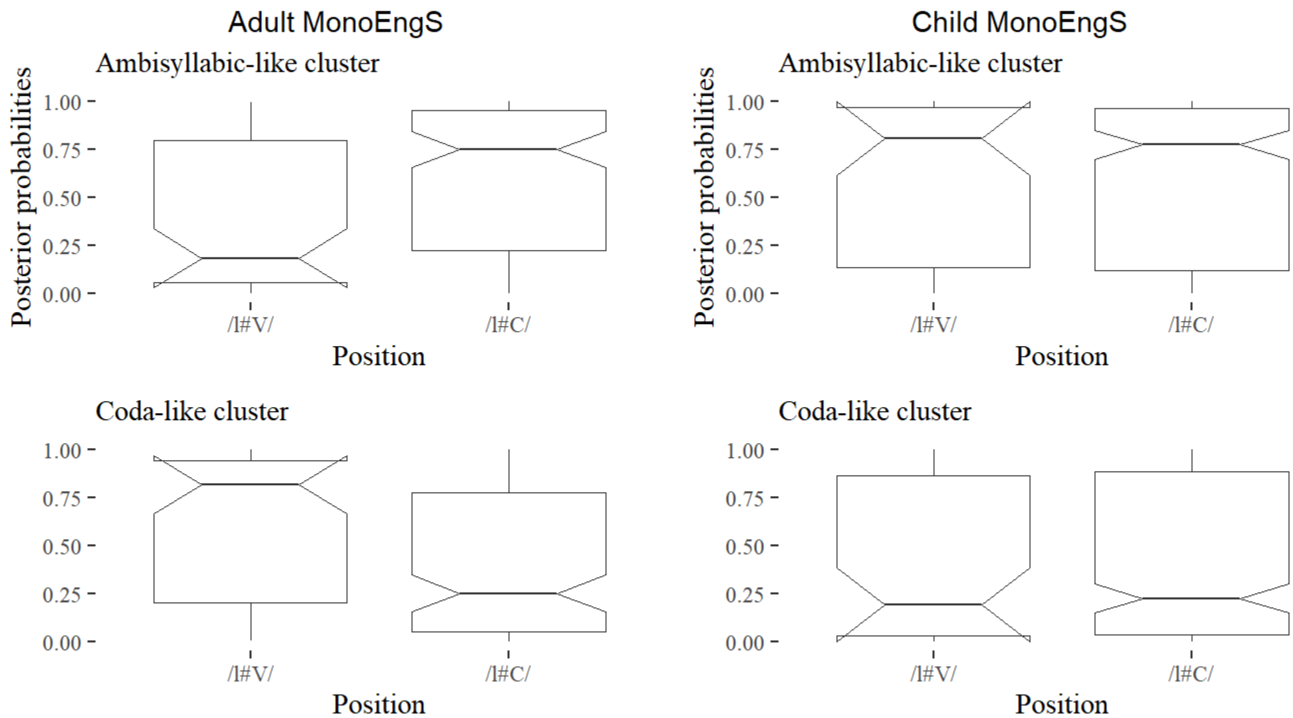


Figure 4.4: Posterior probabilities of fuzzy clusters (ambisyllabic-like and coda-like clusters) per group

(μ of 0 and a σ of 1000) using the Excel Solver function (KL younger children = 0.10; KL older children = 0.09; KL adults = 0.08). The resulting probabilities for each candidate are shown in Figure 4.5. The general patterns in the grammar are an increasing rate of /ʔ/-epenthesis as grammars mature, along with an increasing rate of codas and a decreasing rate of resyllabified consonants. In the next sections, I examine these patterns in depth.

Table 4.8 shows the weight of each constraint.

4.3.0.1 Glottal stop epenthesis in monolingually raised Spanish speakers

In this section, I examine the relationship between Dep-ʔ, the constraint penalizing /ʔ/-insertion, and the rest of the grammar. To do so, I subtracted the weight of Dep-ʔ to the sum of the rest of the constraints in the grammar (i.e., $\sum_{n \neq DEP}^{5} C$) in the three age periods,

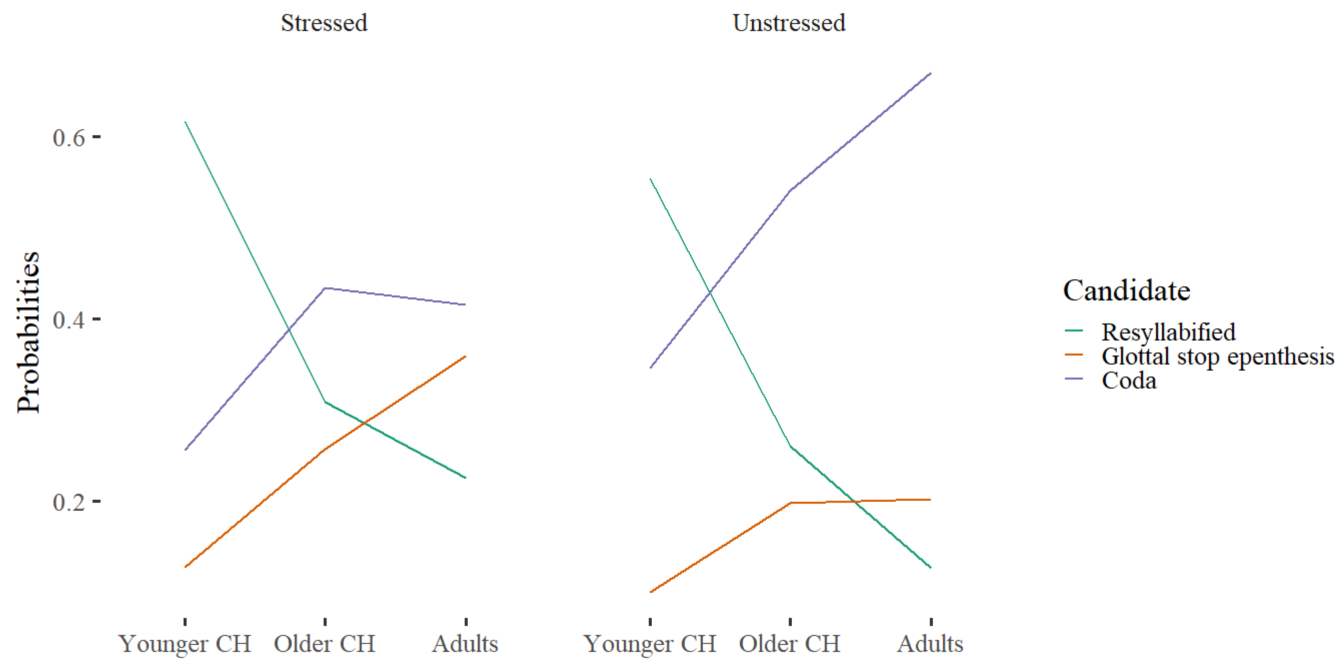


Figure 4.5: Predicted and observed probabilities in the MaxEnt grammars for the monolingually raised Spanish speakers

Spanish	DEP-ʔ	ALIGN-R (σ, ω)	ONSET	ONSET/ˈσ_{Initial}	[*ONSET/LAT]/ˈσ_{Initial}
younger children	1.85	0.01	0.88	0.55	0.18
older children	0.86	0.36	0.00	0.49	0.14
adults	1.35	1.39	0.37	0.96	0.08

Table 4.8: Weights for the Spanish speakers' grammars.

and then calculated the relative difference by dividing the result by $\sum_{n \neq DEP}^{5} C$ (see Table 4.9).

	Δ (DEP, $\sum_{n \neq DEP}^{5} C$)	% difference
younger child SpanMonoS	+0.23	+14.39%
older child SpanMonoS	-0.13	-13.34%
adult SpanMonoS	-1.46	-51.93%

Table 4.9: Difference between DEP-ʔ and rest of the SpanMonoS Spanish grammars and percent difference taking $\sum_{n \neq DEP}^{5} C$ as the reference in the monolingually raised Spanish speakers.

Two trends are observed in the resulting differences. First, the value is positive in the younger child SpanMonoS, indicating that the weight of DEP-ʔ is 14.39% higher than the weight of the /ʔ/-epenthesis allowing constraints. That is, candidates surfacing with /ʔ/-epenthesis will have higher harmony values than the sum of the resyllabified and the coda candidates. The difference turns negative in the older child SpanMonoS and the adult SpanMonoS, demonstrating that DEP-ʔ has a lower relative weight in the grammar than the sum of ONSET and ALIGN-R. For the older child SpanMonoS, the weight of DEP-ʔ is 13.34% lower than the weight of the rest of the grammar, and the change increase in the adult SpanMonoS, as the weight of DEP-ʔ is 51.93% lower than the rest of the grammar, showing that ALIGN -R (σ, STEM) and ONSET gain prominence with respect to DEP-ʔ as the Spanish grammars mature.

To examine the role of the stress-driven constraints, I compared the log-likelihoods[6] of the full model and a basic model without ONSET/ˈσ_{Initial} and [*ONSET/LAT]/ˈ$\sigma_{\text{In.}}$, as shown in Table 4.10. A log likelihood ratio test demonstrated that adding the stress-driven constraints did not significantly improve the model for any of the three grammars.

[6] Log likelihood was calculated with the sum of the products of the observed number of tokens and the log predicted probability for each candidate.

	Basic model	Full model
younger child SpanMonoS	-49.04	-48.82 ($p = 0.50$)
older child SpanMonoS	-77.90	-77.48 ($p = 0.36$)
adult SpanMonoS	-68.38	-66.67 ($p = 0.06$)

Table 4.10: Log-likelihoods for the basic model and the full model including the stress-driven constraints for the SpanMonoS' Spanish grammars

The fact that Δ (Dep, $\sum_{n \neq DEP}^{5} C$) declines with age is challenging to explain from a developmental perspective. This would mean that faithfulness in the grammar decreases as the grammar matures, a claim that is not supported by findings in early speech production, which show that markedness constraints outweigh faithfulness constraints during initial stages (Curtin & Zuraw, 2001; Gnanadesikan, 1995; Jusczyk et al., 2009). Moreover, it is unlikely that consonant epenthesis is disfavored during childhood. The use of consonant epenthesis to fill an empty onset during first stages of language acquisition is a frequent finding in studies on syllabic acquisition. For instance, Fikkert et al. (2004) found that, prior to allowing empty onsets in their grammar, children epenthesize an obstruent as an onset of a vowel-initial word (e.g., *appel* 'apple' /ɑpəl/ [ˈpaːpuː]). Moreover, the fact that Align-R has a low weight in the younger children's grammars implies that misalignments in the syllabic structure are more available between 6 and 8 years than afterwards. However, evidence from first language acquisition indicates that resyllabification is preceded by an initial stage at the onset of two-word production, in which Spanish-speaking children prefer to glottalize (Lleó, 2016). Apart from this, consonant-to-vowel coordination involves complex coordination of the tongue movements, which might not reach adult-like values until seven years of age (Nittrouer, 1993). In other words, it is unlikely that the differences between the three grammars have a developmental explanation. Instead, and as discussed in section 3.7.1, I propose that the development of theory of mind skills combined with phonological enhancement lies at the center of the difference in glottal phonation. 5-yo-8- year olds are less likely to evaluate novel words as unpredictable to the listener than older children or adults.

Older children and adults analyze the degree of predictability of the content word and transfer this information to their phonologies. The present phenomenon could be described as an instance of Message-Oriented Phonology (MOP) (Kawahara & Lee, 2018), which takes the standpoint that phonology is driven by principles that seek to make message transfer effective. These principles that result in phonological reduction or enhancement are likely to arise at the word-level (Hall et al., 2018). Kawahara and Lee (2018) put forth the notion of 'I-Map' (i.e., information map) to integrate predictability (i.e., units of information or entropy) into the generative phonological framework. In the 'I-Map', the rankings of the faithfulness constraints are dependent on lexical predictability. The faithfulness of a contrast A will be higher ranked than those of contrast B if the entropy (i.e., predictability) of contrast A is higher from that of contrast B. In this study, the 'I-Map' has to be extended to markedness constraints, word perceptibility is enhanced with phonological augmentation, as opposed to faithfulness to the underlying representation. In a MaxEnt grammar, the 'I-Map' can be formalized using a scaled-constraint system, in which inputs are indexed with measures of predictability. Each word would be assigned an entropy score based on the perceived degree of word unpredictability (i.e., speakers evaluate how unlikely it is for the listener to retrieve the word from the speech signal based on the contextual information). The unpredictability-sensitive scales would encourage phonological enhancement in more unpredictable word-sequences. In the current analysis, ONSET and a non-prosodically sensitive *ONSET/X would be scaled constraints. Real words would have low values and novel words would have high values assigned to their unpredictability index. The weights of ONSET and *ONSET/X would be scaled as a function of the inputs' unpredictability scores. This account would explain the asymmetry found between the younger children and the two other groups, as it is possible that younger children have not incorporated the scale in their grammars, or that the inputs are not indexed to an unpredictability score.

4.3.0.2 Codas and resyllabified consonants in monolingually raised Spanish speakers

In this section, I explore the probabilities of the consonant emerging as a coda or as a resyllabified consonant by calculating the probability of tokens classified as resyllabified consonants out of the total tokens produced with modal phonation (see Table 4.11)

	Pred. prob. ˈσ	Mean obs. ˈσ	Pred. prob. σ	Mean obs. prob. σ
younger child SpanMonoS	0.67	0.67	0.63	0.63
older child SpanMonoS	0.37	0.37	0.33	0.33
adult SpanMonoS	0.30	0.30	0.21	0.21

Table 4.11: Proportion of predicted and observed probabilities for resyllabified consonants out of the consonants produced with modal phonation. ˈσ for initial stressed syllables and σ for initial unstressed syllables

Among the tokens produced with modal phonation, the predicted probabilities for the resyllabified consonants show a decreasing tendency across the three age periods (younger child SpanMonoS = 0.65, older child SpanMonoS = 0.35, adult SpanMonoS = 0.25). The results demonstrate that younger child SpanMonoS prefer resyllabified candidates over coda candidates, and the probabilities reverse in the older children and adults, indicating that resyllabified candidates will surface less often in the grammars from children older than 8 years old and those from adults than in the grammars of children between the ages of 6 to 8. While a predominant ONSET/σ_{Initial} constraint in younger children's grammars is a result that supports findings on first language acquisition, the increase in weight of the ALIGN -R (σ, STEM) constraint is unexpected. The consensus in Spanish phonology is that consonants in word-external position resyllabify to the following onset, which is translated into low weights of ALIGN -R (σ, STEM) and low harmony scores to resyllabified candidates in MaxEnt grammars. We would, thus, expect that the relationship between ONSET/σ_{Initial}

and ALIGN -R (σ, STEM) would be one in which ONSET has a higher weight than ALIGN-R. These results lay the ground for proposing that resyllabification may not be a uniform process affecting all the consonants in coda position, but it may rather be optional during speech production or, at least, subject to individual variation. Resyllabification has already been claimed to be optional for certain consonants. In Ecuadorian Spanish, Robinson (2012) suggests that some consonants undergo resyllabification (i.e., /l/), and others do not (i.e., /n/, /s/). Moreover, other word-external phonological processes can undergo more than one type of repair. For instance, word-external hiatuses can be repaired with the formation of a diphthong, vowel deletion, or with the maintenance of the hiatus (Aguilar, 2003; Alba, 2006; Jenkins, 1999; Souza, 2009). Lexical frequency (Alba, 2006; Jenkins, 1999; Souza, 2009) and speech rate (Souza, 2009) have been found to influence the rates of these repair strategies. In addition, work in French (Encrevé, 1988; Laks, 2009 as cited in Somlensky & Goldrick [2016]) has shown that the liaison consonant can sometimes be syllabified in the coda position (i.e., j'avais un rêve 'I had a dream' pronounced [ʝa.vɛz.ɛ.ʁɛ̃v] from Goldrick and Smolensky [2016, p. 13] citing Laks [2009]).

Under a scenario in which resyllabification is optional, the higher rates of resyllabification in younger children could tentatively be associated to speech rate. First, the mean duration of /V#l/ and /C#l/ are higher in the children's productions (/V#l/; M = 101 ms, /C#l/; M = 82 ms) than in the adults' productions (/V#l/; M = 87.14 ms, /C#l/; M = 74 ms), which suggests lower speech rates in the group of children, when compared to those of adults. Second, it is possible that, as a word-external process, resyllabification is affected by similar factors than other connected speech phenomena, such as hiatus resolution. If so, as in the case of hiatus resolution(Souza, 2009), resyllabification may be affected by speech rate. Assuming that there is a sine qua non relationship between duration and resyllabification and that faster speech rates may result in phonetic reduction (Gendrot & Adda-Decker, 2007; Hirata & Tsukada, 2004; Jaworski, 2009; Nadeu, 2014, among others), it is possible that in faster speech, consonants in /C#V/ positions are produced as coda consonants to ease phonetic effort. In this case, the higher rates of resyllabified consonants in children would be due to a lower speech rate in the children's productions when compared to that of adults.

4.4 Grammars of monolingually raised English speakers

For the English data, three MaxEnt grammars were fitted using Excel Solver with the aggregated probabilities from the experimental design. As in the grammars for Spanish, I used phonetic data to classify the tokens into candidates with glottal phonation and candidates with modal phonation. I then used unsupervised learning with the distributions of the tokens /l#C/ and /l#V/ to classify the intervocalic tokens as coda or ambisyllabic candidates. As in the case of Spanish, I set a weak prior in the three grammars (μ = 0, σ = 1000). KL divergences were 0.13 for the younger and older children and 0.15 for the adults. Table 4.12 shows the weight of each constraint. The general patterns in the grammar are a preference for /ʔ/-epenthesis, reflected by a relative low weight of Dep-ʔ and a low preference for ambisyllabic and coda candidates, as shown by the relative high weights of Onset and Align -R. In the next sections, I examine the properties of the fitted grammars.

English	Dep-ʔ	Align-R (σ, ω)	Onset	Onset/ˈσ_{Initial}	[*Onset/Lat]/ˈσ_{Initial}
younger children	0.17	2.51	1.32	1.81	0.96
older children	0.03	3.77	1.59	2.07	3.14
adults	0.15	0.44	1.50	1.33	1.67

Table 4.12: Weights for the EngMonoS' grammars

4.4.0.1 Glottal stop epenthesis

As in the case of the Spanish SpanMonoS, to quantify the inequality between Dep-ʔ and the rest of the grammar, I calculated Δ (Align-R, Onset) and the relative difference between Dep-ʔ and the rest of the constraints (see Table 4.13).

	Δ (Dep, $\sum_{n \neq DEP}^{5} C$)	% difference
younger child EngMonoS	-6.43	97.46%
older child EngMonoS	-10.53	99.68%
adult EngMonoS	-4.67	98.36%

Table 4.13: Difference between Dep-ʔ and rest of the SpanMonoS Spanish grammars and percent difference taking $\sum_{n \neq DEP}^{5} C$ as the reference in the monolingually raised English speakers.

In the case of English, the difference is negative in the three grammars, indicating that all three prefer /ʔ/-epenthesis over the sum of the ambisyllabic and coda candidates. The percent difference shows a slight increase between the younger child EngMonoS and the older child EngMonoS, and a slight decrease between the older child EngMonoS and the adult EngMonoS. From an acquisitional perspective, these findings demonstrate a U-shaped learning pattern in the rate of glottal phonation, as demonstrated in Figure 4.6.

With regard to prosodic prominence, adding the two stress-driven constraints in the EngMonoS' models significantly improved the log likelihood of the older child EngMonoS' grammar ($p = 0.02$) and that of the adult EngMonoS ($p = 0.01$). In addition, a marginal improvement was found in the grammar of the younger child EngMonoS ($p = 0.09$).

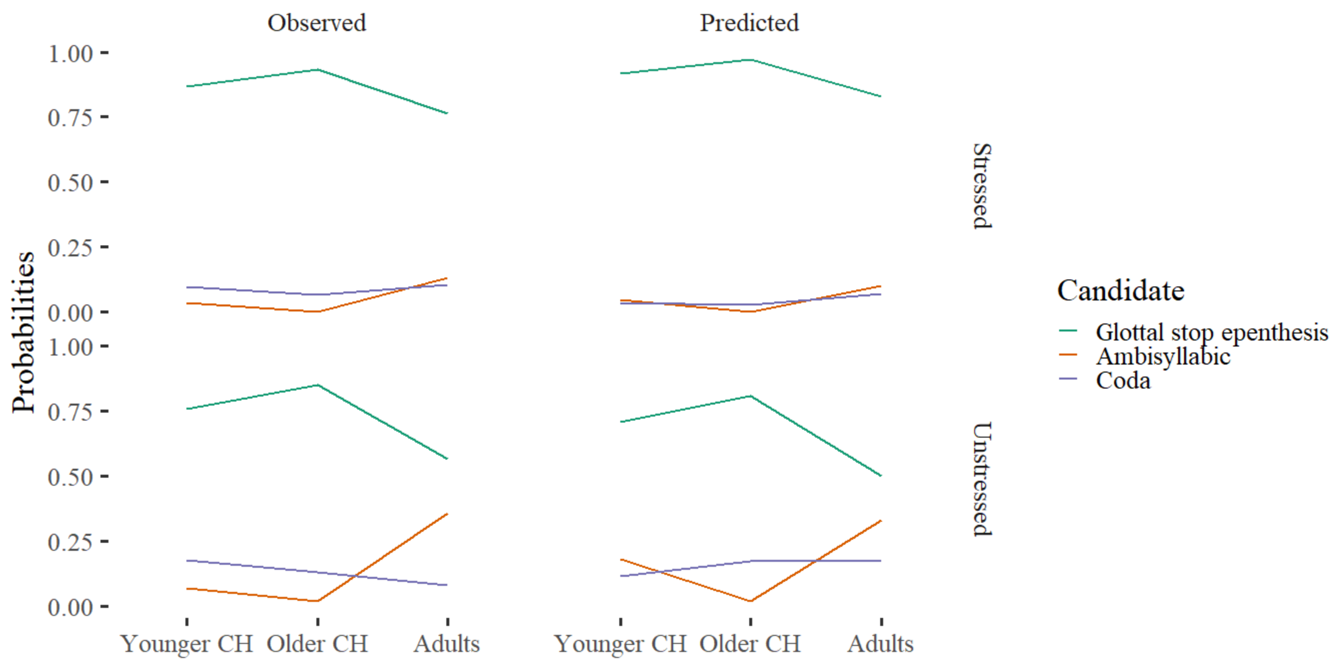


Figure 4.6: Predicted probabilities in the MaxEnt grammars for the monolingually raised English speakers

	Basic model	Full model
younger child EngMonoS	-35.22	-32.86 ($p = 0.09$)
older child EngMonoS	-34.55	-30.82 ($p = 0.02$)
adult EngMonoS	-64.83	-60.22 ($p = 0.01$)

Table 4.14: Log-likelihoods for the basic model and the full model including the stress-driven constraints for the EngMonoS English grammars

4.4.0.2 Codas and ambisyllabic consonants

As in the section for Spanish, I calculated the probability of tokens classified as ambsyllabic consonants out of the total tokens produced with modal phonation (see Table **??**).

	Pred. prob. ˈσ	Mean obs. ˈσ	Pred. prob. σ	Mean obs. prob. σ
younger child EngMonoS	0.05	0.03	0.07	0.07
older child EngMonoS	0.00	0.00	0.02	0.02
adult EngMonoS	0.11	0.13	0.37	0.35

Table 4.15: Proportion of predicted and observed probabilities for ambisyllabic consonants out of the consonants produced with modal phonation. ˈσ for initial stressed syllables and σ for initial unstressed syllables in English

Before analyzing the results, recall that these percentages are extracted from a small sample size as a low percentage of tokens were produced with modal phonation (younger child EngMonoS = 18.75%, older child EngMonoS = 10.89%, adult EngMonoS = 33.67%). The results show similar preferences for ambisyllabic consonants in the younger child EngMonoS and the adult EngMonoS, and they both differ from older child EngMonoS. Since a developmental explanation is not likely in this case, because children produce similar rates of ambisyllabic consonants to those of adults since the beginning of testing (younger child EngMonoS), it is possible that

4.5 Conclusion

In this section, I have discussed the phonological implications of my results by comparing the development of the constraint weights in monolingually raised Spanish speakers and English speakers. The experimental results from the word production tasks 2a and 2b (i.e., novel words) were used as inputs in the models. In these experiments, the target consonant in /l#V/ position was also elicited in /l#C/ and /V#l/ positions, which permitted the calculation of the coda and resyllabified or ambisyllabic candidates for the models.

In regard to the difference between Dep-ʔ and the rest of constraints in the fitted grammars, my results show that, in the Spanish models, the difference is larger and negative (i.e., lower weights of Dep-ʔ with respect to the rest of the relevant constraints) as the grammars mature, allowing greater rates of candidates with glottal phonation to emerge in the older children's and adults' grammars. English monolingual grammars demonstrate the reverse pattern. When compared to the children, higher weights of Dep-ʔ and lower weights of Onset and Align-R in the adult grammar result in lower rates of glottal phonation. To explain the conflicting results between the Spanish and English groups, I have argued that two factors come into play: language maturation and sensitivity to the unpredictability of novel words.

Before laying out an explanation of this conflicting pattern, recall that English and Spanish differ in their rates of glottal phonation for the real words. Spanish speakers produce an overall low rate of glottal phonation in /C#V/ sequences in real words, and English speakers produce an overall high rate of glottal phonation in stress-initial real words. This asymmetry suggests that a preference for /ʔ/-stop insertion in prominent positions is already part of the adult English phonology. The high rates of glottal phonation in the adult English input may cause English-speaking children to extend an initial stage in the grammar in which Dep-ʔ is weighted lower than the other relevant constraints. If this initial stage exists in Spanish, it is overcome earlier because the prevalence of modal phonation in the input allows children to increase the weight of Dep-ʔ. For this reason, the results for Spanish do not show a decrease in the rate of glottal phonation with age.

Spanish speakers do not show a pattern of acquisition in the rate of glottal phonation at the ages of testing, because the weight of Dep-ʔ with respect to the active constraints in the grammar decreases with age. This means that, if children increase the weight Dep-ʔ during early childhood, they do so before 5 years of age. Instead, an explanation of these results should suggest factors that come into play to cause novel words to be evaluated with lower values of Dep-ʔ in the older child SpanMonoS and adult SpanMonoS, when compared to the younger child SpanMonoS. I have argued that Spanish speakers show a sensitivity to the unpredictability of novel words. This sensitivity is expressed in higher rates of glottal phonation that enhance the perceptibility of the psycholinguistically relevant cues for retrieval (i.e., head of the prosodic word). Tuning on to the unpredictability of novel words may not be available to 6-8 year olds, as they need to make use of theory of mind skills to evaluate listener-oriented unpredictability and adjust their phonological constraints accordingly. A question that arises for any account that tie phonological enhancement to novel word unpredictability is why English speakers do not show the same increasing pattern in glottal phonation across the child and the adult grammars. I claim that the English phonology already resorts to phonological enhancement and that the rate of glottal phonation shows a ceiling effect, which means that the unpredictability of novel words is unlikely to be reflected in even higher weights of ONSET/$ˈ\sigma_{\text{Initial}}$ or [*ONSET/LAT]/$ˈ\sigma_{\text{Initial}}$ in the English grammars. A ceiling effect is supported by the fact that the Spanish grammars show lower rates of glottal phonation than the English grammars. Moreover, recall that the pairwise comparisons in the experimental results showed that only the older children produce a higher proportion of glottal phonation in the novel words than in the real words. Although one could posit that only the older children are attuned to the unpredictability of novel words, it is an unlikely explanation given the fact that adults do not show a significant difference between the two sets of words. Instead, I have posited in Chapter 3 that older children may be learning high weights of DEP-ʔ as a function of word frequency as children get exposed to input with ambisyllabic consonants. Less frequent words are more likely to be evaluated with low weights of DEP-ʔ, as its value has had fewer opportunities to update.

To summarize, the lower weight of Dep-ʔ with respect to the rest of the relevant constraints in the grammars of Spanish speaking older children and adults is likely due to a developed sensitivity to the unpredictability of novel words, which is not demonstrated in the younger children. In English, the rate of glottal phonation may be showing ceiling effects and sensitivity to unpredictability may not be reflected in the results. Instead, I have argued that the increasing relevance of Dep-ʔ with respect to the rest of the grammar as language mature is specific to English, as English shows a preference for glottal phonation in prosodically-prominent positions. Thus, English-speaking children are likely to need more input to update Dep-ʔ to the adult-like target.

As for the probabilities for coda and ambisyllabic/resyllabified candidates, the two grammars also show divergent patterns. The weight of Align-R increases across the grammars of Spanish non-heritage speakers, indicating a growing penalty for resyllabified consonants as the Spanish grammars mature. It is possible that, despite the assumption that resyllabification is a categorical process in Spanish (Colina, 1997; Harris, 1983; Hualde, 1991), it is, in fact, an optional phonological one, that may be conditioned by factors such as speech rate or lexical frequency, as in the case of hiatus resolution (Alba, 2006; Souza, 2009). This would provide an explanation to recent findings in Spanish phonetics (Hualde & Prieto, 2014; Strycharczuk & Kohlberger, 2016) showing that the mean duration of /s/ in /s#V/ position is longer than the mean duration of /s/ in /s#C/ position but shorter than that of /s/ in /V#s/ position. If resyllabification is optional and conditioned by speech rate, the higher number of resyllabified consonants in the children's grammars when compared to those in the adults' grammars may emerge due to a lower speech rate in the former group. Indeed, the mean durations of /l/ in the /V#l/ and /C#l/ conditions were higher in the group of children (i.e., M in /V#l/ = 101 ms M in /l#C/ = 82 ms) than in the group of adults (i.e., M in /V#l/ = 87.14 ms M in /l#C/ = 74 ms).

In English, however, the predicted rate of ambisyllabic consonants is higher in the adult grammars than in the children's grammars. One possibility is that English-speaking children acquire resyllabification patterns later than Spanish-speaking children because the English input contains fewer instances of /l#V/ sequences produced with modal phonation. From a phonetics perspective, nevertheless, acquiring the articulatory patterns of the English /l/ in ambisyllabic position may involve more complexity than using duration as a cue for resyllabification.

4.6 Predicting language transfer in Spanish heritage grammars

In light of these findings, I predict that, if majority-to-heritage language transfer occurs in Spanish heritage phonological grammars, Spanish heritage speakers will demonstrate higher weights for Align-R and Onset than for Dep-ʔ (i.e., preference for candidates with /ʔ/-epenthesis over coda candidates or resyllabified candidates), and higher weights for the stress-driven constraints than for the general constraints (i.e., preference for glottal phonation in prominent positions). If heritage-to-majority language transfer appears in the English of Spanish heritage speakers, their fitted grammars will show lower weights for Align-R and Onset than for Dep-ʔ (i.e., preference for ambisyllabic or coda candidates over candidates with /ʔ/- epenthesis), and similar weights for the stress-driven and the general constraints (i.e., no preference for glottal phonation in prosodically-prominent syllables at word edges).

