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2016

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UNIVERSITY OF CALIFORNIA, SAN DIEGO

**Cross-language Activation and the Phonetics of Code-switching**

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

in

Linguistics

by

Page Elizabeth Piccinini

Committee in charge:

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2016

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Chair

University of California, San Diego

2016

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## ACKNOWLEDGEMENTS

This dissertation was completed with the help and patience (and appreciated distractions) of many people. To my advisor, Marc Garellek, thank you for all the time and thought you put into this project. I am deeply appreciative for all you've done for me over the last two and half years. To the rest of my committee, Eric Baković, Sarah Creel, Tamar Gollan, and Rachel Mayberry, thank you for your insightful comments over the years. Each you has provided me with indispensable help at different points during my time at UCSD.

In addition to my committee, I want to express my gratitude to the other advisors who have allowed me to get this far. Ann Bradlow, without the time spent in your lab as a bewildered undergraduate I never would have made the leap to pursuing a PhD. Amalia Arvaniti, thank you for all of your advice and comments from the beginning of my graduate school journey. Alejandrina Cristia, thank you for welcoming a strange student into your lab and opening my eyes to the many other sides of research.

On a more personal note, to my cohort, Younah Chung, Gustavo Guajardo, Mark Myslín, Gary Patterson, and Nadav Sofer, I'm so glad you are the five people I got to spend those early classes with. Thank you also to my other fellow UCSD graduate students over the years, Rebecca Colavin, Gwendolyn Gillingham, Bethany Keffala, Ryan Lepic, Savithry Namboodiripad, Bożena Pająk, Amanda Ritchart, Lisa Rosenfelt, and Scott Seyfarth. I can't begin to express how lucky I was to have all of you handy, whether it was to nerd-out over some exciting new results, or to talk about anything but research for a little bit (shout out to the book club). During this last year Team Paris kept me going when finishing seemed so close, but also so far away. Christina Bergmann, Julia Carbajal, Alexander Martin, and Sho Tsuji, thanks for making me take a break every once in a while for a coffee or a pastry. Over in Massachusetts, Meghan Armstrong, you've been the best late night GChat support a graduate student could ask for.

I have been lucky enough to work in several different labs in multiple countries during my time in graduate school. At UCSD I was able to be a part of the Phonetic Lab, PhonCo (the group formerly known as SaDPhIG), the LASR Lab, and the CRL. Abroad, thank you to the GrEP Group in Barcelona and the LSCP in Paris for welcoming me with open arms.

This work could not have been completed without the help of many undergraduate research assistants, Esperanza González, Criccely Grijalva, Zully Herrarte, Richard Kroeger, Linnea Lagerstrom, Hilda Parra, Mireya Pinell-Cruz, Rosa Quezada, and Gerardo Soto-Becerra. Thank you for all the time and energy you put into this project.

Thank you to my parents for all of your support throughout the years, whether it be attending graduate school or moving to a foreign country. I could not be more lucky to have been born your daughter.

Finally, thank you to Eric Kramer for all the little and big things. From introducing me to dplyr (a massive time saver), to making me laugh at the moments when I most needed it (an appreciated time spender), I couldn't imagine my life without you.

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## ABSTRACT OF THE DISSERTATION

### **Cross-language Activation and the Phonetics of Code-switching**

by

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Doctor of Philosophy in Linguistics

University of California, San Diego, 2016

Professor Marc Garellek, Chair

It is now well established that bilinguals have both languages activated to some degree at all times. This cross-language activation has been documented in several research paradigms, including picture naming, reading, and electrophysiological studies. What is less well understood is how the degree a language is activated can vary in different language environments or contexts. Furthermore, when investigating effects of order of acquisition and language dominance, past research has been mixed, as the two variables are often conflated. In this dissertation, I test how degree of cross-