Despite the asymmetry between the predicted probabilities for coda and resyllabified or ambisyllabic candidates in the two languages during language development (i.e., higher probability of resyllabified consonants during childhood than during adulthood in Spanish, and lower probability of ambisyllabic consonants during childhood than during adulthood in English), predictions of language transfer in the observed probabilities of resyllabified or ambisyllabic candidates between the two languages should be taken with caution. I determined the observed probabilities for each candidate using different measures in the two languages (i.e., duration for Spanish and F2-F1 for English), suggesting that any prediction of cross-linguistic phonological transfer should take into account the phonetics-phonology interface. For instance, the rate of resyllabified consonants in the Spanish grammars of child heritage speakers may not necessarily influence the rate of ambisyllabic consonants in their English grammars, as child heritage speakers may still not be sufficiently exposed to the surface phonetic cues of syllabification in English. For this reason, the extent to which language transfer may affect the weights of Onset and Align-R cannot be reliably predicted in this work.

CHAPTER 5

Spanish HS' production of glottal phonation in repairs of empty onsets in Spanish and English

5.1 Introduction

In this chapter I build upon the results from the monolingual speakers and I examine the data from the child and adult heritage speakers (HS) in both Spanish and English. I explore the prevalence of glottal phonation in the production of /C#V/ sequences in HS' grammars by comparing them to the results of Chapter 3. More specifically, I explore whether degree of glottal phonation is affected by age (i.e., younger children, older children, adults), primary stress, presence of the lexicon, and amount of input and output.

5.2 Research questions

In light of the literature reviewed in Chapter 1 and Chapter 2, I ask the following questions:

1. In the Spanish speech productions, do Spanish HS present greater rates of glottalization than monolingually raised Spanish speakers in Mexico?

    - I predict that Spanish HS will present transfer of glottal phonation in their Spanish productions. Influence from English into Spanish will result in the production of /C#V/ sequences with greater rates of glottalization than those found in monolingually raised Spanish speakers in Mexico and more similar to those of monolingually raised English speakers.

2. In the English speech productions, do Spanish HS present smaller rates of glottalization than monolingually raised American English speakers?

    - I predict that Spanish HS will present transfer of modal phonation in their English productions. Influence from Spanish into English will result in the production of /C#V/ sequences with rates of glottalization smaller than those produced by American English speakers.

3. Are adult HS more likely to produce glottal phonation than child HS in Spanish?

    - I predict that majority-to-heritage language transfer will be more likely to occur during adulthood and late childhood, as speakers leave their household and are systematically exposed to the majority language (i.e., younger child HS < older child HS < adults).

4. Are adult HS more likely to produce glottal phonation than child HS in English?

    - I predict that heritage-to-majority language transfer will be more likely to occur during childhood than during adulthood, as the heritage language is spoken at home and HS have daily exposure to it (i.e., younger child HS < older child HS < adults).

5. Does the amount of input and output in Spanish predict the rates of glottalization in the Spanish and English of Spanish HS?

    - I predict that HS with a higher amount of Spanish input and output will present lower rates of glottal phonation in Spanish and English than HS with a lower amount of Spanish input and output.

6. Are child grammars more likely to be affected by Spanish input and output than adult grammars? That is, will the amount of Spanish input and output have a greater effect on child grammars than in adult grammars?

    - I predict that, during language maturation, child grammars will be more susceptible to language transfer and, thus, more likely to be affected by Spanish input and output.

7. Are Spanish HS more likely to produce greater rates of glottal phonation in novel words than in real words than monolingually raised speakers?

    - If phonological constraints are sensitive to the lexicon and the rate of glottal phonation is more frequent in novel words than in real words, it is possible that the non-lexically specified inputs will be more likely to be evaluated with English-like constraints weights, and vice-versa, as they may be more permeable to language transfer.

5.3 Methods

5.3.1 Test materials

Same experiments as Chapter 3.

5.3.2 Linguistic background questionnaire

5.3.3 Parental linguistic background questionnaire

A linguistic background questionnaire was administered to the parents of Spanish heritage children and the parents of the Spanish-speaking children from Mexico in order to calculate the amount of home (i.e., input and output) and school (i.e., input) exposure to Spanish and English. The questionnaire was based on Gathercole et al. (2014), a questionnaire for bilingual children. The questionnaire had two parts. The first part elicited information about the caregivers' place of origin, residence, age of arrival in the US, education level, and postal code (21 questions). The second part elicited information about the number of hours that the caregivers and siblings interact with the child (5 questions) percentage of input and output of Spanish and English from/to caregiver 1, caregiver 2, younger and older siblings (12 questions), number of hours exposed to Spanish and English entertainment (2 questions), and other significant events (1 question). The second part was used to calculate the amount of input and output in Spanish.

Home and school input. In order to calculate relative input, I considered the responses to the school input and the home input. First, the number of hours that the child spends at school was divided by the child's awake time (i.e., in number of hours).

$$Weight\, School = \frac{Hours\, School}{Total\, Hours}$$

To calculate the home weight, the school weight was subtracted from 1. The number of hours that the child spends with caregiver 1, caregiver 2, siblings was divided by the child's awake time.

$$Weight\, Caregiver1 = Weight\, Home \times \frac{Hours\, Caregiver1}{Hours\, Caregiver1 + Caregiver2 + Siblings}$$

The resulting weights were applied to the percentages of English and Spanish input (i.e., caregiver 1, caregiver 2, siblings). The final values for all the family members were added (i.e., caregiver 1, caregiver 2, siblings). I also considered whether, the family member that interacted the most when all the family members were present.

Home output. To calculate relative output, we applied the same procedures as the ones described above. However, we did not include the school weight, as parents could not reliably answer to the amount of output produced by the child during school hours.

5.3.4 Adult linguistic background questionnaire

With the aim of shedding light on the dynamic input/output across the speakers' lifespan, we replicated the previous questionnaire and expanded the target periods in the adult questionnaires. For this, we elicited the same data on input and output for the following life stages: primary school to middle school, high school period, and university. We followed the same system to average the weights as in the previous questionnaire. In this case, the school hours for primary school to middle school were set to 5 hours and the hours for high school and university were set to 6 hours [1]. Given the lack of previous literature on the effect of language exposure across speakers' lifespan, we distributed the weights for each period equally by dividing the added weights by 3.

5.3.5 Participants

5.3.5.1 Adult participants

Adult Spanish HS Twenty-five adult HS of Mexican descent participated in this study. The participants were undergraduate students at the UCLA Spanish and Portuguese department and were recruited in linguistics and heritage language courses. Data of five participants were removed due to excessive noise in the signal or audio clipping. The remaining 20 US-born HS (15 F, mean age = 20;7 years, age range = 18;11 to 26;7) were included in the study. Except for one participant, all the HS' primary caregivers immigrated from various parts of Mexico. The remaining participant reported having one of their caregivers born in the US. The mean age of arrival in the US of the caregivers was 20.1 years (SD = 6.02 years). All the HS were exposed to Spanish since birth and to English before the age of 5 (M = 3.3 years, SD = 1.59 years). The mean percentage of Spanish input was 47.47% (SD = 14.22%) and the mean percentage of Spanish output was 53.14% (SD = 20.76%). figure 5.1 shows

[1] The Los Angeles Unified School District sets the instructional minutes for primary school and middle school to 300, and the instructional minutes for high school to 360 (**EducationEducation**).

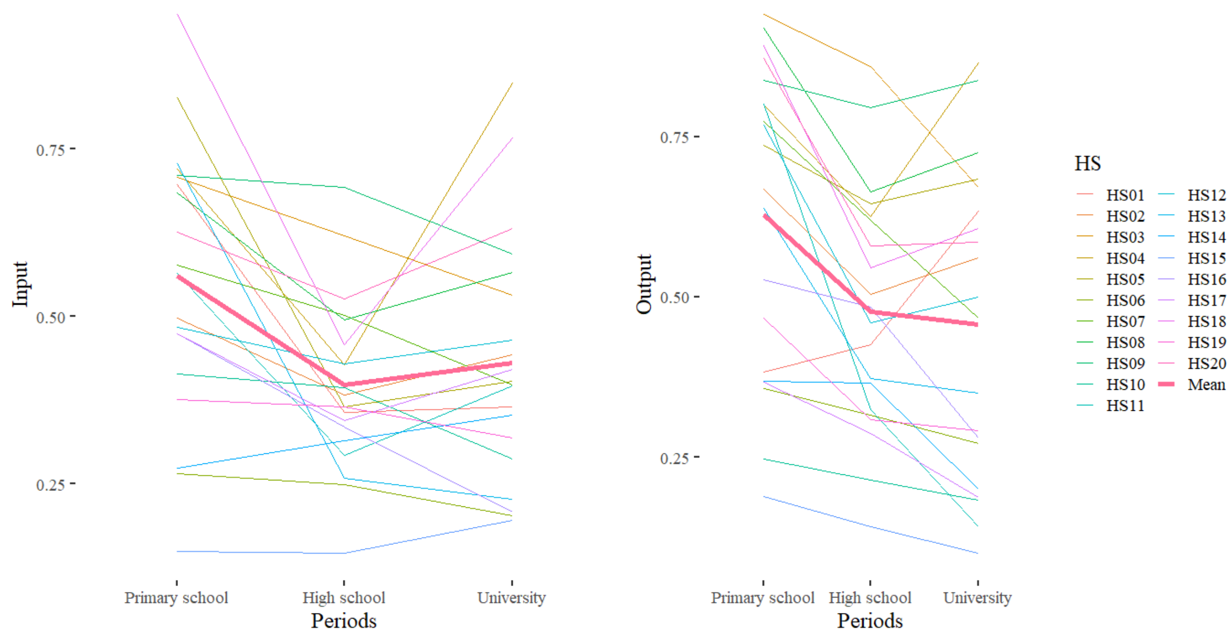


Figure 5.1: Proportion of Spanish input and output in adult HS by period

the proportion of Spanish input and output for the three periods (i.e., primary school, high school, university). Participants showed a decrease in the percentage of Spanish input from primary school to high school (M = -15.23%, SD = 17.77%) and a slight increase (M = 3.33%, SD = 13%) in the percentage of Spanish input from high school to university. It is possible that the increase in the percentage of input is related to the fact that participants enrolled in the Spanish programs at the UCLA Spanish and Portuguese Department. In regard to output, participants demonstrated a decrease in the percentage of Spanish output from primary school to high school (M = -15.08%, SD = 13.51%) and a decrease (M = -2.00%, SD = 12.22%) from high school to university. This means that the increase of Spanish input, probably class-related input, does not necessarily lead to higher percentages of output. The participants were compensated with course credit for their participation in the study.

5.3.5.2 Child participants

Child HS Sixty-seven typically-developing Spanish child HS were enrolled in the study. Seventeen participants were removed because they only completed the Spanish session.[2] Upon revising the questionnaires, four participants were excluded for being enrolled in Hebrew and Mandarin immersion programs. The remaining 44 participants were divided into a group of 19 younger child HS (11F, mean age = 6;5 years, age range = 5;2 to 8) and a group of 25 older child HS (12 F, mean age = 10;1 years, age range = 8;2 to 11;11). Except for 4 participants, the rest of the child HS were born in the US. The mean age of arrival in the US of the 4 children was 22 months (SD = 11 months). All the children had at least one caregiver from Mexico. 30 children had two caregivers from Mexico or were in a monoparental family (N = 1), 4 child HS had one caregiver from Mexico and one from El Salvador, and 10 child HS had one caregiver from Mexico and one caregiver from an English-speaking country. Out of the US born caregivers, 5 were speakers of Spanish as a heritage language (3 for caregiver 1, 2 for caregiver 2). The mean age of arrival for caregiver 1 was 22.16 years (SD = 10.78 years) and the mean age of arrival for caregiver 2 was 22.14 years (SD = 10.01 years). All the speakers had been exposed to Spanish since birth. The mean age of exposure to English was 1.52 years (SD = 1.49 years). 20 participants were enrolled in a Spanish bilingual program at the time of testing.[3] The younger child HS had a mean input of 61.62% (SD = 15.98%) and a mean output of 54.86% (SD = 31.42%). The older child HS had a mean input of 57.95% (SD = 22.04%) and a mean output of 52.64% (28.71%). Except for two participants, the rest of the child HS had been receiving online education (i.e., limited contact with the school community) at least six months prior to the time of testing. While the child groups did not differ from the adults in their amount of Spanish output ($F(2) = 0.025$, $p = 0.97$), they received more Spanish input ($F(2) = 3.32$, $p = 0.04$). Post-hoc Tukey

[2] 14 of these participants only completed one session due to schools' closing during the COVID-19 pandemic.

[3] The percentage of exposure to Spanish at school has been included in the calculations for Spanish input.

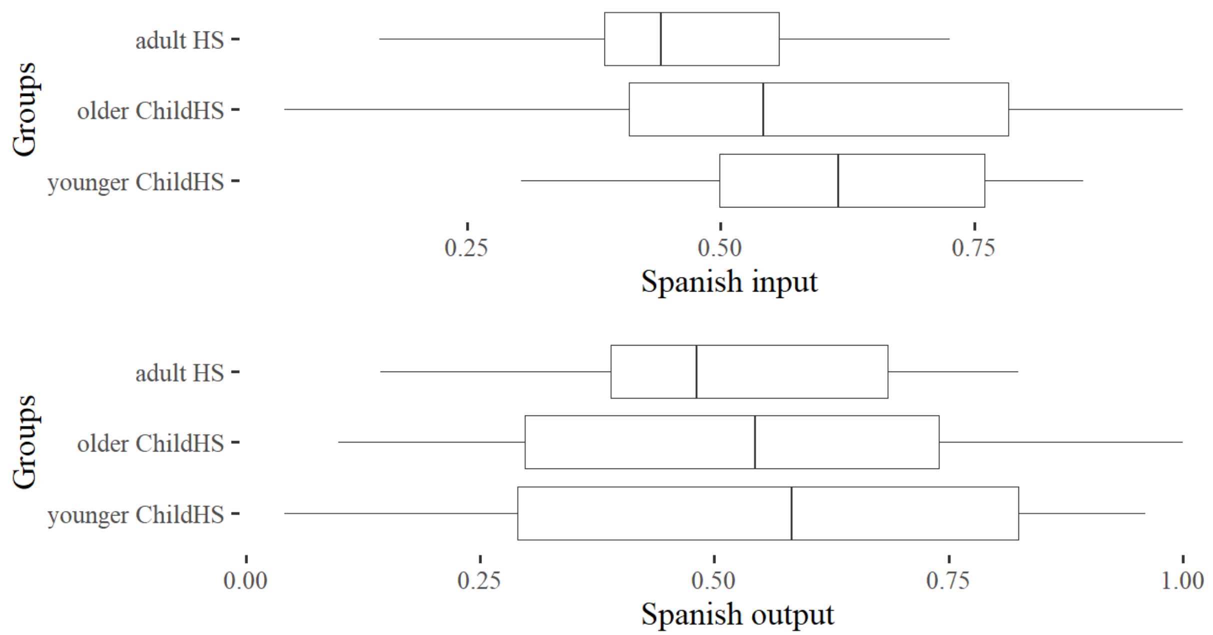


Figure 5.2: Proportion of Spanish input and output for younger child HS, older child HS and adults.

tests results indicated that younger child HS received a significantly higher mean of Spanish input than adult HS ($p = 0.04$). Participants were compensated with a $15 gift card.

5.3.6 Experimental protocol

The experimenter followed the same protocol as the one presented in Chapter 4. However, the HS completed the experiments in two sessions. The first session included the experiments in Spanish, and the second session included the experiments in English in all the cases.

5.4 Results for Spanish

5.4.1 Real words

Of the 3279 tokens produced, 142 tokens were removed due to pauses longer than 150 ms between the function word and the content word, deletion of the initial vowel of the content word, creakiness across the complete function and content word sequence or production of the wrong function word. The remaining 3139 tokens were submitted to analysis.

5.4.1.1 Rate of glottal phonation in HS: comparing with monolingually raised Spanish speakers

Figure 5.3 shows the proportion of glottal phonation by age, type of speaker, consonant and stress. A mixed effects logistic regression was conducted using the package lme4 (Bates et al., 2015) and post-hoc tests were run using the package emmeans (Lenth et al., 2020). The variables age (i.e., younger children, older children, adults), type of speaker (i.e., SpanMonoS, HS, as described in Chapter 3) stress (i.e., stressed, unstressed) and consonant (i.e., /n/, /l/, /s/) were included as fixed effects, along with the interactions between consonant and age, stress and age, stress and type of speaker, and type of speaker and age. The intercepts for participant and word were allowed to vary.[4] The categorical variables were contrast coded using simple coding, by which each level is compared to the reference level and the intercept is the grand mean.

The model demonstrated that HS glottalize more often (M = 22.07%, SE = 2.08) than SpanMonoS (M = 1.88%, SE = 0.34)(β = 3.77, z = 6.11, p < 0.001).

The model showed a main effect of consonant with /s/ (i.e., reference level = /l/) (β = 1.71, z = 7.07, p < 0.001), indicating that coda /s/ (M = 16.23%, SE = 1.15) is more

[4]The syntax for the model was: glmer(Glottal.rate ~ Consonant * Type.of.Speaker + Age * Type.of.Speaker *Stress + (1|Participant) + (1|Word), family = "binomial").

likely to present glottal phonation than coda /l/ (M = 8.72%, SE = 0.88), an interaction between age (i.e., adults) and consonant (i.e., /s/) showed that the difference between the coda /s/ and the coda /l/ is greater in the adults ($p = 0.001$) than in the younger children ($p = 0.038$).

With respect to interactions, my results showed that type of speakers interacted with age (i.e., adults) (β = -4.14, z = -2.80, $p = 0.001$). Post-hoc tests with Tukey adjustment showed that the younger children (M = 37.56%, SE = 2.35) and older children (M = 21.37%, SE = 1.68) in the HS group glottalized significantly more than the those in the SpanMonoS group (younger child SpanMonoS M = 1.58%, SE = 1.09, older child SpanMonoS = M = 1.61%, SE = 2.35) ($p < 0.001$ and $p = 0.0016$ respectively), but no significant difference was found between the two adult groups (adult SpanMonoS M = 2.48%, SE = 0.68, adult HS = M = 9.76%, SE = 2.60).

My results also showed an interaction between type of speaker and stress (β = -1.27, z = -2.45, $p = 0.01$). Post-hoc analyses showed that, while HS demonstrated a significant difference in the rate glottal phonation between the two levels of stress (β = -2.39, z = -6.96, $p < 0.001$), SpanMonoS did not show such significant difference (β = -1.11, z =2.10, p = 0.15). Lastly, no interactions were found between stress and age.

5.4.1.2 The effects of Spanish input and output in the HS' rate of glottal phonation

In order to calculate the effect of Spanish input and output on the rate of glottal phonation, I subset the tokens produced by the child and adult HS (N = 1542). A Pearson correlation showed that the data for Spanish input and output were significantly correlated ($r(1559)$ = 0.68, $p < 0.001$), thus I ran two separate mixed effects logistic regressions with the Spanish input and the Spanish output results respectively. In each model, the variables of Spanish input/output, age (i.e., younger children, older children, adults), initial primary stress (i.e., yes, no), consonant (i.e, /l/, /s/, /n/) were entered as fixed effects. I ran separate models

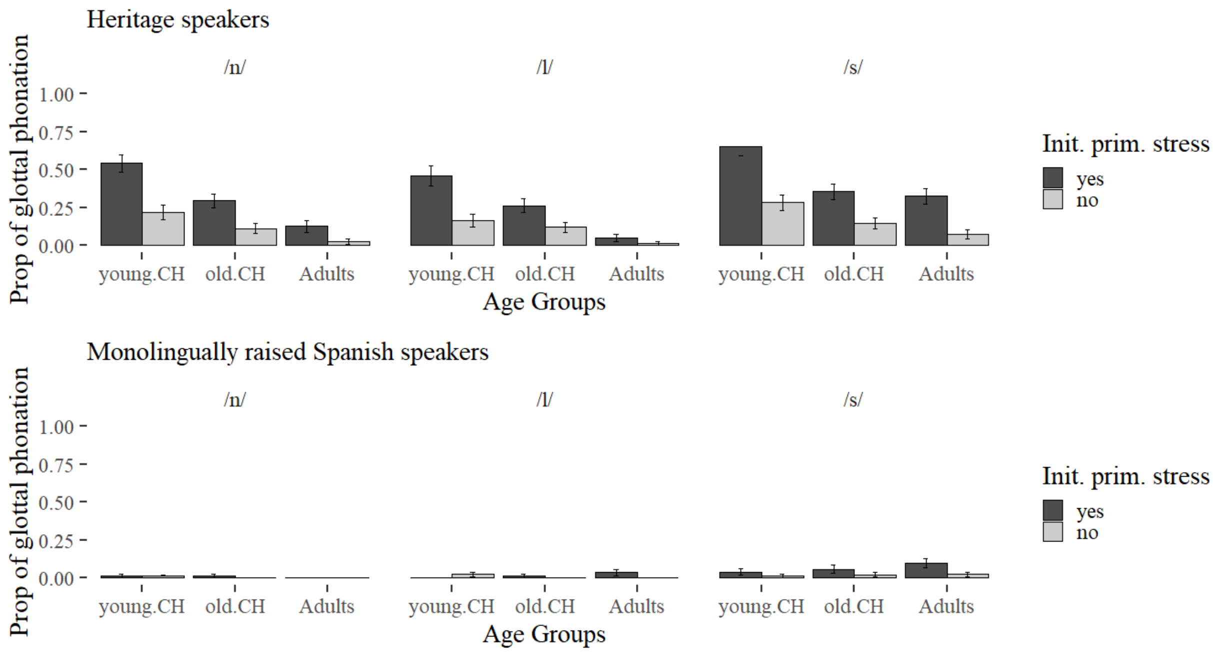


Figure 5.3: Proportion of glottal phonation in Spanish by age, type of speaker and stress (left) and proportion of glottal phonation in Spanish by age, type of speaker and consonant type (right)

with two-way interactions for the four variables, but none of the interactions turned out to be significant. That is, my data did not support a model with interaction terms. I hence assumed that the effects of input/output, stress, consonant, and age are the same among each level of the other two variables. Participant and content word were allowed random intercepts.[5] The predicted probabilities for input and output are plotted in Figure 5.4.

The model with Spanish input showed that input was not a significant predictor of glottal phonation. For the model with Spanish output, my results demonstrated that Spanish output significantly predicts the rate of glottal phonation (β = -3.08, z = -2.31, p = 0.02). The main effect of Spanish output had a negative and large effect on the dependent variable

[5]The syntax for the models was: glmer(Glottal.rate ~ Spanish input + Primary stress + Age + Consonant + (1|Participant)+ (1|Word), family = "binomial") and glmer(Glottal.rate ~ Spanish output + Primary stress + Age + Consonant + (1|Participant)+ (1|Word), family = "binomial").

(OR = 0.04, CI[0.002, 0.7], d = -1.77). That is, an increase in Spanish output reduced the likelihood of glottal phonation.

In addition, younger children produced a greater rate of glottal phonation (M = 37.76%, SE = 2.34) than older children (β = -1.74, z = -2.01, p = 0.04, M = 21.25%, SE = 1.66) and adults (β = -3.39, z = -3.63, $p < 0.02$, M = 9.88%, SE = 1.33). After releveling the model (i.e., older children), no main effect was found between older children and adults. A main effect was also found for initial primary stress (β = 2.32, z = 7.6, $p < 0.001$), indicating that stress vowel initial words were more often glottalized (M = 32.06%, SE = 1.69) than unstressed vowel initial words (M = 12.41%, SE = 1.18). Finally, vowel-initial words preceding the consonant /s/ (M = 28.68%, SE = 2.00) were more likely to be glottalized than those preceding the consonant /n/ (M = 21.25%, SE = 1.78) (β = 0.95, z = -2.47, $p < 0.001$), and vowel-initial words preceding the consonant /l/ were also more likely to be glottalized (M = 16.40%, SE = 1.65) than those preceding the consonant /n/ (β = -0.59, z = 4.14, $p < 0.001$).

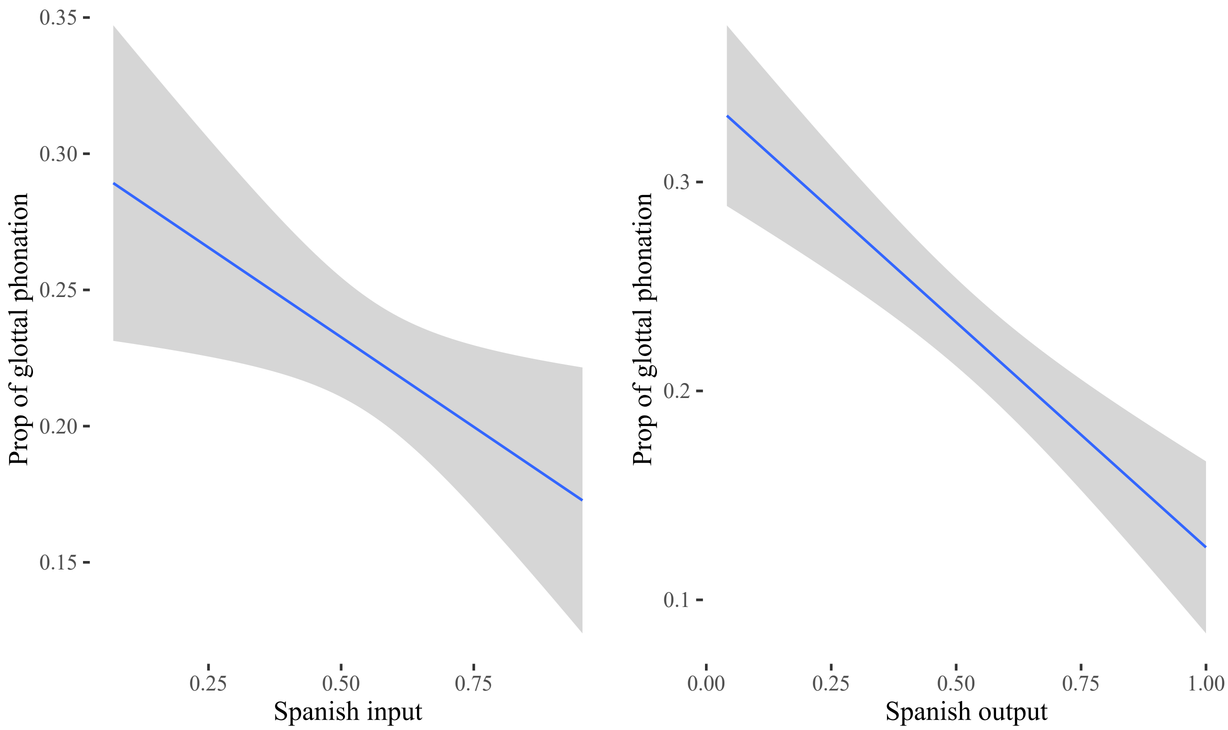


Figure 5.4: Predicted probabilities for percentage of Spanish input and output

5.4.2 Novel words

5.4.2.1 Rate of glottal phonation in HS: comparing with monolingually raised Spanish speakers

Out of the 1021 tokens that were produced, 102 tokens were removed due to a pause between the function word and the content word (i.e., a silent gap longer than 150 ms). The remaining 919 ambisyllabic tokens were submitted to a generalized logistic model. The variables age (i.e., younger children, older children, adults), type of speakers (i.e., HS, SpanMonoS), and initial primary stress (i.e., yes, no) and their interactions were entered as fixed variables and the intercepts for participant and word were allowed to vary.[6] The categorical variables were

[6]The model syntax was: glmer(Glottal.rate ~ Primary stress * Age * Type of speaker + (1|Participant) + (1|Word), family = "binomial").

contrast coded using simple coding. Figure 5.5 shows the rate of glottal phonation in the novel words. The model showed that a main effect of type of speaker (β = 0.98, z = 2.54, p = 0.01) conditioned by age at the level of older children (β = -1.88, z = -2.14, p = 0.03) and adults (β = -3.62, z = -3.69, p < 0.001). That is, while the difference in the rate of glottal phonation between SpanMonoS and HS was significantly different in the younger children (β = -2.81, z = -4.00, < 0.001), the difference in rate of glottal phonation did not reach significance in older children (β = -0.93, z = -1.59, p = 0.60), or the adults (β = 0.81, z = 1.20, p = 0.83). That is, younger child HS (M = 52.03%, SE = 4.52%) produced a greater rate of glotal phonation than younger child SpanMonoS (M = 11.45%, SE = 2.79%), older child HS (M = 35.87%, SE = 3.55%) and adult HS (M = 20.86%, SE = 6.30%) produced a similar rate of glottal phonation than older child SpanMonoS (M = 23.53%, SE = 5.52%) and adult SpanMonoS (M = 28.38%, SE = 3.72%) respectively.

Finally, the model showed a main effect of stress, showing that syllables containing primary stress were more often glottalized (M = 32.78%, SE = 2.14) than syllables without initial primary stress (M = 23.57%, SE = 2.03) (β = -0.82, z = -3.31, p < 0.001).

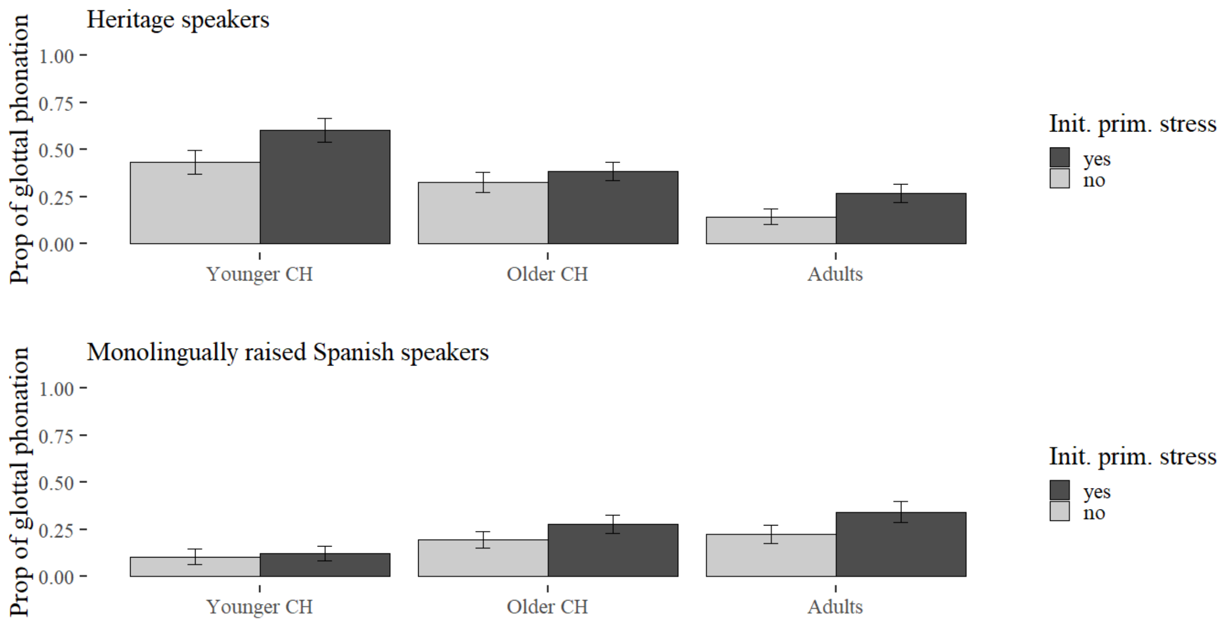


Figure 5.5: Proportion of glottal phonation by HS and SpanMonoS in Spanish novel words

5.4.2.2 The effects of Spanish input and output in the HS' rate of glottal phonation

The data for the HS was subset to examine the effect of Spanish input and output in the rate of glottal phonation (N = 441). As in the case of real words, a Pearson correlation showed that the data for Spanish input and output were significantly correlated ($r(438) = 20.68$, $p < 0.001$), thus I ran two separate mixed effects logistic regressions with the Spanish input and the Spanish output results respectively. In each model the variables of Spanish input/output, age (i.e., younger children, older children, adults), and initial primary stress (i.e., yes, no) and the interactions between initial primary stress and age were entered as fixed effects.[7] Participant and content word were allowed random intercepts.

[7] The model syntax was: glmer(Glottal.rate ~ Spanish input + Primary stress * Age + (1|Participant)+ (1|Word), family = "binomial") and glmer(Glottal.rate ~ Spanish output + Primary stress * Age + (1|Participant)+ (1|Word), family = "binomial").

Neither the model for input nor output showed that they had an effect on the rate of glottal phonation of novel words. Both models showed a main effect of age with adults (input model: β = -2.75, z = -3.16, p < 0.001, output model: β = -2.70, z = -3.21, p < 0.001), and a main effect of stress (input model: β = 1.17, z = 2.69, p < 0.001, output model: β = 1.17, z = 2.69, p < 0.001).

5.4.2.3 The effects of the lexicon in the HS' rate of glottal phonation

The /l/-coda tokens were taken as a subset from the real words' data set (N = 927). I ran a generalized logistic regression with two-way interactions between the variables age (i.e., younger children, older children, adults), initial primary stress (i.e., yes, no), and type of word (i.e., real words, novel words).The interactions with stress turned out to be non-significant. Thus, I assumed that the effect of stress is the same across levels of the other three variables.[8] The intercept was allowed to differ by participant and word. Pairwise comparisons were performed with post-hoc Tukey tests.

The results, as presented in Figure 5.6 showed that, when stress and age were set at the mean, novel words were more likely to be glottalized than real words (β = 3.02, z = 8.39, p < 0.001). In addition, HS were more likely to demonstrate glottal phonation than SpanMonoS (β = 2.98, z = 8.30, p < 0.001), but this effect was conditioned by an interaction between type of speaker and age (i.e., younger children and adults) (β = -4.20, z = -3.73, p < 0.001). That is, the difference between the two levels of type of speaker was greater in younger children (β = -3.19, z = -4.59, p < 0.001) than in adults (β = 0.37, z = 0.51, p = 0.99). In addition, the model showed an interaction between type of word and type of speaker (β = -2.15, z = -3.70, p < 0.001). Pairwise comparisons demonstrated that the difference between HS and SpanMonoS was greater in the real words (β = -3.40, z = -5.11, p < 0.001) than in the novel words (β = -1.25, z = -2.97, p = 0.01).

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[8]The syntax for the model was: glmer(Glottal.rate ~ Stress + Age * Type.of.Word * Type.of.Speaker+ (1|Participant)+ (1|Word), family = "binomial").

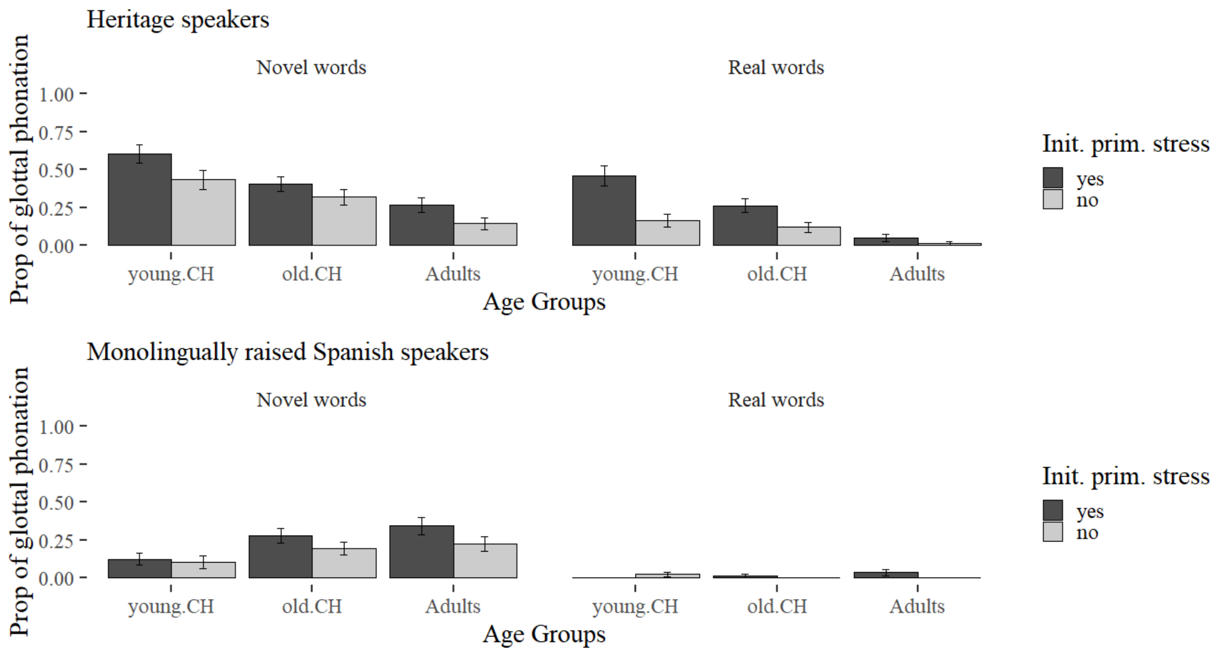


Figure 5.6: Proportion of glottal phonation by type of speaker, age, and type of word in Spanish

5.5 Results for English

5.5.1 Real words

5.5.1.1 Rate of glottal phonation in HS: comparing with monolingually raised English speakers

Out of the 3117 tokens produced, 347 tokens were removed due to pauses longer than 150 ms between the function and content word, incorrect production of function word (i.e., 'a' for 'an'), lack of function word, creakiness throughout the sequence or repetitions. The 2770 tokens were submitted to a logistic model with the variables initial primary stress (i.e., yes, no), age (i.e., younger children, older children, adults), type of speaker (i.e., HS, EngMonoS), consonant (i.e., /l/, /n/, /s/) and their interactions as fixed effects.[9] Figure 5.7 shows the proportion of glottal phonation by age group, type of speaker, stress, and consonant.

My results demonstrated a first order effect of type of speaker, indicating that HS produced a lower rate of glottal phonation (M = 46.33%, SE = 1.33) than that of EngMonoS (M = 59.72%, SE = 1.33) (β = -1.21, t = -3.60, p < 0.001). In addition, type of speakers interacted with initial primary stress (β = -0.66, t = -2.36, p = 0.01). Post-hoc pairwise comparisons showed that the difference in the rate of glottal phonation between EngMonoS and HS was greater in syllables with primary stress (p < 0.001) than in syllables without primary stress (p = 0.04). Initial primary stress significantly predicted rate of glottal phonation (β = 2.01, t = 2.04, p = 0.04), confirming that words with primary stress in the initial syllable are more likely to show glottal phonation (M = 77.77%, SE = 2.22) than words without primary stress in the initial syllable (M = 29.89%, SE = 1.21). With respect to consonant type, sequences with coda /n/ (M = 38.51%, SE = 1.62) were less likely to be glottalized than those with /l/ (M = 61.05%, SE = 1.61) (β = 2.02, t = 12.12, p < 0.001) and /s/ (M = 58.76%, SE = 1.59) (β = 1.74, t = 11.46, p < 0.001). Consonant type effect was not conditioned by any of the other variables.

5.5.1.2 The effects of Spanish input and output in the HS' rate of glottal phonation

Two separate models were run to examine whether the amount of Spanish input or output predicts rate of glottal phonation in the English of the child and adult HS (N = 1425). In the two models, input or output were entered as fixed effects, along with initial primary stress, age, and consonant.[10] Neither of the two models showed that input nor output significantly

[9] The model syntax was glmer(Glottal.rate ~ Consonant * Stress * Age.Group * Type.of.speaker + (1|Participant)+ (1|Word), family = "binomial").

[10] The model syntax was glmer(Glottal.rate ~ Spanish input + Primary stress + Age + Consonant + (1|Participant)+ (1|Word), family = "binomial") and glmer(Glottal.rate ~ Spanish output + Primary stress + Age + Consonant + (1|Participant)+ (1|Word), family = "binomial").

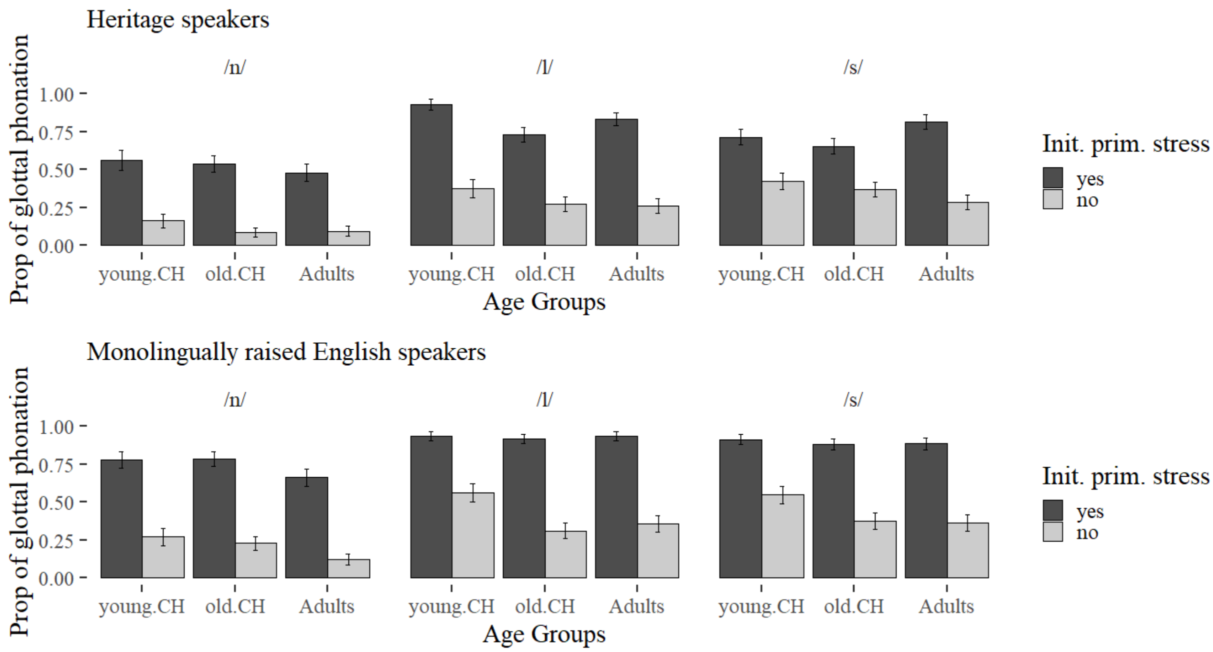


Figure 5.7: Proportion of glottal phonation by age, type of speaker, consonant, and stress in English real words

predicted rate of glottal phonation. The effects of stress and consonant were replicated, in that words with initial primary stress were significantly more glottalized than words without initial primary stress in the model for input ($\beta = 2.97$, $z = 12.18$, $p < 0.001$) and the model for output ($\beta = 2.97$, $z = 12.18$, $p < 0.001$). Vowel-initial words following /n/ showed lower rates of glottal phonation than those following /l/ (model input: β =-1.96, z = -6.85, $p <$ 0.001, model output: β =-1.96, z = -6.85, $p < 0.001$) or /s/ (model for input: β =-1.77, z = -6.26, $p < 0.001$, model for output: β =-1.77, z = -6.26, $p < 0.001$). No first order effect of age was found in any of the models.

5.5.2 Novel words

5.5.2.1 Rate of glottal phonation in HS: comparing with monolingually raised English speakers

Out of the 1034 derived onsets produced, 142 tokens were removed due to pauses longer than 150 ms, non-target-like production of the content word (i.e., adding a consonant as the onset of the content word, such as *baboons*), non-target-like production of the sequence (i.e., *all of the egoons*) or creaky phonation throughout the complete sequence. The remaining 892 tokens were submitted to a mixed effects logistic regression with initial primary stress (i.e., yes, no), age (i.e., younger children, older children, adults), type of speaker (i.e., HS, EngMonoS) and their interactions as fixed effects. As in the previous models, participant and word were allowed to have random intercepts.[11]

Figure 5.8 showed that EngMonoS produced a higher rate of glottal phonation (M = 78.71%, SE = 1.84) than HS (M = 56.79%, SE = 2.46%) (β = -1.64, t = -3.60, $p < 0.001$). In addition, vowel-initial words with initial primary stress were more likely to be glottalized (M = 85.06%, SE = 1.75) than vowel-initial words without initial primary stress (M = 56.86%, SE = 2.26) (β = -2.21, t = -5.93, $p < 0.001$).

In regard to interactions, the effect of type of speaker was conditioned by age (i.e., older children β = -2.26, t = 1.97, $p < 0.04$). After releveling the model (i.e., older children), an interaction between age and type of speaker was also found with the adult EngMonoS (β = 3.03, t = 2.91, $p < 0.001$). Pairwise comparisons showed no significant differences between younger child EngMonoS (M = 81.20%, SE = 3.4%) and younger child HS (M = 65.00%, SE = 4.37%) (β = 1.15, z = 1.37 p = 0.74), as well as between adult HS (M = 57.97%, SE = 4.21%) and adult EngMonoS (M = 66.09%, SE = 3.69%) (β = 0.37, z = 0.52, p = 0.99). On the contrary, older child HS (M = 48.70%, SE = 2.32%) produced lower rates of glottal

[11] The model syntax was: glmer(Glottal.rate ~ Primary stress * Age * Type of speaker + (1|Participant)+ (1|Word), family = “binomial”).

phonation than older child EngMonoS (M = 88.71%, SE = 2.33%) ($\beta = 3.41$, $z = 4.40$, $p < 0.001$).

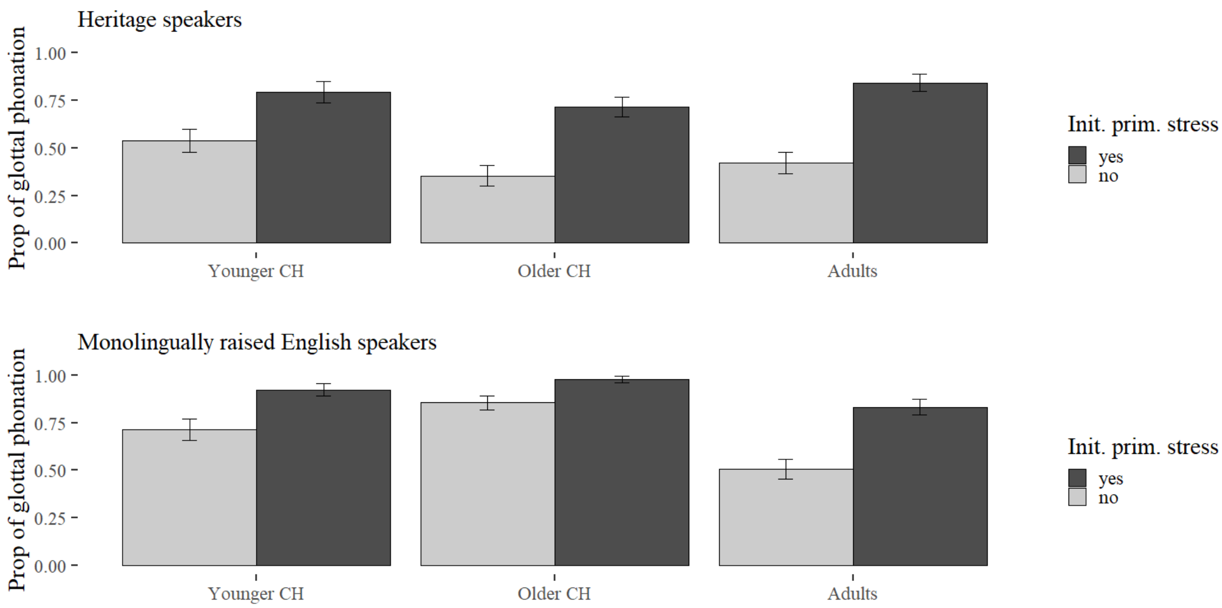


Figure 5.8: Rate of glottal phonation in HS and EngMonoS novel words in English

5.5.2.2 The effects of Spanish input and output in the HS' rate of glottal phonation

The data for the HS was subset to examine the effect of Spanish input and output in the rate of glottal phonation (N = 416). In each model the variables of Spanish input/output, age (i.e., younger children, older children, adults), and initial primary stress (i.e., yes, no) and their interactions were entered as fixed effects. Participant and content word were allowed random intercepts. [12]

Neither of the models showed that amount of language input or output was a significant predictor of rate of glottal phonation. Stress showed a main effect ($\beta = 2.66$, $z = 7.61$, $p <$

[12]The model syntax was: glmer(Glottal.rate ~ Spanish input / Spanish output + Primary stress + Age + (1|Participant)+ (1|Word), family = "binomial").

0.001), but no main effect for age was found.

5.5.2.3 The effects of the lexicon in the HS' rate of glottal phonation

The /l/-coda tokens for this analysis were a subset from the real words' data set (N = 924). A generalized logistic regression was run with the variables age (i.e., younger children, older children, adults), initial primary stress (i.e., yes, no), and type of word (i.e., real words, novel words) and the interactions between age, type of speaker and type of word as fixed effects. The intercept was allowed to differ by participant and word.[13]

With regard to main effects, my results showed that EngMonoS produced a higher rate of glottal phonation (M = 72.50%, SE = 1.44%) than HS (M = 56.10%, SE = 1.70%) (β = -1.10, t = -3.51, $p < 0.001$). As in the other models, stressed syllables were also more often glottalized (M = 86.34%, SE = 1.16) than unstressed syllables (M = 49.79%, SE = 1.62) (β = -2.90, t = -10.29, $p < 0.001$). A main effect of age (i.e., older children) showed that younger children produced a significantly greater rate of glottal phonation (M = 71.77%, SE = 2.00%) than older children (M = 62.97%, SE = 1.84%) (β = -0.78, t = -2.03, $p < 0.04$).

While my results did not show a main effect in type of word, it showed a significant interaction between type of word and stress (β = 1.81, t = 3.24, $p < 0.001$), indicating that the difference in glottal phonation between levels of stress was moderated by type of word (i.e., real and novel word). Pairwise comparisons showed that the difference in glottal phonation between the two levels of stress was greater for real words (β = 3.80, t = 9.32, $p < 0.001$) than for novel words (β = 1.99, t = 5.19, $p < 0.001$).

Moreover, type of word interacted with age (i.e., adults) (β = 1.16, t = 2.72, $p < 0.001$). Pairwise comparisons indicated that that only older children showed a significant difference between the novel and the real words (β = -1.25, t =-3.41, $p < 0.001$).

[13]The syntax for the model was: glmer(Glottal.rate ~ Stress * Age.Group * Type.of.Word *Type.of.speaker + (1|Participant)+ (1|word), family = "binomial").

A tendency towards significance was found in a three-way interaction between type of speaker, age, and type of word (β = -1.49, z =-1.75, p = 0.07). Pairwise comparisons demonstrated that, in the rate of glottal phonation between real and novel words was only significant for the EngMonoS (β = -2.16, z =-4.11, p = 0.002).

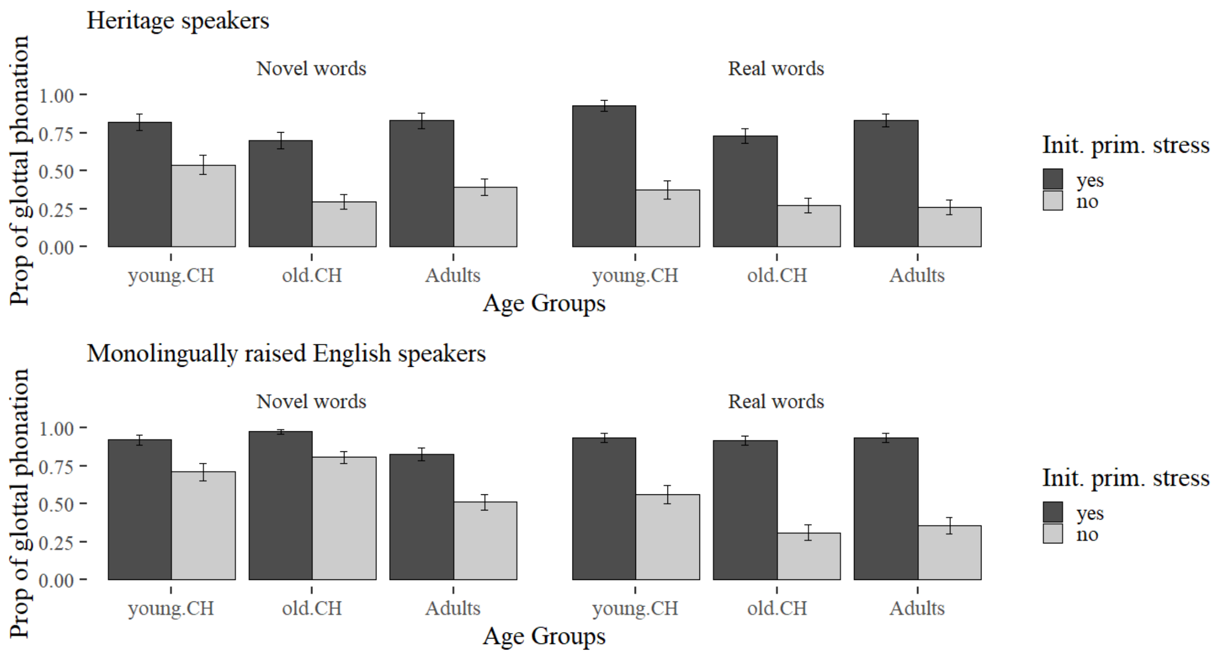


Figure 5.9: Proportion of glottal phonation by age, type of speaker and type of word in English

5.6 Discussion

5.6.1 Spanish

5.6.1.1 Assessing majority-to-heritage language transfer during language development

In my research questions, I asked whether Spanish HS present greater rates of glottal phonation than those of monolingually raised Spanish speakers and, if so, whether the higher rates are moderated by age. For real words, my findings showed that younger child HS and older children produced a greater rate of glottal phonation than their monolingually raised peers (younger child HS $M = 37.56\%$, younger child SpanMonoS $M = 1.56\%$, older child HS $M = 21.37\%$ older child SpanMonoS $M = 1.58\%$). No significant difference in the rate of glottal phonation was found between the two adult groups (adult HS $M = 9.76\%$, adult SpanMonoS $M = 2.42\%$). Furthermore, recall that the monolingually raised Spanish speakers produced an overall low proportion of glottal phonation. Thus, the comparatively higher rate of glottal phonation produced by child HS indicates that child HS are using English-like phonology to repair empty onsets. In other words, a constraint forbidding segmental (i.e., DEP) bears less weight in child HS' grammars than in the grammars of the monolingually raised Spanish speakers. While not reaching statistical significance, among the groups of children, younger children show slightly higher rates of glottal phonation than older children. These findings open up two possibilities, namely delayed development of resyllabification or stronger cross-linguistic transfer of glottal phonation. In the former hypothesis, we should consider that delayed development necessitates for evidence in the monolingually raised children of a stage in which words with primary stress are glottalized to a larger extent than words without primary stress. Although stress turned out to be a significant predictor for rate of glottalization in my results for SpanMonoS in Chapter 3, an interaction between stress and age was not supported by my data. At this point, I do not exclude the possibility that a larger sample size could support this interaction. As it stands, when compared to adult SpanMonoS, my data does not provide evidence for a period in which monolingually raised children show greater rates of prosodically-conditioned glottal phonation (younger children $M = 1.56\%$, older children $M = 1.67\%$, adults $M = 2.42\%$).

As we are entertaining the possibility of delayed development for HS, it is possible, that this same stage occurs before age 5 in monolingually raised Spanish-speaking children. In this regard, Lleó (2016) found an initial stage in which Spanish-speaking monolingual children show glottal phonation (around 2 years of age), but no information is provided as to whether vowel-initial glottalization in this stage is conditioned by prosodic prominence. For this reason, further research is needed in younger Spanish-speaking monolingual children to examine whether prosodic-prominence conditioned vowel-initial glottalization is, indeed, a developmental stage in monolingual speech production. The second possibility is that children are more likely to evaluate word junctures with English-like phonology (i.e., prosodic-prominence conditioned vowel-initial glottalization) than adults. This would indicate that child grammars are more permeable to language transfer than adult grammars. This hypothesis would be fully supported if my findings also showed that child HS present a greater rate of language transfer than adult in their English grammars (i.e., lower rates of glottal phonation). My findings for English did not show an interaction between type of speaker and age group. Nevertheless, when comparing the estimated marginal means using the package *emmeans* (Type of speaker + Age Group), the pairwise comparisons showed that children presented larger coefficients (younger children; $\beta = 1.38$, $p = 0.18$, older children = $\beta = 1.28$, $p = 0.17$) than the adults ($\beta = 0.79$, $p = 1.28$, $p = 0.76$). Therefore, I argue that my findings most likely support an explanation of asymmetrical degrees of language transfer during grammar maturation (childhood > adulthood). These results, however, should be taken with caution, as the effect of age did not consistently appear in all the models (i.e., model of input).

5.6.1.2 The effects of Spanish input and output in the rate of glottal phonation

With regard to language exposure, amount of output, but not input, was found to be a predictor for glottal phonation in the real words ($p = 0.02$). This suggests that 'hearing' a language (i.e., input) is not enough to show patterns from non-heritage grammars. Instead, higher frequency of speech production in the heritage language reduces the likelihood of majority-language transfer. My results are supported by previous evidence in the syntactic and semantic domains showing that input and output have independent contributions in bilingual children's language proficiency, and that output showed a symmetrical predicting power for Spanish and English morphosyntactic and semantic screening test scores (Bohman et al., 2010). In particular, Bohman et al. (2010) notes that the different contribution of input and output as predictors in their dependent variables suggests that "using a language (i.e., output) forces the learner to process the language in a way that only hearing it (i.e., input) does not" (Bohman et al., 2010, p.339).

Moreover, language processing could explain the differential effect of input and output in heritage grammars, as already suggested in Polinsky and Scontras (2020). When producing speech in the heritage language, speakers may gain practice in allocating cognitive resources to the processing tasks in bilingual speech production, such as language inhibition. The more they practice, the more likely will they be to successfully inhibit the majority language during heritage language production. Another possibility to explain my results would rest on articulatory factors. First, recall that although child SpanMonoS produce modal phonation in /C#V/ sequences, consonant duration is not adult-like between the ages of 5 and 8. This means that, even children raised in a Spanish-speaking country need some years of speech production to achieve adult-like connected speech. Child HS with less output will have fewer opportunities to adjust the consonant-to-vowel tongue movements and might resort to glottal phonation for a longer time. Glottal phonation has the articulatory advantage of not involving tongue gestures, which may give extra time to the speakers to prepare for the next vocalic segment. In addition, for child HS, glottal phonation is already very salient in their English phonology. A late development of Spanish-like articulation in child HS has already been found for the trill, a typically late-developing sound (Menke, 2018; Repiso-Puigdelliura & Kim, 2021).

Apart from the direct effects of language output on the child HS' articulatory or phonological representations, a child's own output may also predict target-like production in the heritage language because it can be a proxy of identity in the heritage language, which promotes heritage language maintenance. As highlighted by Serratrice (2020), child HS have a choice of speaking one of their two languages, and by exercising their choice they are also affirming their identity and agency, which could have implications in heritage language maintenance (Serratrice, 2020, p. 47)

5.6.1.3 Listener-oriented predictability in the novel words

My results for novel words showed that younger and older child HS demonstrated greater rates of glottal phonation than their monolingually raised counterparts (younger child HS M = 52.03%, younger child SpanMonoS M = 11.45%, older child HS M = 36.76%, older child SpanMonoS M = 23.53%). As in the case of the real words, the two adult groups did not show a significant difference in their rate of glottal phonation (adult HS M = 28.38%, adult SpanMonoS M = 20.86%). Unexpectedly, while the rate of glottal phonation decreased across the three age periods in the HS' grammars, it increased in the grammars of the monolingually raised Spanish speakers. This indicates that the rate of glottal phonation may be affected by different processes in the SpanMonoS and the HS' grammars. I sustained in Chapter 3, that the grammars of the monolingually raised Spanish speakers are affected by a predicatbility-based process, encouraging older children and adults to enhance the boundaries of the prosodic words. The decreasing rate of glottal phonation across groups in the HS' grammars, however, is similar to the pattern observed in the EngMonoS, at least between childhod and adulthood. This would suggest that the behaviour in the HS' grammars may be rather explained by heritage-to-majority language transfer.

5.6.2 English

5.6.2.1 Assessing heritage-to-majority language-transfer

My findings for English show that, for both the real and novel words, HS demonstrate a lower proportion of glottal phonation (real words = 46.33%, novel words = 59.40%) than that of monolingually raised English speakers (real words = 59.72%, novel words = 79.62%). However, in the novel words, the main effect is conditioned by age. This interaction will be discussed in the next section.

The main effect of type of speaker in the real words supports the hypothesis of heritage-to-majority language transfer (i.e., Spanish to English language transfer). That is to say, the HS' production of English /C#V/ sequences is influenced by the Spanish-like low probabilities of /ʔ/-epenthesis in the output. This scenario supports bidirectional transfer in the grammars of HS. Nevertheless, the strength of language transfer does not seem to be not symmetrical. When comparing the English and Spanish grammars, the difference in the rate of glottal phonation between the HS and the monolingually raised speakers (see Table 5.1), is greater in Spanish in 4 out of the 6 grammars. This suggests that the heritage language shows a greater influence from the majority language than vice versa. This result is not surprising, as findings in the bilingual literature show that the societal language is less affected by language transfer than the heritage language (Llama & López-Morelos, 2016)

Δ(HS, Mono)	**English**	**Spanish**
younger children	real words = -14.61% novel words = -20.76%	real words = +36.24% novel words = +40.58%
older children	real words = -14.62% novel words = -42.97%	real words = +19.68% novel words = +13.23%
adults	real words = -9.20% novel words = -3.62%	real words = +7.78% novel words = -7.52%[14]

Table 5.1: Difference in the rate of glottal phonation between heritage speakers and monolingually raised speakers

5.6.2.2 The effects of age in heritage-to-majority language transfer

While I found no interaction between type of speaker and age in the real words, the novel words showed that the difference between HS and EngMonoS only reached significance in

[14] In this case, the SpanMonoS produced a greater rate of glottal phonation (28.37%) than the HS (20.86%).

the group of older children. When comparing the mean percentages of glottal phonation, the results demonstrate that younger children produce a similarly high rate of glottal phonation in the group of EngMonoS (M = 81.68%) and in the group of HS (M = 65.00%).[15] In the second age cohort (i.e., older children), HS decrease their rate of glottal phonation to 53.37% but EngMonoS increase theirs to 91.48%. That is to say, while HS are learning to produce word-external junctures with modal phonation at similar rates as adult speakers (EngMonoS M = 66.09%, HS M = 61.44%), monolingually raised children present a U-shaped behaviour. On the one hand, as discussed in Chapter 4, the EngMonoS may present this developmental pattern because, around 8 years of age, they may have created a second set of constraints to evaluate prosodically-prominent words, for which they now have less evidence of modal phonation in their input. The older child HS, on the other hand, may update the prosodically-prominence-driven constraints with evidence of modal phonation from Spanish, or may evaluate their English input partly using Spanish-like constraint weights. In the first case, the pressure of the heritage language would result in acceleration in the HS' English grammar during language acquisition, because HS would use Spanish input to evaluate the English constraints (i.e., more evidence of modal phonation in the Spanish input than in the English input). In the second case, this superficial acceleration would be a result of the HS' use of the Spanish constraint weights to evaluate English input (i.e., partial activation of the Spanish constraint weights when evaluating English grammar). These two hypotheses have different implications for heritage language modeling. In the first one, a model of heritage language acquisition should formalize a device by which the English grammar can update the English-specific constraint weights using evidence from the Spanish input. One possibility is that random noise in the grammar causes misclassification of the Spanish input as belonging to the English grammar. Another possibility is that there is partial activation of the English weights when evaluating the Spanish input. In the second hypothesis, the cross-linguistic

[15]It is possible that the post-hoc pairwise comparisons could not find a significant difference in the two estimated marginal means due to lack of power, because the main model did not show an interaction between younger children and older children.

interaction does not arise during acquisition, but rather during input evaluation. In this case, a model of heritage language production should incorporate a mechanism by which both Spanish and English weights are active during input evaluation.

The effects of age, however, were not found in the real words. In addition, the model comparing the real and the novel words showed that only the older children (i.e., HS and EngMonoS) produced higher rates of glottal phonation in the novel words (EngMonoS $M = 91.48\%$, HS $M = 53.37\%$) than in the real words (EngMonoS $M = 60.79\%$, HS $M = 50.00\%$). This indicates that only older children were sensitive to the effect of the lexicon. More specifically, as reported above, the difference in the rate of glottal phonation was higher in the EngMonoS than in the HS. Although my model did not support a statistically significant three-way interaction, it showed a marginal tendency towards significance ($p = 0.09$). This suggests that the effect of age in the novel words may have been a byproduct of the increased sensitivity in the evaluation of the novel words by the older child EngMonoS. It is possible, however, that this increased sensitivity in the group of older child EngMonoS is an artifact of the sample of participants selected for this experiment. For this reason, future research should replicate this study with a different population to examine whether the present sample of 8-to-11 year olds in the EngMonoS are, indeed, a representative sample of the bigger population.

Furthermore, the fact that age did not moderate the rate of glottal phonation in the real words or that input / output did not turn out to be significant predictors of glottal phonation in the HS suggests the possibility that influence from Spanish does not arise at the individual level, but rather at the community level. This hypothesis would be supported by studies on Chicano English showing that this dialect is influenced by a Mexican Spanish substrate (e.g., greater monophthonguization of vowels, lesser vowel reduction, Spanish-like place of articulation of stops, such as apico-dental production of alveolar stops)(**Ana2008ChicanoPhonology**; Fought, 2003) If this was the case for the production of /C#V/ sequences, lower rates of glottal phonation would be found in Chicano English when compared to other varieties of American English. To tease these two hypotheses apart, further studies should exclusively examine the speech of Chicano English speakers with little productive knowledge of Spanish. Although ethnicity was not included as part of the study's questionnaire, it is unlikely that the participants in this study are speakers of Chicano English, as they reported not to be raised in Spanish-speaking families. However, the lack of information about the participants' ethnicity is a limitation of this study that should be addressed in the future.

I now turn to discuss the effects of the lexicon and their relationship with HS. When comparing the rate of glottal phonation in the real and novel words, my results did not show an interaction between type of word and type of speakers, indicating that the effects of the lexicon do not affect differently the HS than the EngMonoS. That is, my results do not support a hypothesis in which the grammar for newly encountered words is more likely to be subject to cross-linguistic transfer than the grammar for real words.

5.7 Conclusion

The results of this study shed some light into the phonology of child and adult HS. For the experiments in Spanish, my findings indicate that child HS, but not adults, produce a greater rate of glottal phonation than the monolingually raised Spanish speakers in Mexico. These results align with previous studies providing evidence for majority-to-heritage language transfer (Amengual, 2012; Elias et al., 2017; Kim, 2020; Kim & Repiso-Puigdelliura, 2021; Lleó, 2016b; Ronquest, 2013; Shelton et al., 2017, among others). I argue that the higher prominence of glottal phonation in the child HS could be due to a greater permeability of child grammars to majority language phonological properties. In addition, the amount of Spanish output is negatively correlated with the rate of glottal phonation. Language processing effects, such as untrained inhibitory skills, and lack of habitual heritage language articulation may explain higher glottal phonation rates in the speech of some heritage speakers, compared to that of the monolingually raised speakers.

For the experiments in English, HS present a lower rate of glottal phonation than that of the English monolinguals. In the novel words, however, this effect is conditioned by age, as only older child HS present a lower rate of glottal phonation than older child EngMonoS. The rate of glottal phonation is not conditioned by language exposure or use in any of the experiments. The lack of a uniform effect of language exposure and use precludes the opportunity of firmly identifying a possible source of individual variation. In consequence, I hypothesize that these findings could be a result of heritage-to-majority language transfer at the individual level, or a result of contact-induced language change at the societal level (i.e., Chicano English).

My results contribute to the field of heritage language phonology by putting forth the importance of examining the HS' two grammars. We can build better models of heritage grammars if we account for the pressures exerted by both the heritage and the majority languages. Moreover, my study has shed some light on the trajectory of majority language transfer across the HS' lifespan. It is important to continue the practice of studying HS with cross-sectional designs to better understand the effects of language transfer in developing grammars to design stronger curricula during primary school for heritage language maintenance.

CHAPTER 6

Coactivation of the Spanish HS' grammars: the case of repairs of empty onsets in Spanish and English

6.1 Introduction

As in the case of monolingual phonological acquisition, bilingual acquisition also requires a model that allows for probabilistic learning. Lleó (2016a, s. 2.6) posits that modeling interaction in absolute categories as proposed in Paradis and Genesee (1996) seems to be "insufficient to explain a rather stochastic acquisition model in which some phonological areas are more prone to interaction (more vulnerable) than others (more resilient)". For this reason, I continue to use weighted constraints to formalize bilingual language acquisition. In the first part of this chapter, with the aim of comparing the constraint weights from the monolingually raised Spanish and English speakers, I model the experimental results from Chapter 5 using the formalization introduced in Chapter 4. Considering that a model for Spanish HS should take into account speaker-specific degrees of language dominance (i.e., as shown by the effects of output in Chapter 5) and link the constraints of the grammar to the maturation of the executive function (i.e., as shown by the effects of age in Chapter 5), in the second part of this grammar, I propose a model for Spanish heritage grammars based on the Gradient Symbolic Computation framework (Smolensky et al., 2014; Smolensky et al., 2020) and on Goldrick et al.'s (2016) proposal of coactivation in bilingual grammars.

6.2 Candidates and the constraint set

To evaluate the Spanish heritage grammars in comparison to the American English monolingual grammars and the Spanish non-heritage grammars, I fitted the grammars with the same set of constraints used in Chapter 4 and assuming the same candidates for each input. As in Chapter 4, the aggregated probabilities for the candidates with /ʔ/-epenthesis were drawn from the annotated data in the experimental section of this chapter. To label the tokens containing modal phonation as being coda candidates or resyllabified/ambisyllabic candidates, I used the same strategies presented in the Sections 4.2.3.6 and 4.2.3.3 in Chapter 4. For Spanish, the distributions for /l#C/ and /V#l/ are shown in Figure 6.1. As in the reference distributions for the monolingually raised Spanish speakers, the HS' distributions show overall higher means and standard deviations in the children group than in the group of adults.

For English, I ran fuzzy clustering with the /l#V/ and /l#C/ tokens produced with modal phonation by the adult HS and those produced with modal phonation by the child HS. Table 6.1 shows that the /l#V/ tokens in the adult HS and child HS demonstrate a 10% difference in the mean probabilities of belonging to the ambisyllabic-like cluster or the coda-like cluster. This resulted in 24 tokens were classified as coda and 34 as ambisyllabic in the adult HS, and 53 tokens classified as coda and 64 as ambisyllabic in the child HS.

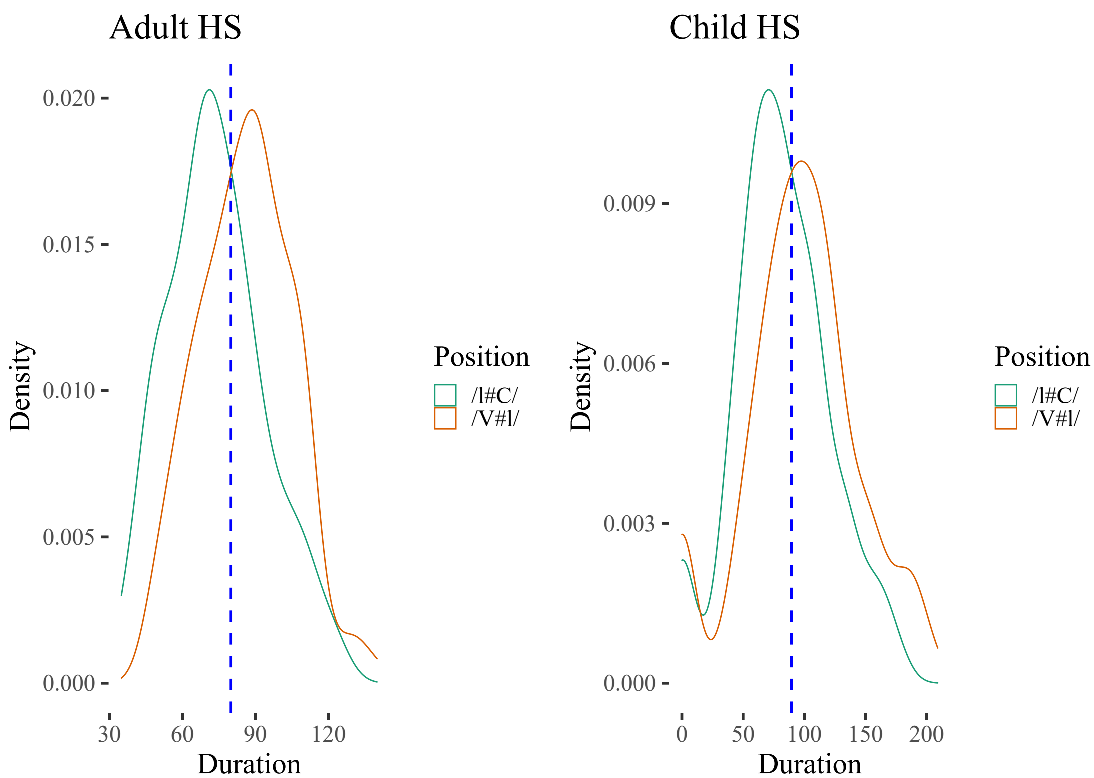


Figure 6.1: Density plots of target consonant duration in /V#l/ and /l#C/ position for the child and adult HS

Adult HS	M prob coda-like cluster	M prob. ambisyllabic-like cluster	Fuzzy sil. index
/l#V/	0.44	0.55	0.72
/l#C/	0.69	0.31	
Child HS			
/l#V/	0.45	0.55	0.79
/l#C/	0.63	0.37	

Table 6.1: Mean probabilities for the tokens in each distribution to fall within each one of the clusters and fuzzy silhouette indices.

For each group, the cluster with the lowest mean (adult EngMonoS M = -2.86, child

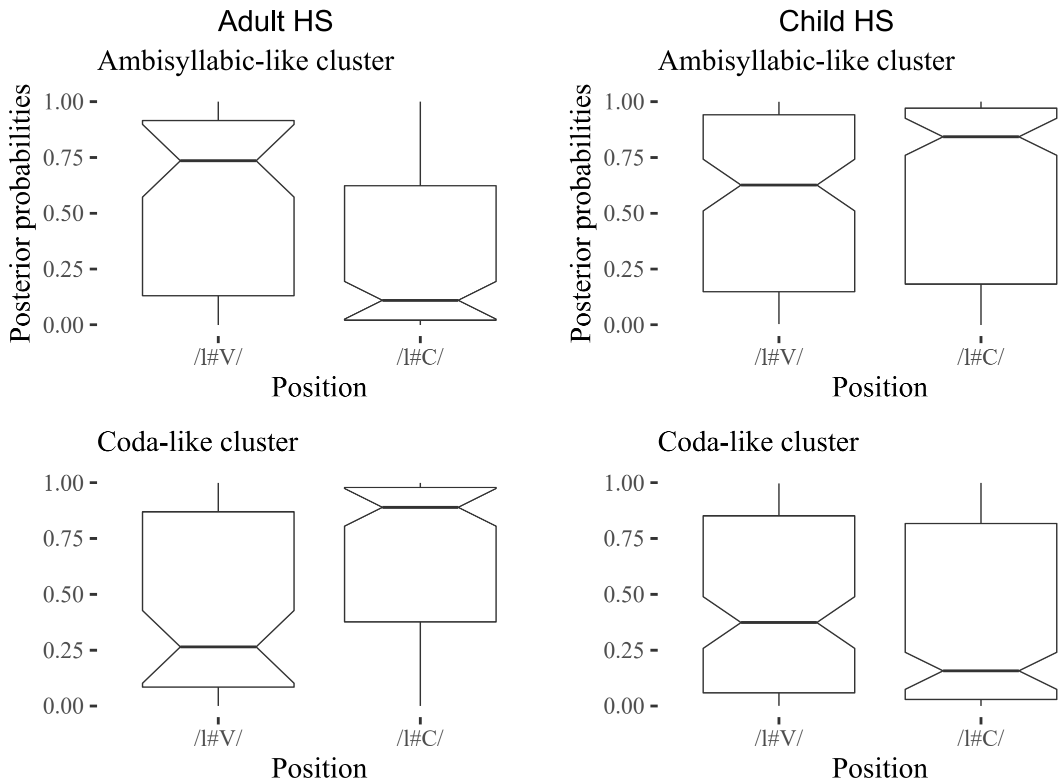


Figure 6.2: Posterior probabilities of fuzzy clusters (ambisyllabic-like and coda-like clusters) per in the HS' groups

EngMonoS M = -0.48) was considered to be coda-like and the cluster with the highest mean (adult $M = 0.78$, children $M = 1.70$) was considered to be ambisyllabic-like. The ambisyllbic tokens were assigned to the cluster for which they demonstrated higher probability. Table 4.6 shows that /l#V/ tokens were more likely to fall within the ambisyllabic-like cluster in the adult EngMonoS than in the child EngMonoS, which resulted in 39 tokens labeled as ambisyllabic and 20 as coda in the adult EngMonoS, and 18 tokens labeled as ambisyllabic and 28 as coda in the child EngMonoS. Recall that the overall low number of tokens in English produced with modal phonation is due to the fact that the majority of /l#V/ productions were classified as containing glottal phonation.

6.3 Spanish grammars of Spanish heritage speakers

Three MaxEnt grammars were fitted using Excel Solver and a weak prior was entered in the three grammars (i.e., $\mu = 0$ and $\sigma = 1000$). KL divergences were 0.12 for younger child HS, 0.55 for older child HS, and 0.28 for adult HS. Compared to the SpanMonoS' groups, the higher KL-divergences of the HS may be a result of higher intra-token variation in the HS. Figure 6.3 shows the predicted probabilities for the Spanish HS' grammars (left) next to those for the SpanMonoS' grammars (right) (see Chapter 4). As for the general patterns in the grammars, the results for the HS show a decreasing tendency in the predicted probabilities of /ʔ/-epenthesis as grammars mature. This pattern, however, is not found in the SpanMonoS' grammars, as the rate of glottal phonation increase with age. With regard to stress, the HS' grammars show higher predicted probabilities of /ʔ/-epenthesis in the stressed vowel-initial words than in the unstressed vowel-initial words. This is similar to the pattern found in the SpanMonoS' grammars.

The predicted probabilities for the resyllabified candidates decline with age in the HS's grammars, similar to the pattern observed in the SpanMonoS' grammars. Lastly, the probabilities for the coda candidates increase with age in the HS' grammars, which is also a behaviour observed in the Mex'S grammars.

6.3.1 Glottal stop epenthesis

Table 6.2 shows the weights for the Spanish heritage grammars. The weight of Dep-ʔ in the Spanish heritage grammar shows a constant rise from the younger children's grammars to the adult grammars, showing the increasing dispreference of candidates with glottal phonation as grammars mature.

When subtracting the weight of Dep - ʔ to the sum of the Align-R and Onset, the results show that, with age, the weight of Dep-ʔ gains prominence with respect to the Onset and Align-R constraints and the percent difference in the weight of Dep-ʔ with respect to

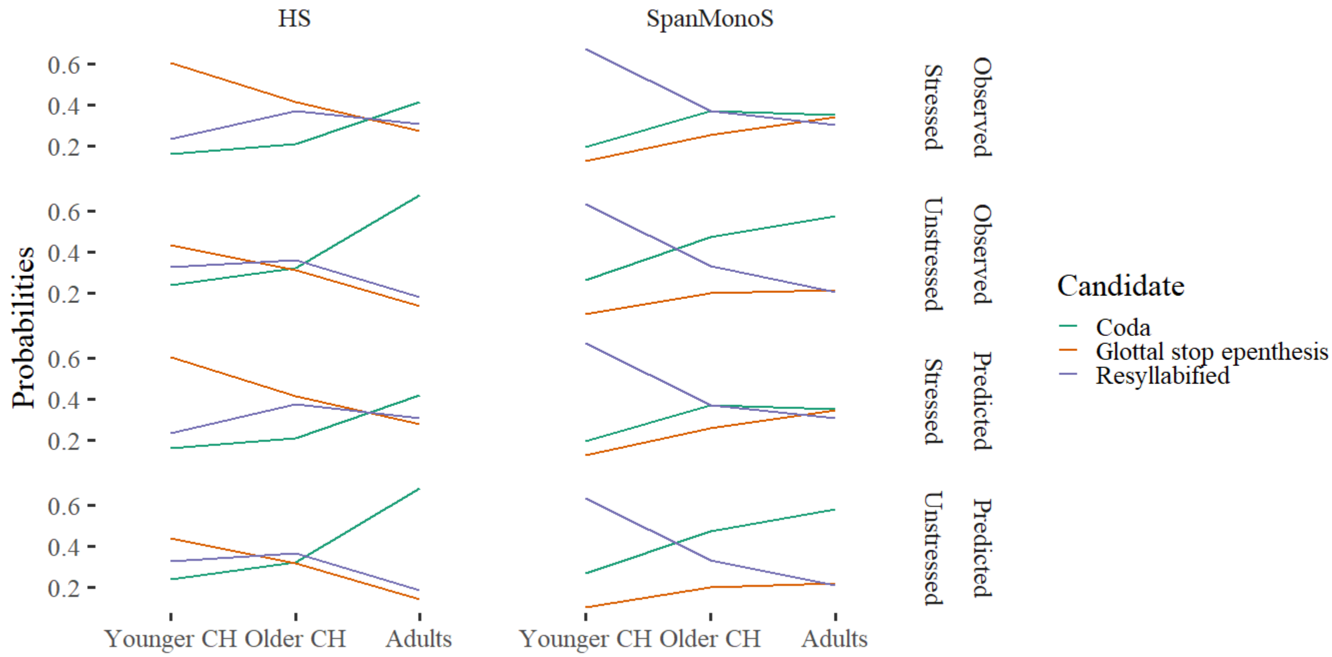


Figure 6.3: Predicted probabilities for the Spanish grammars of Spanish HS

Spanish	Dep-ʔ	Align-R (σ, ω)	Onset	Onset/ˈσ_{Initial}	[*Onset/Lat]/ˈσ_{Initial}
younger child HS	0.00	0.29	0.61	0.72	0.65
older child HS	0.76	1.09	0.50	0.00	0.01
adult HS	1.59	1.31	0.00	1.18	0.17

Table 6.2: Weights for the HS' grammars.

the sum of Onset and Align-R declines as grammars mature (see Table 6.7). That is, the weight of Dep-ʔ is 99.9% lower than the weight of the /ʔ/-epenthesis-allowing-constraints in the younger child HS, 54.91% lower in the older child HS and the percent difference decreases to 30.22% in the adult HS.

	Δ (DEP, $\sum_{n \neq DEP}^{5} C$)	Percent difference
younger child HS	-1.55	-99.9%
older child HS	-0.84	-52.70%
adult HS	+0.10	+6.78%
younger child SpanMonoS	+0.23	+14.39%
older child SpanMonoS	-0.13	-13.34%
adult SpanMonoS	-1.46	-51.93%

Table 6.3: Difference between DEP-ʔ and rest of the SpanMonoS Spanish and HS Spanish grammars and percent difference taking the sum of ONSET and ALIGN-R as the reference.

When compared to the grammars of the monolingually raised Spanish speakers, the relative weight of DEP - ʔ in the Spanish heritage grammars is lower in the younger child HS and older child HS, but higher during adulthood, demonstrating that the grammars of adult SpanMonoS penalize /ʔ/-epenthesis less than the grammars of adult HS. Recall, in addition, that I have argued in Chapter 4 that adult SpanMonoS are attuned to the lexical unpredictability of novel words, which encourages them to enhance the boundaries of the prosodic words. It is possible, then, that the rates of glottal phonation in the adult HS are not guided by lexical unpredicatbility, but by an effect of transfer from the majority language. Therefore, all else being equal, the weights from the Spanish heritage grammars are not compatible with a model of heritage phonology in which the majority and the heritage language are unaffected by each other.

As shown in Table 6.4, adding the stress-driven constraints to the model only significantly improved the fit of the older child HS.

	Basic model	Full model (+ stress-driven C)
younger child HS	-55.37	-54.62 ($p = 0.47$)
older child HS	-86.67	-90.18 ($p < 0.001$)
adult HS	-69.08	-66.97 ($p = 0.12$)

Table 6.4: Log-likelihoods for the basic model and the full model including the stress-driven constraints for the HS' Spanish grammars

6.3.2 Codas and resyllabified consonants

The results for the models showed that HS show a decreasing tendency in the predicted probabilities for resyllabified consonants (see Table 6.5). When compared to the SpanMonoS group, the HS demonstrate smaller differences in the predicted probabilities between the resyllabified and the coda consonants. Moreover, adult HS have a stronger preference for coda consonants than adult SpanMonoS. That is, although HS show a similar developmental pattern compared to that of SpanMonoS, the former group present an overall higher preference for codas than for resyllabified consonants.

	Pred. prob. $ˈ\sigma$	Mean obs. $ˈ\sigma$	Pred. prob. σ	Mean obs. prob. σ
younger child HS	0.23	0.23	0.32	0.32
older child HS	0.23	0.22	0.24	0.29
adult HS	0.31	0.31	0.18	0.18
younger child SpanMonoS	0.67	0.67	0.63	0.63
older child SpanMonoS	0.37	0.37	0.33	0.33
adult SpanMonoS	0.30	0.30	0.21	0.21

Table 6.5: Proportion of predicted and observed probabilities for resyllabified consonants out of the consonants produced with modal phonation. $ˈ\sigma$ for initial stressed syllables and σ for initial unstressed syllables

From a phonological perspective, the overall preference for codas in the HS' group could be explained as a transfer of the preference for codas in the English grammars to the Spanish grammars. That is, HS may assign higher weights to ALIGN-R than to ONSET. Phonology itself, however, is not the only explanation available to account for the greater preference of codas in the Spanish of HS. Instead, the phonetics-phonology interface could provide insights into this pattern. Unlike SpanMonoS, HS are exposed to two strategies to link the hidden structure to the surface structure (e.g., segment duration, degree of darkness in the case of /l/). Since resyllabification results in ambiguous strings in very few cases (i.e., /mi.lo.las/ 'a thousand waves' /mi.lo.las/ 'my Lolas'), linking resyllabification to degree of darkness (i.e., as in English), and not duration, would not translate into regular breakdowns in communication. In consequence, it is possible that HS link resyllabification to more than one phonetic correlate. If this was the case, the tokens labelled as codas in my data should be re-analyzed. Perception studies, similar to that of Lahoz-Bengoechea and Jiménez-Bravo (2020) investigating whether listeners rely on duration to parse ambiguous resyllabified utterances, should investigate whether HS also rely on English-like acoustic correlates to parse syllabic misalignments.

6.4 English grammars of Spanish heritage speakers

I fitted three separate MaxEnt grammars using Excel Solver and a weak prior (i.e., $\mu = 0$ and $\sigma = 1000$). The best fitted grammar was that of the younger child HS (KL = 0.08), followed by that of the older child HS (KL = 0.14) and adult HS (KL = 0.24). Figure 6.4 shows the predicted probabilities for the English HS' grammars (right) and those of the EngMonoS' grammars for comparison (left) (see Chapter 4). with respect to general patterns in the grammars, the predicted probabilities for /ʔ/- epenthesis in the HS' grammars in English incur a decline with age, which is most noticeable in the vowel-initial words with unstressed initial syllables. The difference in the probabilities of /ʔ/- epenthesis between the stressed and unstressed is also observed in the EngMonoS, albeit they older child EngMonoS present a slight increase in the predicted /ʔ/- epenthesis with respect to the younger child EngMonoS that is not observed in the HS. The predicted probabilities of ambisyllabic consonants increase with age both in the HS's grammars and the thr EngMonoS' grammars. Unlike the ambisyllabic consonants, the probabilities for the coda consonants decline with age in both grammars.

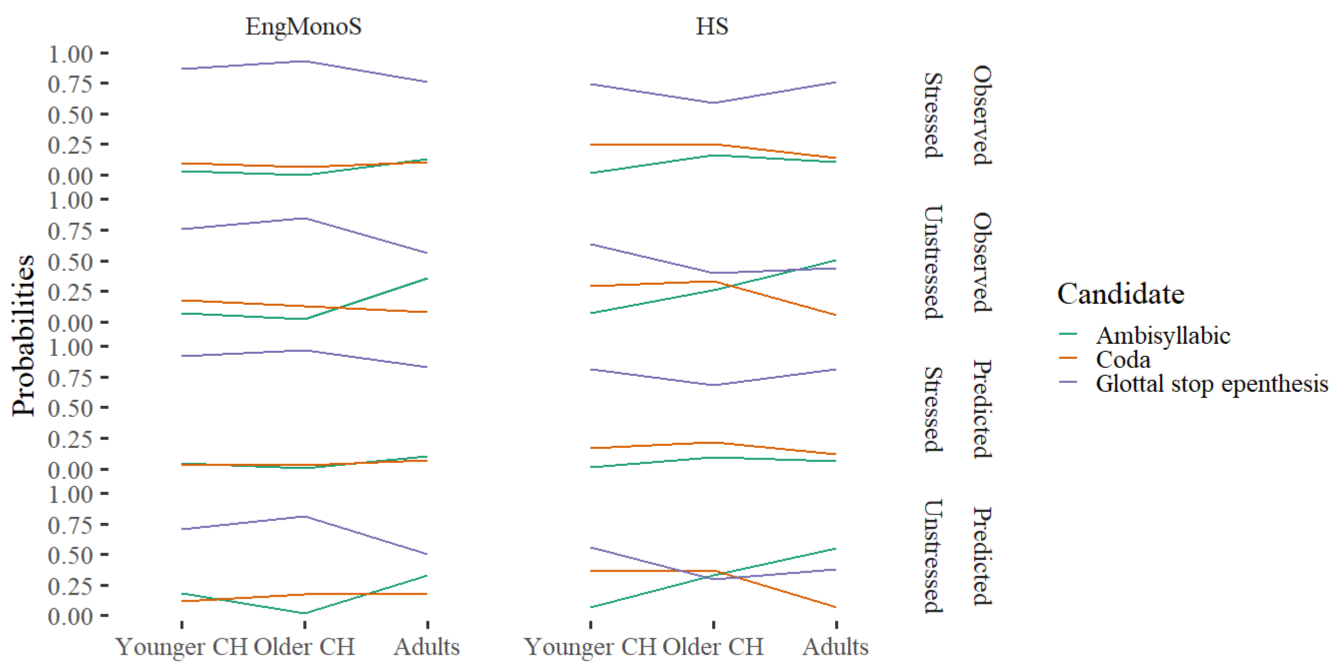


Figure 6.4: Predicted probabilities for the English grammars of the Spanish HS

The weights for each constraint are shown in Table 6.6. As a general tendency, the grammars demonstrate higher weights for Align -R (σ, stem) and Onset than for Dep-ʔ in the three grammars. In the following sections, I explore in depth the changes in the relative weight of Dep- ʔ in the grammar, the relationship between Align -R (σ, stem) and Onset, and the role of the prominence-driven constraints.

English	Dep-ʔ	Align-R (σ, ω)	Onset	Onset/ˈσ_{Initial}	[*Onset/Lat]/ˈσ_{Initial}
younger children	0.00	2.06	0.43	1.14	2.06
older children	0.29	0.20	0.07	1.37	2.05
adults	0.36	0.00	2.02	0.24	2.91

Table 6.6: Weights for the English grammars of the HS.

6.4.1 Glottal stop epenthesis

As in the previous grammars, I calculated the difference between the weight of Dep-ʔ and the weights of the rest of the constraints in the grammar, along with the percent difference taking the sum of Onset and Align-R as the reference.

First, notice that in the three grammars the difference is negative, indicating a preference for /ʔ/-epenthesis over coda and ambisyllabic candidates in the grammar (i.e., the harmony of candidates with /ʔ/-epenthesis is lower than the sum of the harmony scores for coda and ambisyllabic candidates). In the HS' grammars, the percent difference declines by 7.82% from younger child HS to older child HS, and increases by 0.77% from older child HS to adult HS, indicating greater penalties for /ʔ/-epenthesis in the younger child HS than in the older child HS or adults. Moreover, the total change in the percent difference across the three grammars is greater in the HS' groups (7.05%) than in the EngMonoS' groups (0.42%), indicating that HS' grammars attain lower rates of /ʔ/-epenthesis in the end-state adult grammars than the EngMonoS group.

	Δ (Dep, $\sum_{n \neq DEP}^{5} C$)	Percent difference
younger child HS	-5.69	99.99%
older child HS	-3.41	92.17%
adult HS	-4.80	92.94%
younger child EngMonoS	-6.42	97.34%
older child EngMonoS	-10.53	99.67%
adult EngMonoS	-4.79	96.92%

Table 6.7: Difference between Dep-ʔ and rest of the EngMonoS' English and HS' English grammars and percent difference taking $\sum_{n \neq DEP}^{5} C$ as the reference.

In the grammars of the HS's group in English, as shown in Table 6.8 adding the stress driven constraints in the grammar, significantly improved the grammars of the older child HS ($p = 0.001$) and that of the adult HS ($p < 0.001$). When comparing the EngMonoS' to the HS' grammars, the stress driven constraints have a similar role in the children's grammars (i.e., not significant in the younger children and significant in the older child HS and adult HS).

	Basic model	Full model (+ stress-driven C)
younger child HS	-41.21	-39.35 (p = 0.15)
older child HS	-70.10	-63.57 (p = 0.001)
adult HS	-58.09	-47.81 (p < 0.001)
younger child EngMonoS	-35.22	-32.86 (p = 0.09)
older child EngMonoS	-34.55	-30.82 (p = 0.02)
adult EngMonoS	-64.83	-60.22 (p = 0.01)

Table 6.8: Log-likelihoods for the basic model and the full model including the stress-driven constraints for the HS' English grammars

6.4.2 Codas and ambisyllabic consonants

To explore the predicted probabilities for the ambisyllabic candidates, I calculated the probability of tokens classified as ambisyllabic consonants out of the total tokens produced with modal phonation (see Table 6.9). The results show that the preference for ambisyllabic consonants increases across age groups, reaching similar values in adulthood ($M = 0.61$) compared to those of the adult EngMonoS ($M = 0.62$).

	Pred. prob. ˈσ	Mean obs. ˈσ	Pred. prob. σ	Mean obs. prob. σ
younger child HS	0.01	0.01	0.07	0.07
older child HS	0.09	0.16	0.32	0.26
adult HS	0.50	0.54	0.14	0.10
younger child EngMonoS	0.05	0.03	0.07	0.07
older child EngMonoS	0.00	0.00	0.02	0.02
adult EngMonoS	0.11	0.13	0.37	0.35

Table 6.9: Proportion of predicted and observed probabilities for ambisyllabic consonants out of the consonants produced with modal phonation. ˈσ for initial stressed syllables and σ for initial unstressed syllables in English

6.5 Coactivation in heritage grammars

After comparing the constraint weights in the Spanish HS' grammars to those of the non-heritage Spanish speakers and monolingually raised English speakers, the patterns found in my results are not compatible with a model in which there is no interaction between the speakers' two grammars. In Spanish, the HS show a tendency to increase the relative weight of DEP-ʔ in the grammar, a behavior that is not likely a result of Spanish language development (i.e., at least during late childhood), as it is not present in the monolingual grammars. It is also unlikely that it is part of the speakers' input, because my data shows that the end-state grammars (i.e., adult HS' grammars) differ from the developing grammars (i.e., child HS), and no effect of input was found in any of the models in the previous Chapter. In the English of the HS, the penalties for /ʔ/-epenthesis increase with age to a larger extent than in the EngMonoS' grammars. Although the lack of effect of age or amount of input/output in my experimental results (see Chapter 5) do not allow ruling out the possibility of a change at the dialectal level (i.e., Chicano English), for the purposes of the section, I model my results as if this exposure to Spanish was the source of the lower rates of glottal phonation in English.

Existing second language models of constraint-based grammars have assumed that learners copy the whole set of constraints in their first language, which becomes the initial state for the second language phonology (Cardoso, 2007; González & Weissglass, 2017). The learner, then, updates the weights of the second set of constraints until they acquire target-like values. A two-grammar-structure can successfully model a path of acquisition between the first language and the second language, but it does not incorporate leakage from the second language to the first language, which is specifically relevant in cases of early bilingualism.

Instead, my results are compatible with a phonological structure in which the majority language exerts some influence on the heritage language and vice-versa. In particular, a theoretical proposal for HS needs to account for the possibility of bidirectional transfer (i.e., majority-to-heritage and heritage-to-majority language transfer), the asymmetries of such transfer during language development, and consider the effects of language use on the grammars. In order to incorporate all these elements in a heritage language phonological structure, I use the Gradient Symbolic Computation framework (Smolensky et al., 2014; Smolensky et al., 2020) and its implementation for code-mixing (Goldrick et al., 2016) as a departing point.

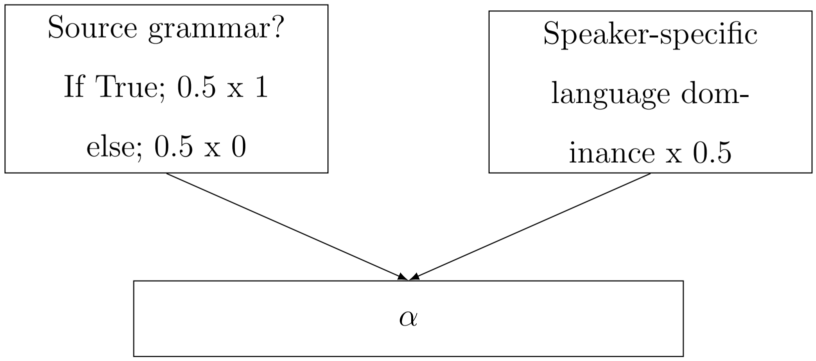
6.5.1 Proposal overview

The current proposal models language transfer as occurring during language evaluation. Following Goldrick et al. (2016), I posit that the heritage speakers' two language-specific grammars (i.e., sets of constraints) are active to a degree when the speakers retrieve the input from the lexicon. Language interaction arises when the set of constraints of the non-intended language evaluates the input in the intended language. In turn, this model assumes that language interaction does not occur during language learning. Instead, bilinguals classify each datum as correctly belonging to Spanish or English during constraint updating. In the current analysis, the language-specific constraint weights of the HS are equal to those of the age-matched monolingually raised speakers. A view stating that language interaction occurs during input evaluation, as opposed to during learning, has the strength of predicting that language interaction can vary as a function of language mode (i.e., monolingual mode vs. bilingual mode (Amengual, 2012; Elias et al., 2017).

At the time of retrieval from the lexicon, the input is connected to the two grammars to a certain degree. The degree of activation (i.e., α) of each language at the time of input evaluation is speaker-specific and is determined by the extent to which the intended language and the non-intended language are affected by grammar-external factors, such as dominance, proficiency, language exposure or use.[1] I formalize α as being weighted with whether the language is intended (0.5) and speaker-specific language dominance (0.5).

Adding to the model, the intentionality to speak the source language predicts language separation when evaluating input in Spanish or English. If α was determined only by speaker-specific dominance, input in Spanish and English would be evaluated with the same constraint weights and the candidate preferences in each language would not be respected. The results presented in Section 6.3 and Section 6.4, however, show that HS respect the language-

[1] Notice that Goldrick et al. (2016) formalize the preference for evaluating an input with the source grammar by adding the scaled language-specific constraint weights to the combined weights of the two languages. However, doubling the weight of the intended language in the current proposal leads to non-monolingual like probabilities when the intended grammar is active at 1 and the constraints are doubled.



specific preferences in each language (i.e., preference for glottal phonation in English, and preference for coda/resyllabified consonant in Spanish).

The two sets of constraint weights are active in relation to each other, which is formalized as the two α summing 1. Spanish-dominant bilinguals will have higher $\alpha_{\ Spanish}$ and English-dominant bilinguals will present higher $\alpha_{\ English}$. Each α contributes to the scaling of the constraint weights. The result of this evaluation is a blend representation as the representational states that attribute probabilities from the non-intended language to the output of the intended language.

To summarize, the proposed process by which language interaction arises is as follows:

1. Learn the language-specific constraint weights. Each datum is classified as belonging to ether Spanish or English.
2. At the time of input retrieval, activate the two sets of language-specific constraints to a degree.
    - Parallel activation is formalized with activation scores linked to each language.
    - The activation scores consist of: 1) intention or non-intention to activate the given language and 2) speaker-specific language dominance.
3. Scale the language-specific constraint weights by each activation score.

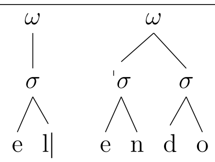
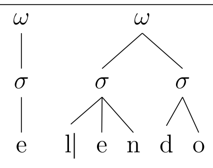
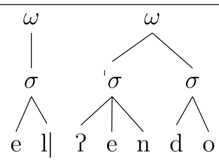
/ el endo/ Sp α 0.5 En α 0.5	**Onset/σ_{Initial}** **Sp W 0.87** **En W 1.99**	**Align -R** **Sp W 0.00** **En W 1.54**	**Dep-ʔ** **Sp W 1.85** **En W 0.17**	**Onset/ˈσ** **Sp W 0.54** **En W 1.48**	**[*Onset/Lat]/ˈ$\sigma_{\text{In.}}$** **Sp W 0.18** **En W 1.58**	H	p
a. 	1			1		2.45	0.13
b. 		1			1	1.66	0.29
c. 			1			1.01	0.57

Table 6.10: Tableau for *el endo* with different activation scores for each language

4. Assign harmony scores to the input of the intended language with the combined constraint weights (i.e., scaled weight of the intended language + scaled weight of the non-intended language).

6.5.2 Predicting activation scores

In order to predict the activation scores for each language, I maintained the constraint weights (i.e., language-specific constraint weights) as fixed parameters and allowing the speaker-specific vale of α to vary. The language-specific constraint weights fed to the grammar were those from the age-matched monolingually raised speakers (i.e., younger children, older children, adults). Matching the age of HS to that of monolingually raised speakers is important to predict child HS activation scores, as it takes into account the possible stages in constraint weights updating in the absence of a strong bidirectional language interaction. For the adult HS, however, the language-specific constraint weights could also be set using constraint weights calculated from data of first generation immigrant speakers, as it is the output to which the heritage language will most likely resemble at its end-state.

The output of the grammars with parallel language activation consists of predicted probabilities and a value for $\alpha_{\ Spanish}$ and $\alpha_{\ English}$. When applied with Excel, the Solver function is applied over an objective cell consisting of the sum of candidate-specific KL divergences. The variable cells are $\alpha_{\ Spanish}$ and $\alpha_{\ English}$ (i.e., the variable cells are shaded in gray in Table 6.11)

Language	**Intended language**	**Speaker-specific lang. dom.**	α		DEP-?	ONSET/σ_{Initial}	ALIGN -R	ONSET/ˈσ	[*ONSET/LAT]/ˈσ
Spanish	1	0	0.5						
					1.854	0.878	0.011	0.547	0.185
				Scal. w.	0.927	0.439	0.006	0.273	0.092
English	0	1	0.5						
					0.168	1.993	1.541	1.482	1.590
				Scal. w.	0.084	0.997	0.770	0.741	0.795
				Tot. w.	1.011	1.436	0.776	1.014	0.887

Table 6.11: Scaled weights and α scores fitted with the MaxEnt Excel Solver for the Spanish grammar of the younger child HS

Table 6.12 shows the Excel solver solutions for the six grammars. Out of the six grammars, it is only in the Spanish grammars of the younger child HS and the older child HS that the non-intended language shows an important contribution (i.e., English). Indeed, when compared to the models with one active grammar,[2] the model fit improves only in the younger child HS and the older child HS grammars.

[2]Table 6.12 shows the KL divergences and log likelihoods of the grammars fitted with observed probabilities from the HS' groups and learned constraint weights from the monolingually raised speakers.

	Spanish grammars				Grammar with α Spanish = 1		
	α Spanish [3]	**α English**[4]	**KL**	**Log lik.**	**KL**	**Log lik.**	**Lik. test ratio (1df)**
younger child HS	0.500	0.500	0.188	-54.390	1.959	-81.463	p <0.001
older child HS	0.843	0.157	0.266	-89.112	0.480	-94.106	p <0.001
adult HS	1.000	0.000	0.226	-70.246	0.226	-70.246	p = 1
	English grammars				**Grammar with α English = 1**		
	α Spanish[5]	α English [6]	KL	Log lik.	KL	Log lik.	
younger child HS	0.267	0.733	0.464	-36.580	0.427	-36.089	p = 0.32
older child HS	0.038	0.962	0.270	-31.281	0.272	-31.336	p = 0.74
adult HS	0.034	0.966	0.310	-62.966	0.740	-70.793	p = 0.64

Table 6.12: Alphas, KL divergences and log likelihoods for the Spanish and English grammars of the HS compared to the models fitted with activation scores = 1

Similarly, Figure 6.5 shows that, unlike the model with α Spanish et at 1, the model with variable activation scores successfully predicts the decreasing rate of glottal phonation observed in the HS' Spanish grammars at both levels of stress. In addition, the model with variable α also predicts the initial lower probabilities of the resyllabified candidates in the words with initial unstressed syllables. Figure 6.6, however, showed that the models with variable α perform similarly to those of English α set at 1.

[3]In the Spanish grammars, the weight of α Spanish consists of 1 for being the intended language summed to the variable score, both weighted at 0.5.

[4]In the Spanish grammars, the weight of α English consists of 0 for being the intended language summed to variable score, both weighted at 0.5.

[5]In the English grammars, the weight of α Spanish consists of 0 for being the non-intended language summed to the variable score, both weighted at 0.5.

[6]In the English grammars, the weight of α English consists of 1 for being the intended language summed to the variable score, both weighted at 0.5.

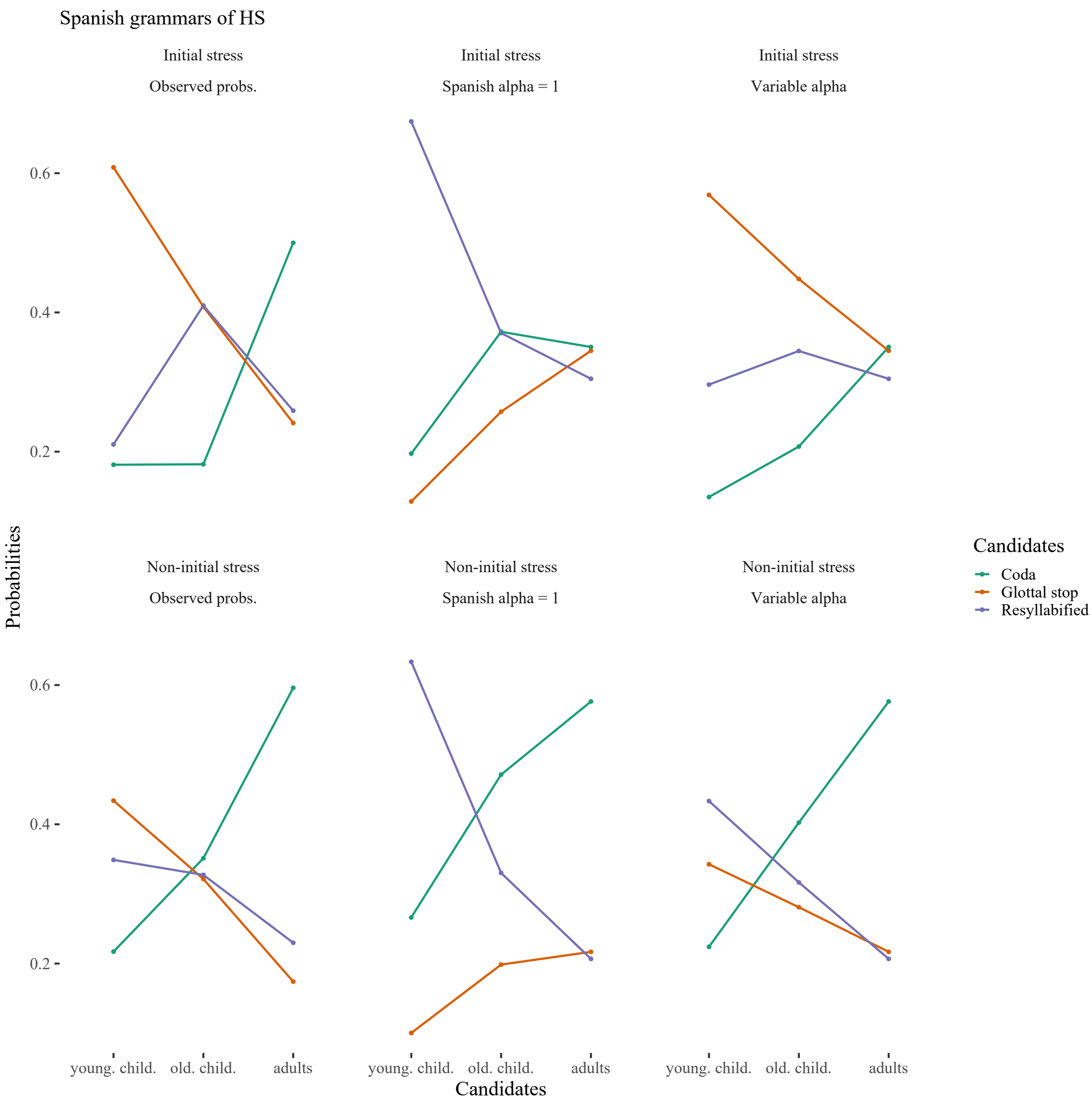


Figure 6.5: Observed probabilities of the HS' Spanish grammars (left) and predicted probabilities of the models with Spanish $\alpha = 1$ (center) and variable activation scores (right)

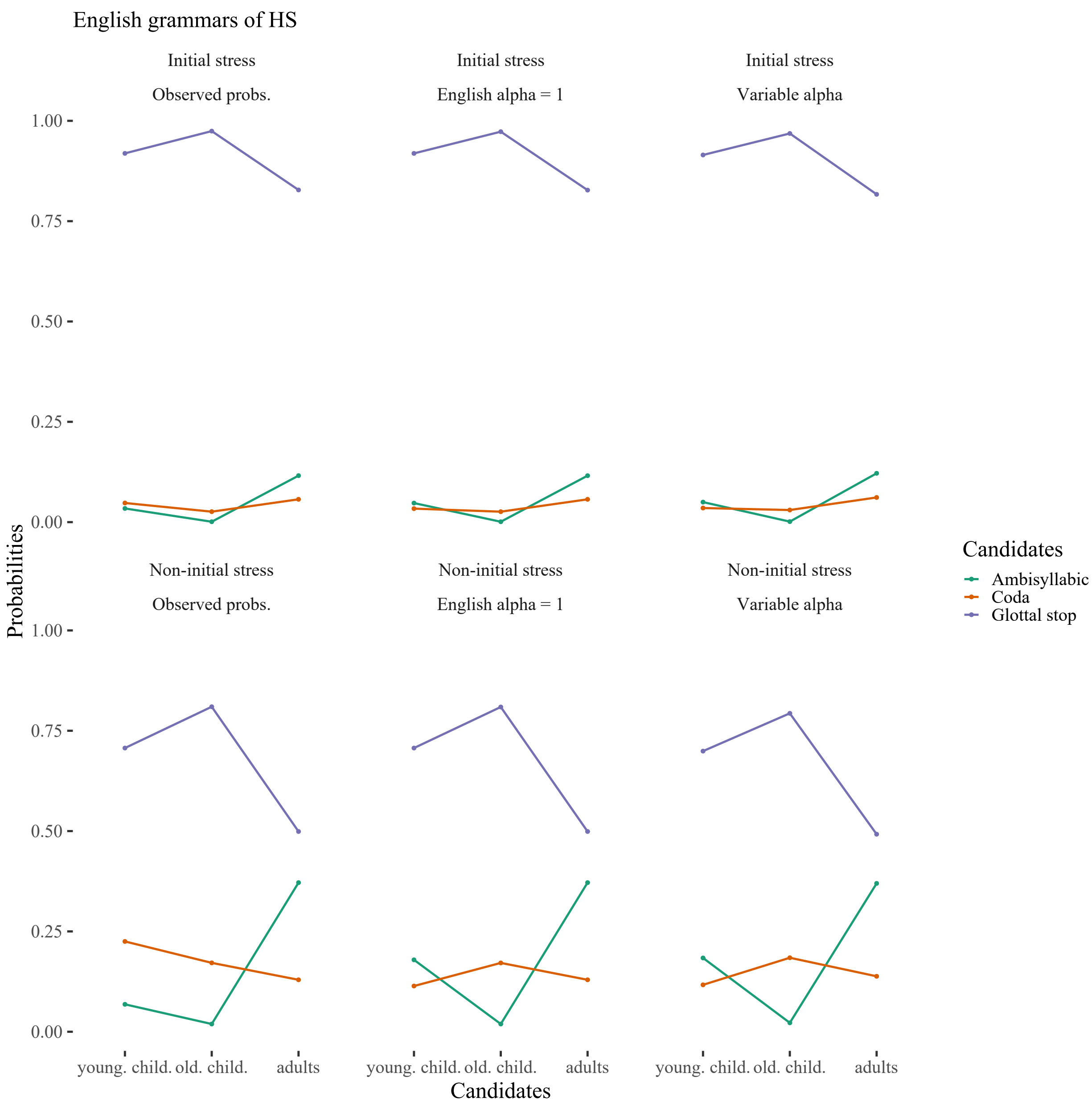


Figure 6.6: Observed probabilities of the HS' English grammars (left) and predicted probabilities of the models with English $\alpha = 1$ (center) and variable activation scores (right)

6.5.3 Applying a bias term to suppress the non-intended language

With respect to the transfer of glottal phonation, recall that my results for novel words in Chapter 5 showed that the younger child HS ($M = 52.03\%$) produced a greater rate of glottal phonation than that of the SpanMonoS ($M = 11.45\%$), and that the older child HS ($M = 35.87\%$) and adult HS ($M = 20.86\%$) produced similar rates of glottal phonation than those of their SpanMonoS counterparts (older SpanMonoS = $M = 23.53\%$ adult SpanMonoS = $M = 28.38\%$). In addition, the models for novel words that included amount of Spanish input and output as fixed factors maintained a main effect of age. This indicates that, in Spanish, child heritage speakers activate the non-intended language to a larger extent than adult heritage speakers, regardless of the amount of language use in the heritage language. In turn, this suggests the possibility of a latent factor that biases the weights towards discrete representations (i.e., activation of only one set of constraint weights). This factor reflects the effects of a maturing bilingual language control that, during childhood, has a weaker effect on the suppression of the non-intended language and gains traction as the grammars mature. As grammars develop, bilingual language control also matures and plays a more important role in discouraging blend representations. Language control requires the input to be evaluated with one set of constraint weights, those of the intended language. One possibility to formalize language control is to penalize the weights during input evaluation. Bilingual language control discourages combined constraint weights and restricts their values to those set by the intended language. This penalty can take the form of a bias term on the constraint weights that is applied to the objective function and prevents the activation scores from transparently express the preferences set by language dominance.[7] The prior is a quadratic term, à la Goldwater and Johnson (2003), which is applied to the model's objective function. In order to differentiate between the bias terms during applied during constraint

[7]Another possibility to formalize this penalty would be to impose a smoothing term on the activation scores. An argument for imposing the penalty on the constraint weights, however, is that it allows the bias term to apply differently across the grammar. It is possible that bilinguals are trained to suppress the non-intended language in familiar constructions but not in unfamiliar ones.

weight learning (Goldwater & Johnson, 2003) and those applied during input evaluation, I will use capital Greek letters to refer to the population standard deviations (σ) and the population means (μ).

The penalty is a Gaussian prior that takes the constraint weight of the intended language as its $\mathbf{M}$. While $\mathbf{M}$ is set by the intended language, Σ is variable and refers to the extent to which the scaled constraint weight can diverge from $\mathbf{M}$. I argue that Σ is age-dependent and decreases as grammars mature.[8]

5. Prior applied to the constraint weights during language evaluation.

   - $\mathbf{M}$: Constraint weight of the intended language. This is the preferred constraint weight to avoid blend representations.

   - Σ: Distance by which the total constraint weight can differ from the preferred constraint weight at the time of input evaluation. In this proposal, Σ is age-related and decreases as language control matures.

During the maturation of language control, speakers learn to inhibit the non-intended language and thus to restrict deviations from the weights of the intended language. This results in a child bilingual phonological structure that is more permeable to bidirectional transfer.

This leads us to hypothesize that bilingual grammars are equipped with two sets of language-specific constraints that are active in parallel during language evaluation and a prior on the constraint weights that requires the final weights to match those of the intended language.

To evaluate whether a bias term on the constraint weights during input evaluation predicts development of language transfer, I adjusted the values of Σ in the Spanish grammars

[8]Following (Green & Abutalebi, 2013), Σ could also be task-dependent, as language control adapts to the nature of the task.

of the younger child HS (i.e., larger effect of the non-intended language) and compared the results to the observed probabilities of the older child HS (see Figure 6.7) and to those of the adult HS (see Figure 6.8). With regard to the rate of candidates with /ʔ/-epenthesis, the observed probabilities of the older children (initial prim. stress = 0.20, non-initial prim. stress = 0.21) are best matched by the younger child HS' grammars with sigma set at 0.75 (initial prim. stress = 0.29, non-initial prim. stress = 0.18). The observed probabilities of the candidates with /ʔ/-epenthesis in the adult HS' grammars (initial prim. stress = 0.24, non-initial prim. stress = 0.17) are best matched by those of the younger child HS with sigma set at 0.25 (initial prim. stress = 0.11, non-initial prim. stress = 0.15). This shows that a stronger prior on the constraint weights results in older-children-like and adult-like observed probabilities for candidates surfacing with /ʔ/-epenthesis at the word juncture.

As for the patterns of the candidates surfacing with coda consonants and those with resyllabified consonants at the word junctures, the predicted probabilities for the younger child HS show that, as the influence of English decreases, the probabilities for the resyllabified candidates increase to a larger degree than those of the coda candidates. This is different from the patterns observed in the older child HS and adult HS, which demonstrate higher probabilities for codas than for resyllabified consonants. That is, increasing the strength of the prior in the younger child HS does not result in better matching probabilities in the older child HS or adult HS. I have discussed in Chapter 4, however, that the preferences for ambisyllabic/resyllabified candidates are not likely to show bidirectional transfer but may reflect speech rate (i.e., lower rate of resyllabified consonants in Spanish-speaking adults) or articulatory development (i.e., lower rate of ambisyllabic consonants in English-speaking children).

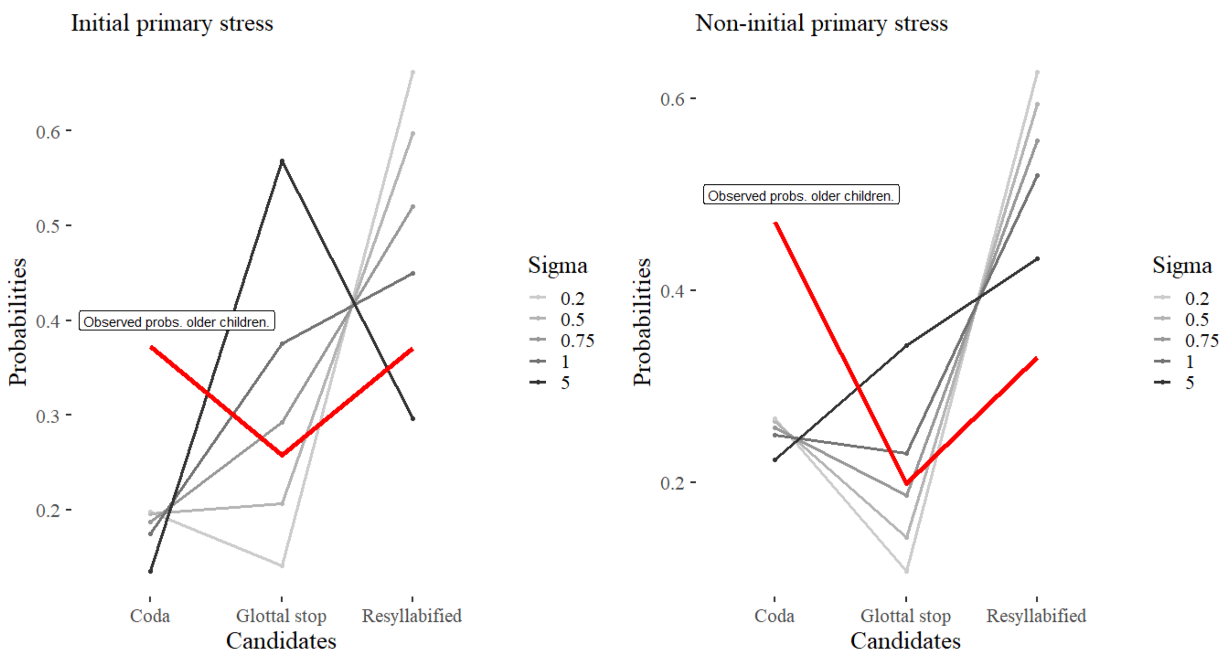


Figure 6.7: Predicted probabilities of the younger child HS' Spanish grammars at different levels of Σ. In red, the observed probabilities of the older child HS

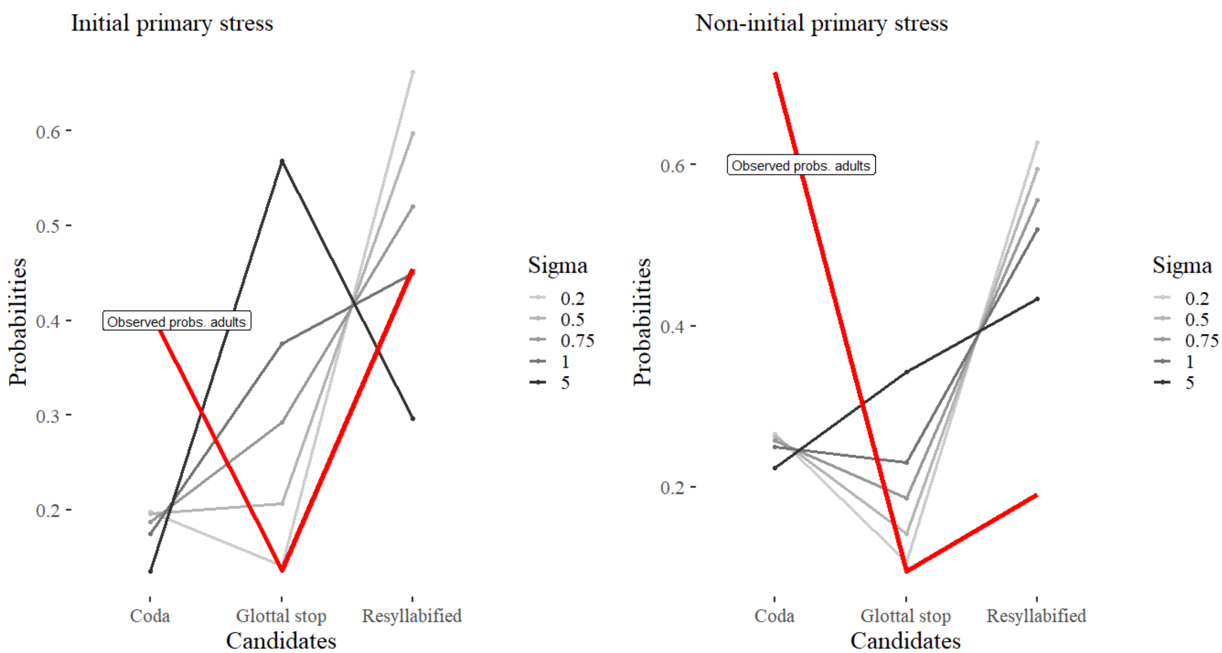


Figure 6.8: Predicted probabilities of the younger child HS' Spanish grammars at different levels of Σ. In red, the observed probabilities of the adult HS

To sum up, applying a prior on the constraint weights during input evaluation that takes the weights of the intended language as its preferred value can predict adult-like rate of /ʔ/-epenthesis in the heritage language (i.e., the language that shows a significant effect of the non-intended language). It is possible, thus, that the activation scores are constrained by a language control mechanism that, as the executive functions mature, is better able to suppress the weights of the non-intended language. The rates of candidates surfacing with resyllabified/coda consonants, nevertheless, did not become more adult-like as the pressure of English decreased. I have argued that these rates may be associated to factors other than transfer (e.g., speech rate for Spanish or articulatory development for English), that result in increasing rates of ambisyllabic consonants in English across the three age groups, and decreasing rates of resyllabified consonants in Spanish across the three age groups. In order to control for these factors, future studies should examine the effects of inhibitory skills on /C#V/ production among the same age groups.

6.5.4 Strengths and limitations

The GSC-based model (Goldrick et al., 2016) proposed in this work for heritage speakers is able to capture bidirectional language transfer by taking into account speaker-specific language dominance and domain-general processing skills. Moreover, this model proposes that the bilingual grammars interface with the speakers' inhibitory skills, which modulate the tendency in the grammar for discrete representations (i.e., *quantization*). The model predicts that, language-dominance being equal, degree of language transfer will correlate with domain-general processing skills and. Similarly, inhibitory control and age being equal, language transfer will correlate with language dominance.

A first limitation of this proposal is that the model focuses on input evaluation and assumes that constraint weight learning will not be affected by the coactivation of the two language-specific constraint weights. The grammars are already fed with language-specific weights, and they learn activation scores from the HS' learning data. Modeling language transfer at input evaluation predicts that the effects of linguistic interaction are dynamic and that bilinguals will diverge in the degree of language transfer based on the nature of their linguistic interaction (e.g., code-mixing, bilingual mode vs. monolingual mode). Nevertheless, this by no means precludes the possibility that, during learning, the language-specific constraint weights are also filtered by English and Spanish activation scores. For instance, an English-dominant heritage speaker (e.g., English $\alpha = 0.6$ and Spanish $\alpha = 0.4$) may update both English and Spanish weights when presented with a Spanish datum. The degree of activation of each language may be translated into a language-specific learning rate. Higher learning rates will be assigned to the highest α and lower learning rates will be assigned to the lowest α. A challenge with this account is that it predicts that transfer will be stronger from the heritage-to-majority language than vice-versa. In other words, the more dominant language will be more affected by the data from the less dominant language because it will be active to a larger extent during constraint weight learning. However, future studies should develop a model for bilingual constraint weight learning and its interaction with input evaluation.

As a second limitation, this proposal does not account for findings showing that cognates are more likely to show language transfer than non-cognates (Amengual, 2012; Shelton & Grant, 2018, among others)). To integrate the effect of cognates, this model could be extended by incorporating activation scores in the input, as suggested in Goldrick et al. (2016). That is, along with the speaker-specific activation scores, the input could also be gradiently activated as a function of the lexical similarities between the two languages. A clear example of gradient coactivation in the input is that of cognate status (see Van Hell et al. [2016] for a recent model), evidence for which has been found in production studies (Amengual, 2012). For instance, a Spanish-dominant bilingual uses a general $\alpha_{\ Spanish}$ to evaluate input, but Spanish-English cognates are 0.2 active in the Spanish grammar and 0.8 active in the English grammar. The resulting harmony for each candidate will be the sum of the product of each violation and (C $\alpha_{\ Spanish}$ * I $\alpha_{\ Spanish}$) * (C $\alpha_{\ English}$ * I $\alpha_{\ English}$), where C is the constraint weight and I is the input. In Tableau 6.13, the input /un.an.xel/ 'an angel' is 0.8 active in English and 0.2 active in Spanish, while the activation of the Spanish grammar is 0.52 and the activation of the English grammar is 0.47. Candidate c receives a harmony of 1 * (0.52 * 0.2) + (0.47 * 0.8) = 0.25. The probability of candidate C increases 0.11 in a cognate lexical element, when compared to a non-cognate lexical element with I $\alpha_{\ Spanish}$ = 1 (33% probability of candidate with /ʔ/- stop epenthesis).

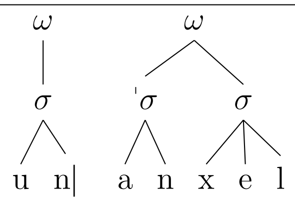
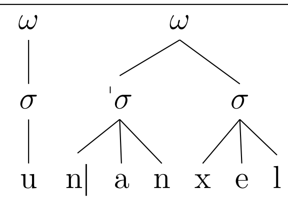
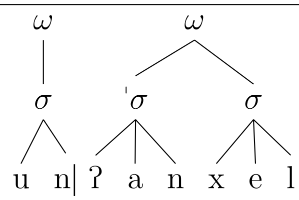
/ un.an.xel/ I $\alpha_{Sp} = 0.2$ I $\alpha_{En} = 0.8$	**Onset** **Sp W 0.27** **En W 0.75**	**Align-R** **Sp W 0.03** **En W 0.58**	**DEP- ʔ** **Sp W 0.93** **En W 0.06**	H	p
a. 	1			0.80	0.25
b. 		1		0.31	0.58
c. 			1	0.25	0.44

Table 6.13: Example of language coactivation for the input ‘un ángel’ with only one candidate

6.6 Conclusion

In this chapter, I first fitted my results using MaxEnt models with single activation for each language. In Spanish, the results of the MaxEnt models with single activation showed that the relative strength of Dep-ʔ increases as the HS’ grammars mature, indicating that the penalties for /ʔ/-epenthesis at word junctures increase across the three grammars. This pattern does not agree with that of non-heritage Spanish groups, as the latter speakers demonstrate decreasing penalties for /ʔ/-epenthesis as grammars mature. In the English HS’ grammars, the penalties for /ʔ/-epenthesis increase at each time period, and they do so to a greater extent than the penalties incurred by /ʔ/-epenthesis in the American English monolingual grammars.

With regard to the coda and ambisyllabic/resyllabified candidates, the Spanish HS' models show that the predicted probabilities of the resyllabified candidates decline with age and those of the coda candidates increase with age, similar to the pattern observed in the Spanish SpanMonoS' grammars. As discussed in Chapter 4, the decrease in resyllabification in the grammar is associated with an overall decrease of consonant duration. Provided that resyllabification is, indeed, mapped to canonical onset-like duration in the surface structure, it is possible that, as in the case of word-external hiatus resolution strategies (Alba, 2006; Souza, 2009), resyllabification is optional and sensitive to grammar external factors, such as speech rate. In support of this view, Kaisse (1985) claims that postlexical rules (i.e., here word-external phonological processes) can be optional and subject to speech rate.

Overall, my findings are not compatible with a grammar with single language activation during input evaluation. Instead, I formalize my results taking Goldrick et al.'s (2016) coactivation model for bilingual grammars as a departing point to evaluate their English and Spanish inputs with two sets of language-specific constraints that are active to a degree during speech production. The extent to which each language is active depends on speaker-specific characteristics, such as language dominance, proficiency, exposure or use. The partial activation of the non-target grammar and its co-presence during language evaluation constitutes a blend representation under the GSC framework. Crucially, the GSC proposes that blends are dispreferred during computation. In my results, I argue that this dispreference is associated with the maturation of the speakers' bilingual language control, as children show greater rates of English-like transfer than adults in their Spanish heritage phonologies. I have formalized the dispreference for blends as a prior applied to the activation scores that fixes the preferred value for each language-specific constraint set (i.e., 0 or 1). The degree to which the activation scores can deviate from this value is the parameter that is dependent on the development of domain-general cognitive skills. My fitted grammars show that the blend states reach discrete representations during adulthood. In Spanish, the younger child HS show the greatest degree of convergence in the language-specific activation scores. In English, the older child HS show a higher activation of the Spanish-specific constraint weights than that of the English-specific constraints. I have argued that the difference between monolingually raised English older children and HS' older children possible reflects the U-shaped behavior present in the English monolingual grammars with regard /ʔ/-epenthesis.

To sum up, in this chapter I have formalized my results using a model of language coactivation based on the GSC framework (Smolensky et al., 2014; Smolensky et al., 2020). This framework provides a theoretical umbrella to examine linguistic phenomena in bilingual speech production and allow researchers to gain some insights into the structure of the phonological structure of bilinguals. For instance, the current model uncovers the role of each of the HS' language during speech production. Lastly, using a prior on the activation scores, this proposal models the interaction between the grammar and the domain-general cognitive skills, establishing a direct link between bilingual language control and its effects in a formal grammar.

CHAPTER 7

Implications, limitations and conclusion

In the first section of this chapter, I summarize the experimental findings presented in Chapter 3 (i.e., monolingually raised Spanish and English grammars) and in Chapter 5 (i.e., Spanish heritage grammars), and the results of the formalization from Chapter 4 and 6. In the second section of this chapter, I address the limitations of my experimental design and phonological models, and I consider future avenues for research.

7.1 Summary of findings and implications

7.1.1 Monolingually raised Spanish and English speakers' production of glottal phonation in repairs of empty onsets

In Chapter 3, I conducted four production tasks to determine the rate of glottal phonation in /C#V/ sequences (i.e., word-external empty onsets) throughout late childhood in the speech of monolingually raised Mexican Spanish speakers and American English speakers.

7.1.1.1 Monolingually raised Mexican Spanish speakers

In Spanish, overall, the rate of glottal phonation was low in the real words. Child Mexican Spanish speakers showed similar patterns to those of adult Mexican Spanish speakers (younger child SpanMonoS $M = 1.56\%$, older child SpanMonoS $M = 1.58\%$, adult SpanMonoS $M = 2.42\%$). My findings align with previous results for monolingually raised Spanish speakers, showing that resyllabification appears almost at the time of two-word utterance production (Lleó, 2016b). However, it is possible that, while children use resyllabification (i.e., modal phonation) as the primary strategy to repair empty onsets, the articulatory patterns of the consonants that undergo resyllabification are still in development, at least in the group of younger children. Recall that Nittrouer (1993) found that, at the age of 7, children did not show adult-like intergestural coordination in schwa-stop-vowel sequences. Follow-up studies should, thus, examine whether the phonetic characteristics of resyllabified consonants develop as children grammars' mature. For example, future studies could explore whether the duration of the resyllabified consonant increases (i.e., more canonical onset-like) as children become more adult-like.

The results for the Spanish novel words were unexpected. Contrary to what I predicted, adult SpanMonoS (M = 28.38%) and older child SpanMonoS (M = 23.53%) produced a higher rate of glottal phonation than that of younger child SpanMonoS (M = 11.45%). I have argued that the group of older children and adult monolingually raised Spanish speakers may have evaluated novel words by considering their unpredictability in the discursive context. While more predictable words have been found to reduce in natural speech, less predictable words are likely to undergo phonetic enhancement (see Hall et al. [2018] for a review). Listener-oriented accounts of predictability posit that the speakers has implicit knowledge of the listener's mental state (see Turnbull [2015, 2019] for reviews). As hypothesized in Turnbull (2019), such listener-oriented accounts predict that the speaker will have to use theory of mind skills (i.e., the ability to attribute mental states to others) in order to decide whether a given lexical item has to be phonetically reduced or enhanced. It follows that speakers with developing theory of mind skills will be less likely to successfully compute the predictability of lexical items than speakers with mature theory of mind skills. So it is possible that the high rate of glottal phonation (i.e., phonetic enhancement of the prosodic word boundaries) found in the speech of adults and older children stems from the fact they identified the novel words as being less predictable to the listener than the real words. In the group of younger children, however, the developing theory of mind skills may have prevented the speakers to evaluate the novel words as being less predictable than the real words.

An implication of these findings is the fact that /ʔ/-epenthesis appears to be also a possible strategy to repair word-external empty onsets in Mexican Spanish. This is not the first study documenting strengthening of word-initial vowels in Mexican Spanish. Garellek (2014) found evidence for word-initial electrographic (EGG) contact in word-initial vowels, likely caused by an initial glottal stop or voicing with an increased vocal fold contact, in the speech of Mexican Spanish speakers. However, Garellek's (2104) findings may not completely represent Mexican Spanish speakers in Mexico, because the study participants were either HS of Spanish (7 speakers were born and raised in Los Angeles) or had been exposed to American English on a daily basis (i.e., all participants were students at the University of California, Los Angeles). In any case, this raises the question whether glottal phonation in the speech production of my adult participants was also influenced by English, since my participants were also somewhat proficient in English (i.e., exposed to English 30% of the time or less). To tentatively address this question, I ran a Pearson's correlation to examine the relationship between Spanish input and rate of glottal phonation, and Spanish output and rate of glottal phonation in the subset of the adult participants. Neither Spanish input nor output turned to be significantly related with rate of glottal phonation (Spanish input: $r(146) = 0.15$, $p= 0.06$, Spanish output: $r(146) = 0.14$, $p= 0.09$). Hence, it is unlikely that influence from English is the source of glottal phonation in Spanish. I would not discard, however, that a larger sample size could uncover a significant relationship between language use and rate of glottal phonation, given the trend towards significance demonstrated in the relationship between Spanish input and proportion of glottal phonation.

7.1.1.2 Monolingually raised American English speakers

Similar to the results for Spanish, in the English real words, age did not turn out to be a significant predictor of the rate of glottal phonation. It is noteworthy to highlight, however, that while I did not observe any trend in the words with initial primary stress, I found that the rate of glottal phonation decreased with age in the non-primary stress condition. That is, in the words without primary stress, the younger children produced higher rates of glottal phonation (M = 46.86%) than the older children (M = 30.62%), and the older children produced lower rates of glottal phonation than the adults (M = 27.73%). Thus, although my data did not support an effect of age conditioned by stress in the real words, this relationship should be studied with a larger sample size. In the novel words, the younger and the older children showed a higher proportion of glottal phonation than the adults. This means that a potential effect of age cannot be understood without taking into account the influence from the lexicon. In other words, in the absence of the lexicon, age emerges as a significant predictor of glottal stop phonation. Moreover, when comparing the real words to the novel words in the /l/ subset, I found that the younger children produced a similarly high rate of glottal phonation (real words M = 74.26%, novel words M = 81.20%), the older children demonstrated a higher rate of glottal phonation in the novel words than in the real words (real words M = 60.79%, novel words M = 88.71%), and adults produced an equally lower rate of glottal phonation in both the real and the novel words (real words M = 64.51%, novel words M = 66.09%). I argued that these results suggest that English speakers are sensitive to the lexicon during learning. In an initial stage, between 6 and 8 years of age, /ʔ/-epenthesis is favored in children's grammars and both real and novel words are evaluated by the same set of constraints, since the younger children showed equal amounts of glottal phonation in the real and novel words. As children's vocabularies grow and have more experience with connected speech, they are more exposed to the production of specific word-sequences containing modal phonation at the prosodic edges. Arguably, children create an indexed grammar for the words that are stored in the lexicon and evaluate those using both with lexically-specific constraints and a general set of constraints. At this point, between 8 and 11 years, the newly encountered words are maximally separated from the real words, probably because the constraints evaluating the novel words update more slowly than those evaluating words in the lexicon. By adulthood, the constraints that evaluate the new words finally achieve similar values to those that evaluate the real words and both the real and novel words present, again, similar rates of glottal phonation.

Taken together, my findings align with the view that phonological knowledge is dependent on vocabulary growth. While the impact of vocabulary size on the acquisition of phonological patterns is still understudied in first language acquisition, vocabulary size has been found to have a predictive role on the acquisition of high-probability and low-probability phoneme sequences (Munson, 2001). Moreover, in adult second language acquisition, vocabulary size correlates with phonolexical encoding (i.e., encoding of phonological contrasts in the lexicon) (Daidone & Darcy, 2021; Llompart, 2021). In turn, my results underline the importance of using novel words to understand the acquisition of phonological patterns, as these are less likely to be affected by the children's varying vocabulary sizes.

7.1.1.3 The effects of prosodic prominence

The four experiments in this study show that primary stress affects the presence of glottal phonation in word-initial position. That is, both the Spanish and English experiments show greater rates of glottal phonation in prosodically prominent vowels than in non-prosodically prominent vowels. Thus, my study contributes to the growing body of literature suggesting that prosodic prominence is a key factor influencing production of word-initial glottalization (Dilley et al., 1996; Garellek, 2013, 2014; Pierrehumbert, 1995) and that its role appears to be universal (Garellek, 2014).

7.1.1.4 The effects of the preceding type of function word

The result for type of consonant do not support the prediction that late-acquired consonants reduce the rate of acquisition of adult-like /C#V/ sequences when compared to early-acquired consonants, as no interaction between age and type of consonant was found in the results. Instead, first order effects were found across the age groups. In English, when compared to /n/ or /s/, the lateral had a greater effect on the rate of glottal phonation of the following vowel-initial. In Spanish, when compared to /l/ or /n/, /s/ had a greater effect on the rate of glottal phonation of the following vowel-initial word.

This opens the question of whether the observed effects can be attributed to the type of consonant. For the English results (i.e., /l/ favoring glottal phonation), one could argue that producing /l/ in ambisyllabic position is costly because it undergoes articulatory changes in derived onset position (Gick, 2003; Gick et al., 2006; Sproat & Fujimura, 1993). In turn, this added cost would reduce the probability of producing modal phonation (i.e., ambisyllabic /l/) at word junctures. However, the nasal consonant, which shows low rates of glottal phonation, also presents different articulatory patterns that vary depending on its syllabic position. More specifically, Byrd et al. (2009) found that derived onsets and canonical onsets differ in their velum-tip coordination. While canonical onsets present near-synchrony in the articulation of the tongue tip gesture and the velum lowering gesture, derived onsets show sequential articulation of the two gestures. Moreover, Umeda (1978) examined the influence of different types of phonemes preceding the content word on vowel-initial glottalization and reported similar rates of glottal phonation for vowel-initial words in front of sonorants (52.7%), voiceless fricatives, and stops (58.9%).

All things considered, it is unlikely that the complexity of consonant articulation in intervocalic position explains my results. Instead, a more plausible account is that the type of word preceding the content word has an effect on the likelihood of glottalization of the vowel-initial word. Garellek (2012) found that function words, as opposed to content words (i.e., preceding the vowel-initial word), increased the likelihood of full glottal stops in word-initial vowels. The author argues that a glottal stop at the juncture between a function and a content word prevents the function word from becoming a proclitic on the target word, and increases the degree of perceived prominence of the content word (Garellek, 2012, p. 10). In the case of the present study, however, the function words with less lexical meaning ('an', 'un' *an*, 'el' *the*), and, thus, more likely to become proclitic on the target word, are those that have lower rates of glottal stop insertion. It is probable that, among the set of function words, the words that contribute greater lexical content ('all', 'dos') are those that speakers are less likely to merge with the following content word. That is, in these cases, speakers seek to increase the perceived prominence of both the content word and the function word. Hence, the lexical content of the preceding type of function word has an impact on the rate of glottal phonation of the following vowel-initial word.

7.1.2 Spanish HS' production of glottal phonation in repairs of empty onsets in Spanish and English

In Chapter 5, I compared the results of the monolingually raised participants to those of the Spanish HS. In this section, I discuss three aspects of heritage grammars that my results bring to the forefront. First, Spanish HS present properties of English in their Spanish grammars, and features of Spanish in their English grammars. Second, in Spanish, the influence from the majority language into the heritage language is conditioned by age, suggesting that child heritage grammars are more permeable to language transfer than adult grammars. Third, language output is a significant predictor of heritage language speech production.

7.1.2.1 Discussing majority-to-heritage language transfer

The experimental results of this study demonstrated that younger and older child HS (between the ages of 5;2 to 11;11) produced a greater rate of glottal phonation (younger child HS M = 37.76%, older child HS M = 21.37%) than monolingually raised younger and older child Spanish speakers (i.e., between the ages of 5;1 – 11;8 years old) (younger child SpanMonoS M = 1.58%, older child SpanMonoS M =1.61%) in the real words. Adult HS showed a similarly low rate of glottal phonation (M = 9.88%) than that of the monolingually raised Spanish speakers (M = 2.48%). In the case of novel words, only younger child HS (between 5;2 and 8 years old) demonstrated a greater rate of glottal phonation (M = 52.03%) than younger child Spanish Mexican speakers (between 5;1 to 8 years old)(M = 11.45%). These findings suggest that, during language maturation, the majority language has an influence on the heritage language, and that this interaction weakens with age. As heritage grammars become more mature and stable, they are also more resistant to influence from the majority language.

In the absence of the results for monolingually raised English speakers, one could argue that the high rates of glottal phonation in our Spanish child heritage grammars do not reflect greater transfer from English, but instead track the proportion of glottal phonation found in their English grammars. After considering the results for English, I argue that the former explanation is unlikely to explain my results, because I did not observe a significant overall effect of age in the monolingually raised English speakers (i.e., for the real words), confirming that the rate of glottal phonation is comparable across ages. That is, if child HS demonstrate a higher rate of glottal phonation than adults, it is not likely to be a result of age differences in the rate of glottal phonation in English.

Theoretical accounts of language control could provide an explanation for the asymmetry between child HS and adults HS' grammars. Polinsky and Scontras (2020) state that HS, as bilinguals, have to maintain two grammars with limited processing resources. This can create an additional challenge, as they have to allocate enough processing resources to balance and inhibit the appropriate grammars at each time during speech production. For this reason, linguistic features that require high processing costs may be over-taxing for HS. In the present case, I resort to findings showing that children during primary school years are still developing the components of the executive function (Anderson et al., 2001; Davidson et al., 2006; Mazuka et al., 2009; Mezzacappa, 2004; Morra & Camba, 2009), to argue that they will encounter a greater challenge when allocating resources for the two languages, and adequately balancing language control. In fact, children's developing executive function has been claimed to have an effect in sentence processing. Mazuka et al. (2009) stipulate that findings showing that children have more difficulty recovering from wrong sentence interpretations (Novick et al., 2005) are associated to the children's immature executive functions and their increased difficulty to inhibit predominant responses and to switch between choices. Changes in the executive function have been found to have an impact on language control. Kubota et al. (2020) performed a longitudinal study with Japanese-English bilingual children (7-13 years old) and found that development in executive control over one year predicted changes in language control in this population of bilingual speakers. If children are still developing their language control abilities, it is likely that cross-linguistic influence will be easier to permeate in their grammars than in the adult grammars.

7.1.2.2 Discussing heritage-to-majority language transfer

My findings showed that child and adult Spanish HS produced glottal phonation less often (real words M = 46.40%, novel words M = 59.40%) than their English monolingual counterparts (real words M = 59.28%, novel words M = 79.62%). Unlike in the Spanish experiments, neither age nor language exposure predicted rate of glottal phonation in the English experiments. These results open up two possibilities. First, the overall first order effects for type of speaker suggest a scenario in which the heritage language exerts some pressure over the majority language. In such case, language contact at the individual level would require Spanish HS to restructure the phonological constraints from English, the dominant language. This scenario would be supported by recent studies demonstrating that the majority language can be affected by language dominance or language mode (Amengual, 2018; Shea, 2019). For instance, recall that Shea (2019) examined the Spanish and English vowel system of Spanish HS and found that language dominance and English proficiency explained some variance in the English vowel production. Specifically for language dominance, the amount of Spanish spoken outside of home was the principal factor explaining variance in English vowel production. That is, the more Spanish a participant spoke outside home, the less similar their productions were to those of English native speakers. The majority language is also influenced by language mode. Amengual (2018) analyzed the production of the Spanish and English /l/ in monolingual mode (i.e., one language is activated) and in bilingual mode (i.e., both languages are activated), and found that second and third generation Spanish-English bilinguals produced less target-like laterals in Spanish, but also in English, when tested in bilingual mode. That is, pressure from the heritage language into the majority language is a plausible explanation to account for my results. This would support a view in which language transfer is bidirectional and would require researchers in heritage language phonology to examine Spanish HS' two languages to better understand their complete phonological structures.

Although this explanation is compelling, I can not completely rule out a second scenario, which is that of Spanish influence at the societal level. This scenario is supported by the fact that the rate of glottal phonation remains constant across age groups and levels of Spanish input and output. In this case, the English in the Spanish-speaking community would demonstrate less frequent glottal phonation in /C#V/ sequences than English outside the Californian Spanish-speaking community. In fact, Chicano English has been shown to be influenced by a Mexican Spanish substrate. For instance, Chicano English speakers demonstrate greater monophthonguization of vowels, lesser vowel reduction, or Spanish-like place of articulation of stops (Fought, 2003; Otto & Bayley, 2008).

In order to determine whether language influence occurs at the individual or societal level, future studies should include Spanish HS with little Spanish proficiency. If these speakers also show lower rates of glottal phonation than those of the English speakers with little contact with the Spanish-speaking community, we could assume that language contact occurs at the societal level and that Spanish HS produce a similar output to that of their input.

7.1.3 The roles of input and output

My findings demonstrate that language output has an effect on the rate of glottal phonation in the Spanish real words. While reduced input and type of input have primarily been at the center of this debate (Meisel, 2019; Montrul, 2002, 2008; Rothman, 2009), less attention has been given to HS' own output (Serratrice, 2020). Serratrice (2020) links language use with the formation of identity in the heritage language. The author states that child HS have the choice of speaking in either the heritage or the majority language. By choosing to speak the heritage language (i.e., language output), children are also indirectly claiming agency and identity in this language, which will presumably have a positive impact in heritage language maintenance. In addition, language output has also been argued to strengthen the connection between linguistic representations and articulatory system and to improve the cognitive abilities necessary to produce bilingual speech.

Following a processing account of language production (see Section 7.1.2.1), it is possible that children with a higher amount of output in the heritage language gain practice in inhibiting the non-relevant language and activating the adequate linguistic representations. By doing so, producing speech in the heritage language becomes less costly and restructuring the heritage grammar is less necessary.

Studies on heritage language phonology that had previously looked at the role of language use have either collapsed input and output as into one single construct (Rao, 2014; Shea, 2019), or found similar patterns between language and input (i.e., language use with older generations of Spanish speakers) (Kim & Repiso Puigdelliura, 2020). In this respect, I argue that measuring language exposure during childhood provides a better ground for examining the effects of output on language production, as the contexts in which the child uses each language are more controlled and less life events have occurred that could affect their speech production. Moreover, input interruption in the heritage language has not yet taken place during childhood, which renders the group of child HS more comparable among themselves, since the adult HS may have maintained their language exposure to different degrees across their lifespan. For this reason, research on child heritage bilinguals at different stages of their development could more clearly elucidate the effects of language output.

Despite the significant effect of language output in the production of Spanish real words, language input did not turn out to be a significant predictor for heritage speech production. However, I would be cautious to rule out a potential effect of language input in the production of glottal phonation. Recall that language input and output were calculated for three time periods in the adult group (i.e., primary school, high school and university), and only for one time period in children (i.e., primary school). It is possible that, while language output may remain more consistent across the speakers' lifespan, input is more unstable and averaging across three time periods does not reflect the actual effect of language input.[1] Moreover, a larger sample size would have allowed decomposing language input into smaller components, such as number of Spanish-speaking caregivers, number of siblings, or enrollment into a Spanish language immersion school. For example, Gollan et al. (2014) found that the number of speakers that spoke to the participants as children in the heritage language correlates positively with performance in a picture-naming task in the heritage language (i.e., Hebrew, Chinese, Spanish).

7.2 Modeling repairs of empty onsets

7.2.1 Modeling repairs of empty onsets in the grammars of monolingually raised Spanish and English speakers

Using my experimental results (Experiment 2a and 2b), I formalized word-external repairs of empty onsets in monolingual and bilingual Spanish and English.

With regard to the Spanish results, my model contributes to recent proposals for Spanish resyllabification in two main perspectives. To begin with, although DEP-ʔ had already been suggested to be active in bilingual grammars (Lleó, 2016b), this is the first formalization

[1] In an exploratory analysis with only the subset of children, language input appears to be a significant predictor for rate of glottal phonation in the real words (β = -9.32, z = -5.22, p < 0.001), and in the novel words (β = -9.32, z = -5.22, p < 0.001). Moreover, output also appears to be a significant predictor of rate of glottal phonation in the novel words when only the two groups of children are examined (β = -2.71, z = -2.96, p = 0.003).

of resyllabification to incorporate the possibility of satisfying Onset with /ʔ/-epenthesis in monolingual Spanish. While to a lesser extent than in the English grammars, Mexican Spanish grammars also allow segmental epenthesis to emerge in the surface structure. In addition, repairs of empty onsets with /ʔ/-epenthesis are predicted to emerge more often in adult grammars than in child grammars when the lexical items are not stored in the lexicon. Second, resyllabification (i.e., being complete or incomplete) has often been considered a process that is affected by strictly phonological factors (Bradley, 2020; Colina, 1997; Harris, 1983; Hualde, 1991; Robinson, 2012) and that is not sensitive to non-phonological factors such as lexical frequency or speech rate (Lipski, 1999). Analyzing resyllabification as a probabilistic phenomenon (i.e., non-zero probabilities assigned to the coda candidates), however, opens up the possibility to examine whether there are patterns in such probabilities, and, more specifically, whether these patterns have a relationship with language acquisition. In fact, my data show an acquisitional pattern, albeit an unexpected one. My findings demonstrate that both monolingually raised child Spanish speakers and child heritage speakers produce a greater rate of resyllabified consonants than adults (see Table 7.2). This is a surprising result because, from an acquisitional perspective, one would expect the reverse pattern. I have argued in Chapter 4 and 6 that it is possible that this pattern shows that resyllabification is affected by factors other than acquisitional ones, such as speech rate. First, I have shown that children's laterals are overall longer than those of adults (See Table 7.1).

Mean (SD) in ms	**/V#l/**	**/l#V/**	**/l#C/**
younger child SpanMonoS	99.82 (31.48)	102.07 (22.87)	80.62 (25.19)
older child SpanMonoS	95.92 (27.73)	84.49 (20.88)	73.87 (22.75)
adult SpanMonoS	87.13 (19.59)	82.77 (21.62)	74.80 (20.37)
younger child HS	98.88 (32.13)	92.37 (26.42)	80.68 (28.73)
older child HS	97.05 (29.98)	87.84 (25.13)	79.41 (26.65)
adult HS	91.08 (21.49)	76.21 (17.72)	75.26 (21.95)

Table 7.1: Mean duration of consonant per group and position, standard deviations in parentheses.

This being said, I have brought attention to the fact that certain word-external phonological processes, such as hiatus resolution strategies, are affected by speech rate (Alba, 2006; Souza, 2009). Provided that resyllabification is mapped onto duration in the surface structure, it is possible that, in faster speech rate, speakers are less likely to lengthen the target consonant and, as a result, change its affiliation from coda position to canonical onset position.

	SpanMonoS	**HS**
younger children	66.05%	49.67%
older children	37.09%	43.96%
adults	25.57%	13.16%

Table 7.2: Percentage of predicted resyllabified consonants over total modal phonation (i.e., coda consonant and resyllabified)

Nevertheless, the latter is not the only possible explanation for this pattern. To begin with, it is possible that the durational properties of resyllabified laterals fall in an intermediate position between the duration of codas and canonical onsets, similarly to recent findings for the alveolar fricative /s/ (Hualde & Prieto, 2014; Strycharczuk & Kohlberger, 2016). In that case, in particular, the younger child SpanMonoS' mean duration of the lateral in /l#V/ position (younger child SpanMonoS = 102.07 ms) would not be compatible with the duration of a resyllabified consonant. Rather, it would be phonologically compatible with a canonical onset. Under this view, the younger children would produce the vowel-initial word as a /l/-initial word (i.e., /lendo/ instead of /endo/), eliminating, thereby, the need for a misalignment in the syllabic structure. This hypothesis is supported by evidence from French showing that, in early stages of liaison acquisition, children add the liaison consonant in contexts where the consonant is not expected (e.g., /V#V/ 'papa ours' *daddy bear* produced as /papanuʁs/) (Chevrot & Fayol, 2001). Although the child participants in my experiment were not presented with the sequence /el endo/ in connected speech, the 8 target /l/-initial words (i.e., /V#l/ /londa/) could have primed the /lV/ syllabic structure, leading younger children to produce /e#lendo/.

In the English model, /l#V/ tokens were labeled as coda consonants or ambisyllabic consonants using degree of darkness (i.e., F2-F1 in Bark units). Two clusters for each group were obtained using Fuzzy Clustering. Tokens were assigned posterior probabilities depending on the likeliness of belonging to the first (i.e., lower values of F2-F1) or the second cluster (i.e., higher values of F2-F1). The MaxEnt grammars for younger child EngMonoS ($M = 0.59$) and adult EngMonoS ($M = 0.61$) predicted similar probabilities for ambisyllabic consonants. The grammar for older child EngMonoS, however, predicted lower probabilities for ambisyllabic consonants ($M = 0.07$) when compared to the former grammars. Although these results demonstrate a U-shaped behavior in /l/ ambisyllabic production, we should take these findings with caution, as the overall number of tokens produced with modal phonation was low in the grammars of the monolingually raised English speakers (N = 105). Recall that most of the tokens were produced with glottal phonation (N = 388). This means that small changes in the number of observations result in large percentage changes. In light of this limitation, further studies should examine the development of /l/ coarticulation in /l#V/ position to determine whether, indeed, children go through a period in which gestural coupling becomes more coda-like. With regard to the groups of HS, the MaxEnt grammars predicted that the probabilities across the three age groups increased with age (younger child HS $M = 0.12$, older child HS $M = 0.39$, adult HS $M = 0.61$), reaching values of adult EngMonoS. After examining the F2-F1 properties of /l#V/ tokens in the child HS' groups (see Figure 7.1), I argue that these findings are unlikely to reflect a late development of ambisyllabicity in the English phonology of HS denoted by dark laterals in /l#V/ position. Rather, the F2-F1 values show that child HS produce lighter laterals in /l#C/ position (younger child HS $M = 4.36$, $SD = 1.47$, older child HS $M = 4.38$, $SD = 1.81$) than those of the adult HS ($M = 3.32$, $SD = 0.99$), indicating that child HS could be transferring a Spanish-like articulation of the lateral in coda position to their English speech. This means that the tokens produced in /l#V/ and in /l#C/ position are more similar in the speech of child HS than in the adult HS' productions not because the tokens in /l#V/ are not light enough, but rather because laterals in /l#C/ position are as light as those in /l#V/. This pattern can indicate the existence of language transfer during childhood of Spanish-like articulation of coda laterals in the HS' English productions. As in the case with the monolingually raised children, it is necessary to investigate whether the coarticulation of /l/ in /l#V/ position is, indeed, similar to that of /l/ in /l#C/ position.

Despite the novelty of using phonetics data to obtain observed probabilities for the resyllabified/ambisyllabic candidates, my approach has some limitations. First, the difference in the phonetic assumptions between resyllabified and ambisyllabic candidates (i.e., the former behaving like canonical onsets and the latter patterning between codas and canonical onsets) prevented me from using the same method to label the tokens. To summarize the methods, in Spanish, I compared the duration of /l#V/ tokens to two equal samples distributions (i.e., /l#C/ and /V#l/) and decided whether the duration of each token in /l#V/ position was more likely to be drawn from a /l#C/ distribution or a /V#l/ distribution. In English, I have used unsupervised learning to create a coda-like cluster and an ambisyllabic-like cluster.

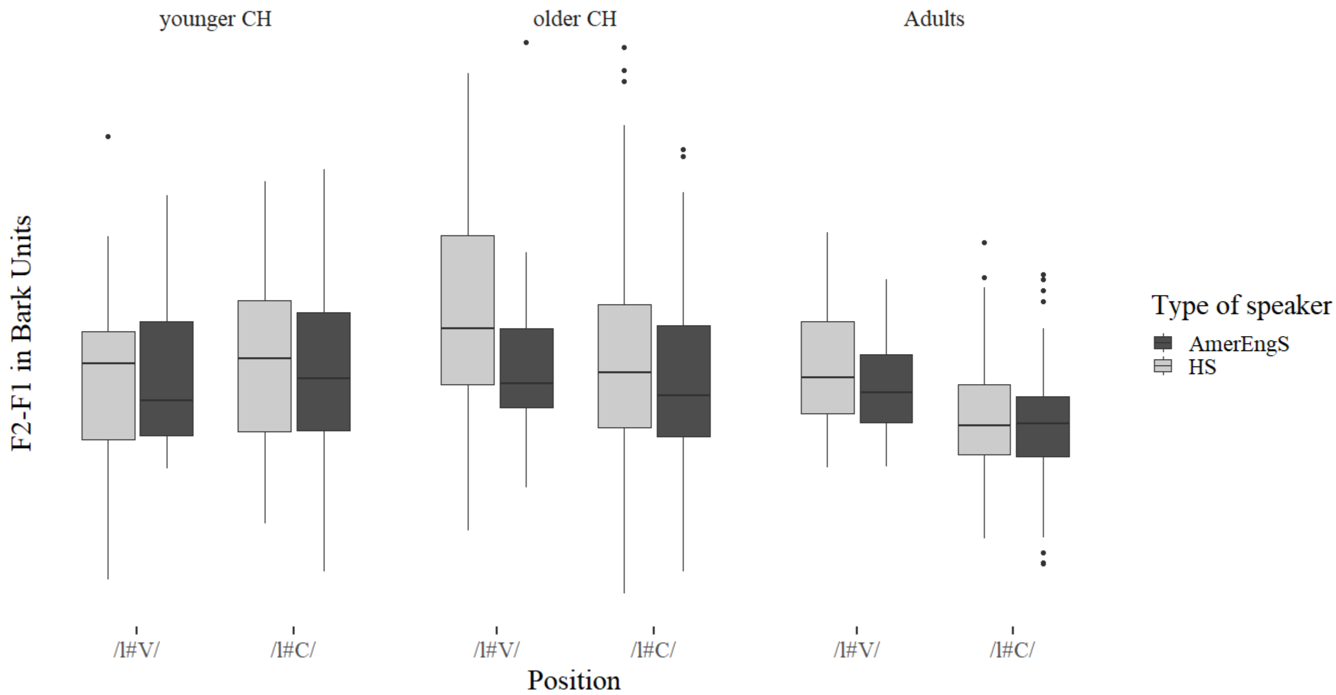


Figure 7.1: F2-F1 in Bark Units per type of speakers and age group

I used the tokens' assigned posterior probabilities to determine membership to one or the other cluster. The use of different strategies may have rendered the between-language probabilities not completely comparable. In particular, assuming that ambisyllabic consonants constitute their own cluster could have resulted in more tokens classified as ambisyllabic consonants than if I had assumed, as in Spanish, that ambisyllabic consonants will pattern with canonical onsets. However, holding this assumption was not supported by the literature (Gick, 2003; Hayes, 2009; Scobbie & Pouplier, 2010).

Furthermore, using the two measures (i.e., duration and F2-F1) separately in each model is not a suitable strategy to be able to detect transfer of acoustic cues of resyllabification in bilingual speech. For instance, as noticed in this section, the HS produce lighter laterals in the coda position, which resulted in small F2-F1 differences between the /l#V/ and the /l#C/ tokens. This means that degree of darkness was arguably not used as a cue of ambisyllabicity in the production of /l#V/ tokens during childhood. Rather, it is possible that HS made the /l#V/ — /l#C/ distinction using duration. For this reason, further implementations of these models should take into account language transfer in the surface structure.

Lastly, in both the English and Spanish models, I have included stress-driven positional constraints to formalize the effect of primary stress. I have discussed the need to include both a stress-driven Onset (i.e., justified by the usefulness of a consonantal gesture to build subglottal pressure in stressed syllables), and a stress-driven Align-L (i.e., legitimized by the pivotal role of prosodic prominent elements for information retrieval) based on my experimental results showing that stress significantly affected the rate of glottal phonation. However, the two constraints only improved significantly the English grammars of older English monolingual children, older child HS and adult HS. The Spanish grammars were not improved by the stress-driven constraints. Although the lack of statistical significance could have been a result of high variation in a low number of inputs, the fact that some English grammars were significantly improved by the stress-driven constraints indicates that English rates of glottal phonation are influenced to a greater extent by prosodic prominence in English than in Spanish.

7.2.2 Coactivation in the Spanish HS' grammars: the case of repairs of empty onsets in Spanish and English

With the aim of understanding how the grammars of the HS differ from those of the Spanish-speaking and English-speaking monolingually raised participants, I fitted six separate grammars for the HS, in which I considered that only the target language is active during language evaluation. My results demonstrate that HS' grammars are not likely to be compatible with a model in which there is no interaction between the two grammars. In Spanish, the HS show that the relative strength of Dep in the grammar increases at each time period, suggesting that child HS' grammars assign lower harmony scores to candidates with /ʔ/-epenthesis than adult HS. This pattern is not attested in the Spanish-speaking monolingually raised children.

In English, HS and EngMonoS show a similar acquisitional pattern in the harmony scores of /ʔ/-epenthesis candidates, also increasing at each age period. Nevertheless, overall, HS show lower penalties for /ʔ/-epenthesis than EngMonoS.

Considering these results, I proposed that /C#V/ sequences in HS' grammars are evaluated by two simultaneously active sets of constraints, taking the GSC-based account of coactivation in bilingual grammars (Goldrick et al., 2016) as a departing point. During input evaluation, HS' activate each one of their language-specific constraint weights to a degree. The degree of language activation is dependent on the HS' language dominance and the intention to speak the source language. For instance, my study shows that language use is an important factor that may mediate the degree of language activation. As a result of the parallel activation of the two languages, the predicted probabilities for the resulting candidates take the form of *blend representations*. I define *blend representations* as representational states that attribute probabilities from the non-intended language to the output of the intended language.[2]

To formalize the tendency in the grammar to disfavor *blend representations* (i.e., *quantization* in the GSC framework), I introduce a bias term on the constraint weights during input evaluation, which reflects the tendency in the language to prefer output that is evaluated with one set of constraint weights. The effect of **M** on the constraint weights is regulated by Σ, whose value allows the scaled constraints to vary from the preferred weights. In other words, the prior represents language control and Σ, its development. During language development, bilingual children are learning to suppress interference from the non-intended language, which is formalized as decreasing values of Σ, allowing the constraint weights to

[2]Notice that this definition differs slightly from that of Goldrick et al. (2016), as they consider *blend representations* those representational states in which representational elements of the two languages occupy a single position in the linguistic structure (i.e., the coactivation of two nouns in the head of a noun phrase). In the case of probabilistic phenomena in monolingual grammars, I have adopted the position that the blend representation is the evaluation of an input in the intended language resulting into probabilities similar to those in the non-intended language. The degree to which the grammar prefers only one candidate (i.e., resyllabification or ambisyllabicity) in monolingual and bilingual grammars is left to further research.

differ a great deal from the preferred weights. At these stages, the grammar is permeable to cross-linguistic transfer, because the activation scores can be fully realized during input evaluation. As language control matures, either with age or with use of the two languages, the values of Σ decrease and allow the intended language to emerge without interference from the non-intended language. That is to say, the extent to which the weights of the non-intended language can alter those of the intended language is determined by Σ. In line with the adaptive control hypothesis (Green & Abutalebi, 2013), the values of Σ can also adapt based on the situational context. For instance, in code-switching mode, the values of Σ may increase to allow language to co-operate instead of competing for selection. The mechanism by which speakers adapt Σ to the task, however, is outside the scope of this dissertation and should be formalized in future research.

More broadly, this proposal is equipped to account for findings in heritage language phonology showing that inter-speaker variation may be dependent on factors relating to language dominance, proficiency, or use (Amengual, 2016; Kim & Repiso Puigdelliura, 2020; Rao, 2014; Shea, 2019). At the same time, a bias on the degree of activation of each language is a first step towards the modeling of language control in the formal grammars.

The proposition that language transfer occurs during input evaluation has the strength of accounting for intra-speaker differences in language transfer, which may be regulated by the monolingual/bilingual mode or the type of task, as has been found in experimental studies (Amengual, 2012; Colantoni et al., 2016; Elias et al., 2017). However, this proposal presumes that constraint learning will be parallel to that of monolingual grammars and that only the intended grammar will be updated during language learning. This is a limitation of this proposal, as it is possible that, to a degree, the two sets of constraint weights are also active during constraint updating. Future accounts of coactivation in bilingual grammars should consider the possibility of parallel activation during constraint learning. For instance, one could consider that each datum in the learning data is analyzed both by the Spanish and the English grammars, but each set of constraint weights is updated with a different learning rate depending on its degree of activation.

7.3 Limitations and further directions

In this section, I address the main limitations of my study and I offer future directions to explore heritage language speech production and, more specifically, the production of /C#V/ sequences. I first discuss my decision of having a baseline of Mexican Spanish speakers as a means to evaluate the speech of Spanish HS. I then turn to consider specific elements of my experimental design; such as the use of novel words, the incorporation of functional elements with varying lexical meaning, and the inclusion of Spanish-English cognates in the target words. I finally examine variation in the production of glottal production and asymmetries in the use of creaky voice and full glottal stops between children and adults.

7.3.1 Choosing the appropriate baseline for HS

Finding an adequate baseline of comparison for HS has been a site of debate in heritage language research (Otheguy, 2016; Rao, 2019; Serratrice, 2020). Comparing non-heritage monolingual speakers to HS may not be appropriate. First, HS' grammars are not the conjunction of two monolingual grammars (Grosjean, 1989). Holding a view in which bilinguals are expected to attain monolingual-like command of a given feature may cover the processing costs of being bilingual. For instance, **FourshaIsBilinguals** tested processing differences in monolinguals and early balanced bilinguals in a grammaticality judgement task. Although the early bilinguals performed with native-like accuracy on the task, they showed longer response times than the monolinguals.

Second, HS may not have been exposed to the same type of input than monolingual speakers. HS are exposed to the language of first generation immigrants (i.e., parents, grandparents), second generation HS (i.e., siblings, teachers) and even second language speakers (i.e., teachers, school peers). In all these cases, the speech of these speakers may be affected in lesser or greater measure by the contact with the majority language (i.e., attrition, L1-to-L2 transfer). This means that the input that HS receive will already have properties from the heritage language. To this regard, a limitation of my study is that 5 caregivers in my group of child HS spoke Spanish as a heritage language, indicating that the child HS' received input may have been more similar to that of the adult HS' group than to that of the adult SpanMonoS. In any case, my results for Spanish still showed that child HS glottalized to a larger adult HS.

In addition, HS are normally not exposed to formal registers of the language, as they do not always have access to formal education in the minority language. This means that they are not exposed to linguistic properties characteristic from such varieties. For example, Pires and Rothman (2009) found that Brazilian Portuguese HS, but not European Portuguese HS, lack knowledge of inflected infinitives, the former being the Portuguese variety in which inflected infinitives have been lost in colloquial registers. That is, inflected infinitives may not have been present in the input of the Brazilian Portuguese HS.

Despite these considerations, I consider that it is also important to examine speech production in monolingual varieties of Spanish in order to better assess how variable the target phenomenon is in monolingual grammars, and how it develops across the speakers' lifespan. Given the scarce experimental research in the production of Spanish word-external processes, I chose to include monolingually raised Spanish speakers in Mexico as the baseline group for this study. However, for the purpose of determining whether HS show the same patterns as those found in their input, a better baseline group would be that of the first generation immigrants (i.e., the generation of the HS' parents) (Otheguy, 2016; Rothman, 2009). Some studies that have incorporated long-term immigrants have found HS' speech production does not significantly differ from that of long-term immigrants (Henriksen, 2015; Kissling, 2018; Repiso-Puigdelliura, 2021b). For example, in a study on Spanish HS' rhotic production, Henriksen (2015) found that the number of occlusions and duration of the trill did not significantly differ from the long-term immigrants. Repiso-Puigdelliura (2021b) showed that child HS but not adults produced greater rates of glottal phonation in spontaneous speech in Spanish than a baseline of long-term immigrants. Other studies, however, have found that the speech production of HS and that of long-term immigrants do not always converge. Colantoni et al. (2016) found that, while the prosody (i.e., selection and realization of pitch accents) of a group of HS and a group of long-term immigrants was comparable in a spoken task, it showed non-convergent patterns in a reading task.

In sum, sometimes HS are more likely to show similar patterns to those of first generation immigrants, suggesting that language contact arises at the societal level. In other cases, adult HS diverge from long-term immigrants, which seems to indicate that language transfer occurs at the individual level and interacts with the process of heritage language acquisition. An even more accurate baseline, albeit difficult to include in experimental designs, would be that of their primary caregivers.

Future directions should explore the possibility of incorporating such speakers to better analyze whether the patterns observed in the child and adult HS are those found in their input, or whether they are unique to their speech productions.

7.3.2 Novel words as proxy for lexical frequency

In this study, lexical frequency was operationalized as the difference between real words (i.e., mostly high frequency real words) and novel words, which satisfied the constraints imposed by the experimental design. The lexical items had to be easily reproducible in a picture, easy to elicit in a word-naming task, and cognitively available for children, which restricted the use of low-frequency words.

However, I was cautious to attribute my results to lexical frequency effects, because it is likely that the novel words were perceived and processed as more psycholinguistically salient than low-frequency real words, and thus, attributed a lower predictability in the experimental setting. That means that I cannot conclusively affirm that the differences in glottal phonation between the real words and the words will be replicated in a study comparing high-frequency words to low-frequency words. Future research should compare words in different frequency bands, potentially using a slightly different experimental design. In particular, for the adult Mexican Spanish speakers, it would be reasonable to examine whether the unexpected asymmetry between real words and novel words also holds for high-frequency and low-frequency words.

7.3.3 The potential effects of type of function word

Due to the time constraints of the experimental design aimed at keeping engagement throughout the task, my study only included one functional item per consonant. As discussed above, the lack of interaction between consonant and age in Spanish and English, but the presence of first order effects for consonant in all the model, suggests that it is more likely that the type of functional item had an effect on the rate of glottal phonation, rather than the consonant itself. The inclusion of one functional item per consonant is thus a limitation of this study. In order to better determine whether the rate of consonant acquisition affects the development of adult-like strategies to repair empty onsets, future research should test more than one functional item with more or less equal contribution to lexical meaning (e.g., numerals). Alternatively, one could also examine whether the lexical meaning of the function word has an effect on the rate of glottal phonation by incorporating similar functional items with varying degrees of semantic meaning (e.g., *a /an*, *The girl has an avocado* vs. *The girl has one avocado*).

7.3.4 The potential effects of Spanish-English cognates

In order to create comparable designs in both languages in terms of lexical frequency, picture recognition, and location of primary stress, I had to include cognates in the two experiments. However, cognates, which share similar phonological, orthographic and semantic representations in the speakers' two languages, can be more sensitive to language interference. In particular for heritage language production, Amengual (2012) found that Spanish HS produced /t/ in Spanish-English cognates (e.g., *teléfono* — *telephone*) with longer VOT values than /t/ in non-cognates (e.g., *teclado* — *keyboard).* Shelton et al. (2017) also showed that Spanish HS break Spanish diphthongs into hiatus more often in cognates (e.g., *historia* — *history*) than in non-cognates (e.g., *aceite* — *oil*).

In the current study, compared to non-cognates, Spanish-English cognates may be more active in their non-target lexicons, which could result in higher activation scores of the non-target word during evaluation of the intended language. In other words, if *ángel* ('angel') is evaluated in Spanish, it may have higher activation values for English than a non-cognate such as *árbol* ('tree´). I have used the Crosslinguistic Overlap Scale for Phonology (Kohnert et al., 2004) to determine the degree of phonological overlap between the words with orthographic similarity in the two languages (see table 7.3).

COSP points	**Initial sounds**	**Syll.**	**/C/ overlap**	**/V/ overlap**	**Total**
isla —island	1	3	1	1	6
avocado — aguacate	2	1	1	1	5
ángel — angel	2	3	2	2	9
animal — animal	2	3	3	2	10
elefante — elephant	2	2	3	2	9
aquarium — acuario	2	3	2	1	8
iguana — iguana	2	3	3	2	10
olive — oliva	2	3	3	2	10

Table 7.3: Degree of phonological overlap between the Spanish-English cognates

Table 7.4 and 7.5 show a breakdown of the results per item and grouped them as Spanish-English cognates or non-cognates. Table 7.4 shows that the cognate with initial primary stress (i.e., *ángel* 'angel') was produced with glottal phonation with a similar frequency than the rest of the tokens under the stressed condition.

The results for the unstressed words show that HS produced Spanish-English more often with glottal phonation than non-cognates. Considering that the cognates *animal* ('animal') and *elefante* ('elephant') bear initial primary stress in English (i.e., *élephant*, *ánimal*), it is possible that HS carried the glottalization of the English stressed-syllables into their Spanish counterparts.

The results for the experiment with Spanish real words, hence, suggest the presence of a cognate status effect in the production of /C#V/ sequences. This effect appears in cases of mismatches in the stress patterns; in cases in which the word in the majority language bears initial stress and the word in the heritage language does not. The inclusion of cognates in the Spanish experiment does not represent a confound to examine the effect of stress, because the potential effects of cognate status bias against my prediction for stress (i.e., glottal phonation in words with initial primary stress > glottal phonation in words without initial primary stress). However, cognate effects represent a confound in relation to the type of speaker, as they bias against the null hypothesis. Considering that monolingually raised speakers will not activate their English representations in their evaluation of cognates, cognate status will only affect the HS. Despite this limitation, my findings still show an interaction between type of speaker and stress, indicating that the difference in the rate of glottal phonation between groups was larger for the words with initial primary stress (SpanMonoS = 2.94%, HS = 12.59%) than for the words without initial primary stress (SpanMonoS = 0.98%, HS = 32.65%). It is true, however, that cognates may have increased the difference in the rate of glottal phonation for the words without primary stress. For this reason, this particular finding (rate of glottal phonation for HS in words without initial primary stress > SpanMonoS in words without initial primary stress) should be taken with caution and should be replicated with non-cognate words.

	Real words	**% glottal phonation**	N
	Initial primary stress		
Cognates	ángel	29.84%	191
Non-cognates	árbol	39.06%	192
	hombre	30.53%	190
	ojo	29.69%	192
	Non-initial primary stress		
Cognates	animal	14.95%	194
	elefante	15.58%	199
Non-cognates	avión	9.33%	193
	espejo	8.38%	191

Table 7.4: Rate of glottal phonation in cognates and non-cognates in Spanish

In English, *island* and *avocado* are considered borderline cognate cases due to their lower degree of phonological overlap when compared to the rest of the cognates. Table 7.5 shows that the cognates with initial primary stress (i.e., *olive*) were not produced less often with glottal phonation than the rest of the items. As for the cognates without initial primary stress, only *aquarium* shows a slightly lower rate of glottal phonation than *umbrella* (i.e., most comparable words because it does not bear initial secondary stress). Therefore, in the case of English, it seems less likely that cognate status had an impact on the production of /C#V/ sequences.

To encapsulate, it is possible that cognate status effects are present in cognates with mismatching stress patterns, which bear initial prominence in the majority language but not in the heritage language. It is, thus, important to examine such effects in future studies, as they can have implications for the phonological structure of HS.

	Real words	**% glottal phonation**	N
	Initial primary stress		
Cognates	olive	70.66%	167
	island	69.54%	174
Non-cognates	onion	68.57%	175
	octopus	65.88%	170
	Non-initial primary stress		
Cognates	aquarium	17.04%	176
	iguana	25.13%	191
	avocado	36.67%	180
Non-cognates	umbrella	22.63%	190

Table 7.5: Rate of glottal phonation in cognates and non-cognates in English

7.3.5 Creaky voice or complete glottal stops

In my study, I collapsed the results of tokens containing creaky phonation and those containing full glottal stops, with the understanding that creaky phonation can be an attempt to insert a glottal consonant at the word juncture (Davidson, 2020). However, my data suggests that children and adults produced junctures with creaky phonation and tokens with full glottal stop insertion at different rates. Table 7.6 shows the number and percentage of tokens produced with creaky phonation and glottal phonation by speaker and age group in the Spanish experiments. In particular, the HS group shows a noteworthy pattern in the production of creaky phonation and full glottal stops, in that an initial prominent preference for glottal stops over creaky phonation retracts as the speakers' grammars mature. In the case of English (see Table 7.7), adults also show a more or less balanced production of creaky phonation when compared to full glottal stops, whereas children show a more clear preference for glottal stops over creaky phonation in the real and novel words. The groups of Spanish

HS also show a reduction of complete glottal stops across age groups, albeit not to the same extent as the monolingually raised English speakers. To encapsulate, child Spanish HS and English monolingual children are more like to produce glottal stops over creaky phonation than their adult counterparts. It seems plausible that this asymmetry is related to the process of language acquisition, in which non-lenited variants are preferred during childhood. There is still little research in the acquisition of consonant lenition. However, Miller (2013) studied the acquisition of /s/ lenition in 2 to 5-year-olds and found that 4-and 5- year-olds have already acquired the /s/-lenition from their caregivers and that 2-to-3 year olds show variable patterns, in that two children appear to have acquired /s/-lenition while the other two do not. A difference between Miller's (2013) and my study is that, in /C#V/ sequences, the presence of the new consonant is mediated by prosodic prominence. It is possible that, in prosodically prominent positions, non-lenited variants of the consonants are maintained during a longer time. In fact, Miller (2013) found that the younger children mostly showed variable patterns of /s/-lenition in utterance final position, which has been demonstrated to be a prominent position that eases children's acquisition of language (Shady & Gerken, 1999). I tentatively argue that complete glottal stops are retained during late childhood given their position in prosodically prominent positions, along with the already discussed potential benefit to ease word segmentation (Pompino-Marschall & Żygis, 2010).

Real words	**Spanish SpanMonoS**		**Spanish HS**	
	Creaky phonation	Glottal stops	Creaky phonation	Glottal stops
younger CH	8 (100%)	0	22 (13.7%)	139 (86.3%)
older CH	4 (44.4%)	5 (55.6%)	35 (27.3%)	93 (72.7%)
adults	7 (53.8%)	6 (46.2%)	28 (57.1%)	21 (42.9%)
Novel words				
younger CH	0	18 (100%)	7 (10.6%)	52 (89.4%)
older CH	2 (4.65%)	41 (95.4%)	8 (11.1%)	64 (88.9%)
adults	3 (6.67%)	42 (93.3%)	9 (26.5%)	25 (73.5%)

Table 7.6: Counts and frequency of creaky phonation and glottal stops in real words and novel words in Spanish

Real words	**EngMono**		**Spanish HS**	
	Creaky phonation	Glottal stops	Creaky phonation	Glottal stops
younger CH	30 (11.2%)	239 (88.8%)	17 (8.1%)	194 (91.1%)
older CH	68 (23.2%)	225 (76.8%)	39 (16.8%)	103 (83.2%)
adults	111 (44.9%)	136 (55.1%)	72 (34.1%)	139 (65.9%)
Novel words				
younger CH	12 (11.8%)	90 (88.2%)	11 (14.1%)	67 (85.9%)
older CH	36 (22.8%)	122 (77.2%)	20 (23.0%)	67 (77%)
adults	57 (49.6%)	58 (50.4%)	25 (26.9%)	68 (73.1%)

Table 7.7: Counts of creaky phonation and glottal stops in real words and novel words in English

7.3.6 The hidden structure

In this work, I have assumed that syllabification, which is part of the hidden structure, affects the surface structure of /l#V/ sequences. More specifically, I have assumed that resyllabified consonants will pattern durationally like canonical onsets, and that ambisyllabic consonants will be lighter than codas. While such approach is advantageous to analyze syllabification as a surface learning problem, it also presents theoretical challenges. In fact, an existing relationship between the hidden structure and the surface structure is not well established in the literature. Despite some evidence showing that listeners rely on phonetic cues (i.e., duration) to determine whether a consonant is resyllabified in ambiguous contexts (Lahoz-Bengoechea & Jiménez-Bravo, 2020), studies on production of ambisyllabic and resyllabified consonants have not yet established reliable correlates for syllabic affiliation (Durvasula & Huang, 2017; Durvasula et al., 2013; Gao & Xu, 2007; Gick, 2003; Hualde & Prieto, 2014; Scobbie & Pouplier, 2010; Strycharczuk & Kohlberger, 2016).

Even provided that there is a consistent relationship between the surface structure and the hidden structure, it is possible that, across speakers, listeners use more than one acoustic correlate to produce resyllabified consonants. In that case, a better approach to find candidate probabilities would be to incorporate more than one phonetic feature to partition the data in unsupervised learning methods.

Another possibility would be to model my results as part of the hidden structure. However, hidden structures pose a problem for MaxEnt grammars, and error-driven learners in general, as the learner does not have access to the mapping between the surface structure and its hidden representation. In surface structure problems, the learner adjusts the weights of the constraints to fit the observed data distribution by comparing the violation profile of the learning datum to that of the current grammar. In hidden structure problems, the learner does not have access to the violation profile of the learning datum because the surface representation is associated to more than one hidden structure. For example, if we do not assume that resyllabified consonants have different durational properties than codas, when the grammar is presented with the sequence /un oso/ 'a bear', the candidate can either violate Onset or Align-L. At this point, the learner has to infer whether to syllabify the string as /un.o.so/ or /u.no.so/.

Despite the challenge posed by hidden structure problems, solutions to their learnability have been implemented in OT-GLA, Harmonic Grammar, and MaxEnt grammars (Boersma & Pater, 2008; Jarosz, 2013; Prickett & Pater, 2019; Tesar, 2004; Tesar & Smolensky, 1998, among others). Among them, Prickett and Pater (2019) have recently formalized a solution that provides results matching the best on-line learner examined in Boersma (2009) for Tesar & Smolensky's (1998) data set (i.e., 91.94% of successfully learned languages). To do so, Prickett and Pater (2019) implement the Expectation Maximization algorithm (Dempster et al., 1977) to calculate output probability, which estimates probabilities in the output based on the current constraint weights. Future models of resyllabification should compare the solution proposed in this work to models implementing hidden structure solutions.

7.4 Conclusion

The main goals of this dissertation were, first, to examine the extent to which cross-linguistic interaction occurs in the grammars of child and adult Spanish HS by examining repairs of word-external empty onsets at the surface structure, and, second, to model these results in order to discuss possible constraint-based models that would be compatible with heritage language learning. I conducted four production tasks that elicited word-external consonant-to-vowel sequences (i.e., functional and lexical words) (i.e., /C#V/) in real words (e.g., *all islands*, *el ojo* 'the eye') and novel words (e.g., *all embos*, *el anbo*), and tested child and adults Mexican Spanish speakers residing in Mexico, child and adult monolingually raised English speakers residing in the Los Angeles area, and child and adult Spanish HS from southern California.

In Chapter 3, I presented the results for the monolingually raised Spanish and English speakers. The results of the experiment eliciting real words showed that, while Spanish speakers prefer to repair empty onsets with modal phonation, English speakers favor glottal phonation over modal phonation in words bearing initial primary stress. With regard to acquisition, from the time of testing (i.e., approximately 5 years old), monolingually raised English and Spanish speakers demonstrate adult-like rates of glottal phonation in the real words. In the novel words, adult Spanish Mexican speakers are more likely to use glottal phonation than child Mexican Spanish speakers. I argued that adult Mexican Spanish speakers are better equipped to process the potential listener-oriented unpredictability of the novel words. In the English novel words, the younger child EngMonoS and older child EngMonoS present higher rates of glottal phonation than the adult EngMonoS, indicating that, in words that are not stored in the lexicon a developmental trajectory can be observed in the rate of glottal phonation (child EngMonoS > adult EngMonoS). My study highlights the relevance of including novel words in child experiments in order to control for frequency and avoid effects of vocabulary size.

In Chapter 4, I formalized the results for the Spanish and English grammars using a weighted-constraint approach. I considered three strategies to repair empty onsets: syllabic misalignment (i.e., resyllabification in Spanish or ambisyllabicity in English), maintenance of the empty onset (i.e., consonant in the coda position), and glottal stop epenthesis (i.e., /ʔ/-epenthesis). I also accounted for the role of primary stress in raising the probabilities of empty onsets to be repaired with /ʔ/-epenthesis.

In Chapter 5, I presented the results of the four production tasks for the HS' participants. With the Spanish real words, child Spanish HS are more likely to use glottal phonation than child Mexican Spanish speakers, but adult HS do not differ in their rate of glottal phonation when compared to their monolingual counterparts. This indicates a greater permeability to language transfer during childhood. I proposed that the greater malleability of child HS' grammars arises because children are still developing the necessary cognitive resources to inhibit and balance the adequate grammars (i.e., bilingual language control). In the Spanish novel words, the younger child HS and the older child HS showed greater rates of glottal phonation than their age-matched peers, but the adult HS and the adult SpanMonoS did not show significantly different rates of glottal phonation. Interestingly, the Spanish HS demonstrated a decreasing pattern in the rate of glottal phonation with age, while Mexican Spanish speakers increase their rate of glottal phonation as their grammars mature. It is, thus, possible that two differentiated processes affect the rate of glottal phonation. While monolingually raised Spanish speakers may enhance the prosodic words boundaries based on the predictability of the lexical items, HS may, instead, show a developmental pattern similar to that of the EngMonoS. Namely, HS show heritage-to-majority language transfer in their English, because their rates of glottal transfer decrease as the grammar matures.

In English, Spanish HS produced glottal phonation less frequently than English monolingual speakers, and this was so regardless of the age or amount of language use. I discussed two possible scenarios to explain these results. First, the difference in glottal phonation between the two groups suggests that language transfer also occurs from the heritage to the majority language, encouraging HS to repair /C#V/ sequences with resyllabification strategies, and to do so more often than their monolingual American English-speaking peers. The second scenario establishes that language contact appears at the societal level. In this case, HS produce outcomes similar to those found in the input that they receive. That is, Spanish HS may be exposed to an English variety that has been influenced by Mexican Spanish and, thus, contains low rates of glottal phonation in prosodically prominent initial vowels. Future studies should analyze the speech of less proficient Spanish HS to determine whether the rates of glottal phonation remain stable regardless of the level of command in the heritage language.

In Chapter 6, I first fitted the results of the HS using the formalization for the monolingually raised speakers. However, my results did not show to be compatible with a model that does not predict transfer between a bilingual's two grammars. Thus, I proposed a GSC-based model of coactivation that accounts for language transfer by considering speaker-specific degrees of language dominance and inhibitory skills. Input is evaluated by two simultaneously active constraint sets, whose activity depends on the speaker's relative dominance in the two languages. Coactivation in the HS' grammars is prevented by a prior applied on the coactivated constraints, requiring the target language to have an activation of 1 and the irrelevant language to have an activation of 0. This model contributes a theoretical formalization to the field of heritage language phonology and predicts that inter-speaker variation in the rates of language transfer will be modulated 1) by speaker-specific degrees of language dominance and 2) by the speakers' ability to inhibit irrelevant languages (i.e., bilingual language control).

APPENDIX A

List of elicitation materials

Experiment 1: Spanish Real Words[1]

Aquí hay un barco y aquí hay "un avión"

'Here there is a ship and here there is a plane'

¿Cuál vuela? "el avión"

'Which one flies?'

Aquí hay dos barcos, y aquí hay "dos aviones"

Aquí hay una flor y aquí hay "un árbol"

'Here there is a flor and here there is a tree'

¿Cuál tiene un tronco grueso? "el árbol"

'Which one has a big trunk'

Aquí hay dos flores, y aquí hay "dos árboles"

Aquí hay un gato, y aquí hay "un elefante"

'Here there is a cat and here there is an elephant'

¿Cuál es más grande? "el elefante"

'Which one is bigger?'

Aquí hay dos gatos y aquí hay "dos elefantes"

Aquí hay una planta, y aquí hay "un animal"

'Here there is a plant and here there is an animal'

¿Cuál tiene patas? "el animal"

'Which one has legs, the animal'

Aquí hay dos plantas y aquí hay "dos animales"

Aquí hay un demonio y, aquí hay "un ángel"

---

[1] **Translations are provided only one time when new words are introduced.**

‘Here there is a demon and here there is an angel’

¿Cuál es blanco y azul? “el ángel”

‘Which one is white and blue? The angel’

Aquí hay dos demonios y aquí hay “dos ángeles”

Aquí hay una silla y aquí hay “un espejo”

‘Here there is a chair and here there is a mirror’

¿Cuál refleja la imagen? “el espejo”

‘Which one reflects the image?’

Aquí hay dos sillas y aquí hay “dos espejos”

Aquí hay una boca, y aquí hay “un ojo”

‘Here there is a mouth and here there is an eye’

¿Cuál es azul? “el ojo”

‘Which one is blue?’

Aquí hay dos bocas y aquí hay “dos ojos”

Aquí hay una mujer, y aquí hay “un hombre”

¿Cuál lleva gafas? “el hombre”

Aquí hay dos mujeres, y aquí hay “dos hombres”

Experiment 2: English Real Words

This is a tomato and this is “an onion”

The girl likes this tomato and the boy likes “this onion”

The girl loves all tomatoes and the boy loves “all onions”

This is a mountain and this is “an island”

The girl likes this mountain and the boy likes “this island”

The girl loves all mountains and the boy loves “all islands”

This is a jacket and this is “an umbrella”

The girl likes this jacket and the boy likes “this umbrella”

The girl loves all jackets and the boy loves “all umbrellas”

This is a pear and this is “an avocado”

The girl likes this pear and the boy likes “this avocado”

The girl loves all pears and the boy likes “all avocados

This is a table is “an aquarium”

The girl likes this table and the boy likes “this aquarium”

The girl loves all tables and the boy likes “all aquariums”

This is a dolphin and this is “an octopus”

The girl likes this dolphin and the boy likes “this octopus”

The girl loves all dolphins and the boy likes “all octopi”

This is a cookie and this is “an olive”

The girl likes this cookie and the boy likes “this olive”

The girl loves all cookies and the boy likes “all olives”

This is a mouse and this is “an iguana”

The girl likes this mouse and the boy likes “this iguana”

The girl loves all mice and the boy loves “all iguanas”

Experiment 3: Spanish Novel Words

Esta cosa se llama plato y esta cosa se llama nanbo. ¿Cuál es blanco? “el nanbo”

’This thing is called plate and this thing is called nanbo. Which one is white?’

Esta cosa se llama fresa y esta cosa se llama londa ¿Cuál es azulada? “la londa”

'This thing is called strawberry and this thing is called londa. Which one is blue?'

Esta cosa se llama barco y esta cosa se llama irgo. ¿Cuál es anaranjado? "el irgo"

'This thing is called ship and this thing is called irgo. Which one is orange?'

Esta cosa se llama silla y esta cosa se llama lamba ¿Cuál es pequeña? "la lamba"

'This thing is called chair and this thing is called lamba. Which one is small?'

Esta cosa se llama nuez y esta cosa se llama lidul ¿Cuál es alargada? "la lidul"

'This thing is called ship and this thing is called irgo. Which one is orange?'

Esta cosa se llama camión y esta cosa se llama milor. ¿Cuál es rojo? "el milor"

'This thing is called truck and this thing is called milor. Which one is red?'

Esta cosa se llama violín y esta cosa se llama berol ¿Cuál es amarillo? "el berol"

'This thing is called violin and this thing is called berol. Which one is yellow?'

Esta cosa se llama peine y esta cosa se llama borgo ¿Cuál es anaranjado? "el borgo"

'This thing is called comb and this thing is called borgo. Which one is orange?'

Esta cosa se llama cajón y esta cosa se llama bodín ¿Cuál es amarillo? "el bodín"

'This thing is called drawer and this thing is called bodín. Which one is yellow?'

Esta cosa se llama libro y esta cosa se llama anbo ¿Cuál es rojo? "el anbo"

'This thing is called book and this thing is called anbo. Which one is red?'

Esta cosa se llama balón y esta cosa se llama adol ¿Cuál es azulado? "el adol"

'This thing is called ball and this thing is called adol. Which one is blue?'

Esta cosa se llama mesa y esta cosa se llama lenba ¿Cuál es anaranjada? "la lenba"

'This thing is called table and this thing is called lenba. Which one is orange?'

Esta cosa se llama dedo y esta cosa se llama belgo ¿Cuál es amarillo? "el belgo"

'This thing is called finger and this thing is called belgo. Which one is yellow?'

Esta cosa se llama nariz y esta cosa se llama laned ¿Cuál es anaranjada? “la laned”

’This thing is called nose and this thing is called laned. Which one is orange?’

Esta cosa se llama vaso y esta cosa se llama mingo ¿Cuál es anaranjado? “el mingo”

’This thing is called glass and this thing is called mingo. Which one is orange?’

Esta cosa se llama bastón y esta cosa se llama obín ¿Cuál es azulado? “el obín”

’This thing is called walking stick and this thing is called obín. Which one is blue?’

Esta cosa se llama cuadro y esta cosa se llama onbo ¿Cuál es anaranjado? “el onbo”

’This thing is called painting and this thing is called onbo. Which one is orange?’

Esta cosa se llama ciudad y esta cosa se llama leriz . ¿Cuál es amarilla? “la leriz”

’This thing is called city and this thing is called leriz. Which one is yellow?’

Esta cosa se llama jarrón y esta cosa se llama madín ¿Cuál es azulado? “el madín”

’This thing is called vase and this thing is called madín. Which one is blue?’

Esta cosa se llama carta y esta cosa se llama lirba ¿Cuál es roja? “la lirba”

’This thing is called letter and this thing is called lirba. Which one is red?’

Esta cosa se llama pañal y esta cosa se llama ilor . ¿Cuál es anaranjado? “el ilor”

’This thing is called diaper and this thing is called ilor. Which one is orange?’

Esta cosa se llama pincel y esta cosa se llama ebón . ¿Cuál es blanco? “el ebón”

’This thing is called brush and this thing is called ebón. Which one is white?’

Esta cosa se llama coche y esta cosa se llama endo . ¿Cuál es rojo? “el endo”

’This thing is called car and this thing is called endo. Which one is red?’

Esta cosa se llama miel y esta cosa se llama lodad ¿Cuál es redonda? “la lodad”

’This thing is called honey and this thing is called lodad. Which one is round?’

Experiment 4: English Novel Words

These are some fancy desserts and these are some funny egoons. The girl loves all desserts and the boy loves “all egoons”

This is a racoon and this is a lemood. What is this? “a lemood”

These are some fancy bottles and these are some funny enbos. The girl loves all desserts and the boy loves “all embos”

These are some fancy hotels and these are some funny nanoods. The girl loves all desserts and the boy loves “all nanoods”

These are some fancy pumpkins and these are some funny menzies. The girl loves all desserts and the boy loves “all menzies”

This is a guitar and this is a lozeen. What is this? “a lozeen”

These are some fancy baguettes and these are some funny noneens. The girl loves all desserts and the boy loves “all noneens”

This is a canoe and this is a linoon. What is this? “a linoon”

These are some fancy plantains and these are some funny ozeeds. The girl loves all plantains and the boy loves“all ozeeds”

This is a dolphin and this is a lamby. What is this? “a lamby”

These are some fancy giraffes and these are some funny abeeds. The girl loves all giraffes and the boy loves “all abeeds”

This is a camel and this is a lonzy. What is this? “a lonzy”

These are some fancy machines and these are some funny iboons. The girl loves all machines and the boy loves “all iboons”

This is a flower and this is a lenzy. What is this? “a lenzy”

This is a monkey and this is a lidzo. What is this? “a lidzo”

This is a balloon and this is a minood. What is this? “all minoods”

These are some fancy rabbits and these are some funny adgies. The girl loves all rabbits and the boy loves “all adgies”.

These are some fancy canals and these are some funny megoons. The girl loves all rabbits and the boy loves “all megoons”.

These are some fancy carrots and these are some funny nadgies. The girl loves all carrots and the boy loves “all nadgies”.

This is a cartoon and this is a lameed. What is this? “a lameed”

These are some fancy lemons and these are some funny ninzos. The girl loves all lemons and the boy loves “all ninzos”.

These are some fancy zebras and these are some funny imbos. The girl loves all zebras and the boy loves “all imbos”

These are some fancy pillows and these are some funny nombos. The girl loves all pillows and the boy loves “all nombos”

These are some fancy mushrooms and these are some funny ombies. The girl loves all mushrooms and the boy loves “all ombies”

APPENDIX B

Parental Background Questionnaire

Linguistic Questionnaire

Your child was selected as a possible participant in this study because he/she is a Spanish- English bilingual speaker and he/she enrolled in the Spanish immersion program and, thus, is exposed to both Spanish and English at school.

We are investigating the development of the Spanish pronunciation over time in early Spanish - English bilinguals and the effect of being enrolled in a Spanish immersion program.

Thank you for filling out this questionnaire.

Family Information

1. Child's name

____

2. Grade

Mark only one oval.

- ( ) Kinder
- ( ) First Grade
- ( ) Second Grade
- ( ) Third Grade
- ( ) Fourth Grade
- ( ) Fifth Grade
- ( ) Sixth Grade

3. Child's birthdate

____

Example: January 7, 2019

4. If s/he was not born in the USA where was s/he born and at what age did s/he arrive to the USA?

____

5. Does your child have siblings? How many?

____

6. Age of first exposure to Spanish:

____

7. Age of first exposure to English:

____

8. When there is more than one person with your child, is there any member of the family that interacts with your child more? (e.g. mother, father, siblings, all the same)

____

Background Caregiver 1

9. Is

Mark only one oval.

- ( ) mother
- ( ) father

10. Country of Origin

____

11. Age of Arrival to the US

____

12. Age

____

13. Highest Education

Mark only one oval.

- ( ) Primary school
- ( ) Middle school
- ( ) High school
- ( ) College
- ( ) Master's degree
- ( ) Doctoral degree

14. Zip Code of Residence

____

Background Caregiver 2

15. Is

Mark only one oval.

- ( ) mother
- ( ) father
- ( ) Other: ______________________________

16. Place of Origin

____

17. Age of Arrival to the US

____

18. Age

____

19. Highest Education

Mark only one oval.

- ( ) Primary School
- ( ) Middle School
- ( ) High School
- ( ) College
- ( ) Master's Degree
- ( ) Doctorate Degree
- ( ) Other: ______________________________

20. Zip Code of Residence

Interaction child and adults

21. On average how many hours a day does the child spend AWAKE?

22. On average how many AWAKE hours a day does the child spend with caregiver 1? Monday to Friday

23. On average how many AWAKE hours a day does the child spend with caregiver 1? Saturday and Sunday

24. On average how many AWAKE hours a day does the child spend with caregiver 2? Monday to Friday

25. On average how many AWAKE hours a day does the child spend with caregiver 2? Saturday and Sunday

Language Background

26. What language(s) does the child's caregiver 1 speak to him or her at home

Mark only one oval.

- Virtually 100% English
- About 90% English, 10% Spanish
- About 80% English, 20% Spanish
- About 60% English, 40% Spanish
- About 50% English, 50% Spanish
- About 40% English, 60% Spanish
- About 20% English, 80% Spanish
- About 10% English, 90% Spanish
- Virtually 100% Spanish
- Other:

27. What language(s) does the child's caregiver 2 speak to him or her at home

Mark only one oval.

- Virtually 100% English
- About 90% English, 10% Spanish
- About 80% English, 20% Spanish
- About 60% English, 40% Spanish
- About 50% English, 50% Spanish
- About 40% English, 60% Spanish
- About 20% English, 80% Spanish
- About 10% English, 90% Spanish
- Virtually 100% Spanish
- Other:

28. What language(s) does the child speak to the caregiver 1 at home?

Mark only one oval.

- Virtually 100% English
- About 90% English, 10% Spanish
- About 80% English, 20% Spanish
- About 60% English, 40% Spanish
- About 50% English, 50% Spanish
- About 40% English, 60% Spanish
- About 20% English, 80% Spanish
- About 10% English, 90% Spanish
- Virtually 100% Spanish
- Other: ______________________

29. What language(s) does the child speak to the caregiver 2 at home?

Mark only one oval.

- Virtually 100% English
- About 90% English, 10% Spanish
- About 80% English, 20% Spanish
- About 60% English, 40% Spanish
- About 50% English, 50% Spanish
- About 40% English, 60% Spanish
- About 20% English, 80% Spanish
- About 10% English, 90% Spanish
- Virtually 100% Spanish
- Other: ______________________

30. How many hours does your child interact with his/her siblings from Monday to Friday?

____

31. How many hours does your child interact with his/her siblings in the we?kend

Mark only one oval.

- Option 1

32. What language(s) does the child's younger siblings speak to him/her (if applicable)?

Mark only one oval.

- Virtually 100% English
- About 90% English, 10% Spanish
- About 80% English, 20% Spanish
- About 60% English, 40% Spanish
- About 50% English, 50% Spanish
- About 40% English, 60% Spanish
- About 20% English, 80% Spanish
- About 10% English, 90% Spanish
- Virtually 100% Spanish
- Other: ______________________

33. What language(s) does the child's older siblings speak to him/her (if applicable)?

Mark only one oval.

- Virtually 100% English
- About 90% English, 10% Spanish
- About 80% English, 20% Spanish
- About 60% English, 40% Spanish
- About 50% English, 50% Spanish
- About 40% English, 60% Spanish
- About 20% English, 80% Spanish
- About 10% English, 90% Spanish
- Virtually 100% Spanish
- Other: ______________________

34. What language(s) does the child speak to his or her younger siblings (if applicable)?

Mark only one oval.

- Virtually 100% English
- About 90% English, 10% Spanish
- About 80% English, 20% Spanish
- About 60% English, 40% Spanish
- About 50% English, 50% Spanish
- About 40% English, 60% Spanish
- About 20% English, 80% Spanish
- About 10% English, 90% Spanish
- Virtually 100% Spanish
- Other: ______________________

35. What language(s) does the child speak to his or her older siblings (if applicable)?

Mark only one oval.

- Virtually 100% English
- About 90% English, 10% Spanish
- About 80% English, 20% Spanish
- About 60% English, 40% Spanish
- About 50% English, 50% Spanish
- About 40% English, 60% Spanish
- About 20% English, 80% Spanish
- About 10% English, 90% Spanish
- Virtually 100% Spanish
- Other: ______________________

36. Any other children older than 6-8 or adults interact with child at least 2-4h/week? Specify who, how many awake hours per week on average.

____

37. What language(s) does the child speak to others (not main caretakers)?

Mark only one oval.

- Virtually 100% English
- About 90% English, 10% Spanish
- About 80% English, 20% Spanish
- About 60% English, 40% Spanish
- About 50% English, 50% Spanish
- About 40% English, 60% Spanish
- About 20% English, 80% Spanish
- About 10% English, 90% Spanish
- Virtually 100% Spanish
- Other: ______________________

38. Does your child hear/watch TV, radio more than an hour a day? If so, in what languages? And how many hours? Spanish TV/radio hours:

Mark only one oval.

1	2	3	4	5	6	7	8	9	10

39. Does your child hear/watch TV, radio more than an hour a day? If so, in what languages? And how many hours? English TV/radio hours:

Mark only one oval.

1	2	3	4	5	6	7	8	9	10

40. Have there been other events that might have had an effect on your child's Spanish or/and English development?

APPENDIX C

Adult Linguistic Background Questionnaire

Linguistic Questionnaire

Questionnaire about English and Spanish exposure

1. Name

2. Birth date

   Example: January 7, 2019

3. Place of birth (city, country)

4. Current place of residence (zip code, city, country)

5. Have you had another place of residence. If so, in what other city have you lived?

6. Caregiver 1 is

   Mark only one oval.

   - Mother
   - Father

7. Place of birth caregiver 1

8. Caregiver 2 is

   Mark only one oval.

   - Mother
   - Father

9. Place of birth caregiver 2

10. What language/s did you learn at home?

11. What languages do you speak with Caregiver 1?

12. What languages do you speak with Caregiver 2?

13. What language do you speak with your siblings?

Linguistic information (0 to 11 years)

14. Did you go to a childcare?

____

15. What languages were you exposed to?

Mark only one oval.

- ◯ Virtually 100% English
- ◯ About 90% English, 10% Spanish
- ◯ About 80% English, 20% Spanish
- ◯ About 60% English, 40% Spanish
- ◯ About 50% English, 50% Spanish
- ◯ About 40% English, 60% Spanish
- ◯ About 20% English, 80% Spanish
- ◯ About 10% English, 90% Spanish
- ◯ Virtually 100% Spanish
- ◯ Other: _______________

16. What primary school did you go to?

____

17. Were you enrolled in a Spanish immersion program?

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Other: _______________

18. What were the languages of instruction?

Mark only one oval.

- ◯ Virtually 100% English
- ◯ About 90% English, 10% Spanish
- ◯ About 80% English, 20% Spanish
- ◯ About 60% English, 40% Spanish
- ◯ About 50% English, 50% Spanish
- ◯ About 40% English, 60% Spanish
- ◯ About 20% English, 80% Spanish
- ◯ About 10% English, 90% Spanish
- ◯ Virtually 100% Spanish
- ◯ Other: _______________

19. From Monday to Friday, how many hours did you spend with the following people?

Mark only one oval per row.

	1	2	3	4	5	6	7	8	9	10	11	12 or more
Caregiver 1	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Caregiver 2	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Older siblings	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Younger siblings	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Friends	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Others	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

20. What languages (percentages) did you hear from 0 to 11 years?

Mark only one oval per row.

	Virtually 100% English	About 90% English, 10% Spanish	About 80% English, 20% Spanish	About 60% English, 40% Spanish	About 50% English, 50% Spanish	About 40% English, 60% Spanish	About 20% English, 80% Spanish	About 10% English, 90% Spanish	Virtually 100% Spanish	Other combination:
What languages did caregiver 1 speak to you?	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
What languages did caregiver 2 speak to you?	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
What languages did your older siblings speak to you?	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
What languages did your younger siblings speak to you?	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
What languages did your friends siblings speak to you?	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
What languages did others speak to you?	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

21. What languages (percentages) did you speak from 0 to 11 years?

Mark only one oval per row.

	Virtually 100% English	About 90% English, 10% Spanish	About 80% English, 20% Spanish	About 60% English, 40% Spanish	About 50% English, 50% Spanish	About 40% English, 60% Spanish	About 20% English, 80% Spanish	About 10% English, 90% Spanish	Virtually 100% Spanish	Other combination:
What languages did you speak to caregiver 1?	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
What languages did you speak to caregiver 2?	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
What languages did you speak to your older siblings?	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
What languages did you speak to your younger siblings?	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
What languages did you speak to your friends?	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
What languages did you speak to others?	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

22. Did you hear/watch TV, radio more than an hour a day in Spanish? And how many hours?

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

23. Did you hear/watch TV, radio more than an hour a day in English? And how many hours?

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭

Linguistic Background (12-18 years)

24. What middle school did you go to?

____

25. Were you enrolled in a Spanish immersion program during middle school?

Mark only one oval.

- ⬭ Yes
- ⬭ No
- ⬭ Other: ____

26. What were the languages of instruction?

Mark only one oval.

- ⬭ Virtually 100% English
- ⬭ About 90% English, 10% Spanish
- ⬭ About 80% English, 20% Spanish
- ⬭ About 60% English, 40% Spanish
- ⬭ About 50% English, 50% Spanish
- ⬭ About 40% English, 60% Spanish
- ⬭ About 20% English, 80% Spanish
- ⬭ About 10% English, 90% Spanish
- ⬭ Virtually 100% Spanish
- ⬭ Other combination:

27. What high school did you go to?

____

28. Were you enrolled in a Spanish immersion program during high school?

Mark only one oval.

- ⬭ Yes
- ⬭ No
- ⬭ Other: ____

29. What were the languages of instruction?

Mark only one oval.

- Virtually 100% English
- About 90% English, 10% Spanish
- About 80% English, 20% Spanish
- About 60% English, 40% Spanish
- About 50% English, 50% Spanish
- About 40% English, 60% Spanish
- About 20% English, 80% Spanish
- About 10% English, 90% Spanish
- Virtually 100% Spanish
- Other combination:

30. From Monday to Friday, how many hours did you spend with the following people?

Mark only one oval per row.

	1	2	3	4	5	6	7	8	9	10	11	12 or more
Caregiver 1												
Caregiver 2												
Older siblings												
Younger siblings												
Friends												
Others												

31. During the weekends, how many hours did you spend with the following people?

Mark only one oval per row.

	1	2	3	4	5	6	7	8	9	10	11	12 or more
Caregiver 1												
Caregiver 2												
Older siblings												
Younger siblings												
Friends												
Others												

32. What languages (percentages) did you hear from 12 to 18 years?

Mark only one oval per row.

	Virtually 100% English	About 90% English, 10% Spanish	About 80% English, 20% Spanish	About 60% English, 40% Spanish	About 50% English, 50% Spanish	About 40% English, 60% Spanish	About 20% English, 80% Spanish	About 10% English, 90% Spanish	Virtually 100% Spanish	Other combination:
What languages did caregiver 1 speak to you?										
What languages did caregiver 2 speak to you?										
What languages did your older siblings speak to you?										
What languages did your younger siblings speak to you?										
What languages did your friends siblings speak to you?										
What languages did others speak to you?										

33. What languages (percentages) did you speak from 12 to 18 years?

Mark only one oval per row.

	Virtually 100% English	About 90% English, 10% Spanish	About 80% English, 20% Spanish	About 60% English, 40% Spanish	About 50% English, 50% Spanish	About 40% English, 60% Spanish	About 20% English, 80% Spanish	About 10% English, 90% Spanish	Virtually 100% Spanish	Other combination:
What languages did you speak to caregiver 1?										
What languages did you speak to caregiver 2?										
What languages did you speak to your older siblings?										
What languages did you speak to your younger siblings?										
What languages did you speak to your friends?										
What languages did you speak to others?										

34. Did you hear/watch TV, radio more than an hour a day in Spanish? And how many hours?

Mark only one oval.

1	2	3	4	5	6	7	8	9	10

35. Did you hear/watch TV, radio more than an hour a day in English? And how many hours?

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Linguistic background (18 to 30 years)

36. What is your Major / Minor at university?

____

37. What are the languages and percentages of instruction?

Mark only one oval.

- ○ Virtually 100% English
- ○ About 90% English, 10% Spanish
- ○ About 80% English, 20% Spanish
- ○ About 60% English, 40% Spanish
- ○ About 50% English, 50% Spanish
- ○ About 40% English, 60% Spanish
- ○ About 20% English, 80% Spanish
- ○ About 10% English, 90% Spanish
- ○ Virtually 100% Spanish
- ○ Other combination:

38. From Monday to Friday, how many hours do you spend with the following people?

Mark only one oval per row.

	1	2	3	4	5	6	7	8	9	10	11	12 or more
Caregiver 1	○	○	○	○	○	○	○	○	○	○	○	○
Caregiver 2	○	○	○	○	○	○	○	○	○	○	○	○
Older siblings	○	○	○	○	○	○	○	○	○	○	○	○
Younger siblings	○	○	○	○	○	○	○	○	○	○	○	○
Friends	○	○	○	○	○	○	○	○	○	○	○	○
Others	○	○	○	○	○	○	○	○	○	○	○	○
Work colleagues	○	○	○	○	○	○	○	○	○	○	○	○

39. During the weekends, how many hours do you spend with the following people?

Mark only one oval per row.

	1	2	3	4	5	6	7	8	9	10	11	12 or more
Caregiver 1	○	○	○	○	○	○	○	○	○	○	○	○
Caregiver 2	○	○	○	○	○	○	○	○	○	○	○	○
Older siblings	○	○	○	○	○	○	○	○	○	○	○	○
Younger siblings	○	○	○	○	○	○	○	○	○	○	○	○
Friends	○	○	○	○	○	○	○	○	○	○	○	○
Others	○	○	○	○	○	○	○	○	○	○	○	○
Work colleagues	○	○	○	○	○	○	○	○	○	○	○	○

40. What languages (percentages) do the following people speak to you since you are 18?

Mark only one oval per row.

	Virtually 100% English	About 90% English, 10% Spanish	About 80% English, 20% Spanish	About 60% English, 40% Spanish	About 50% English, 50% Spanish	About 40% English, 60% Spanish	About 20% English, 80% Spanish	About 10% English, 90% Spanish	Virtually 100% Spanish	Other combination:
What languages does caregiver 1 speak to you?	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
What languages does caregiver 2 speak to you?	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
What languages do your older siblings speak to you?	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
What languages do your younger siblings speak to you?	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
What languages do your friends siblings speak to you?	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
What languages do others speak to you?	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
What languages do work colleagues speak to you? (if applies)	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

41. What languages (percentages) do you speak since you are 18?

Mark only one oval per row.

	Virtually 100% English	About 90% English, 10% Spanish	About 80% English, 20% Spanish	About 60% English, 40% Spanish	About 50% English, 50% Spanish	About 40% English, 60% Spanish	About 20% English, 80% Spanish	About 10% English, 90% Spanish	Virtually 100% Spanish	Other combination:
What languages do you speak to caregiver 1?	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
What languages do you speak to caregiver 2?	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
What languages do you speak to your older siblings?	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
What languages do you speak to your younger siblings?	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
What languages do you speak to your friends?	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
What languages do you speak to others?	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
What languages do you speak to work colleagues (if applies)?	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

42. Do you hear/watch TV, radio more than an hour a day in Spanish? And how many hours?

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭

43. Have there been any significant changes in terms of your linguistic background that you haven't mentioned?

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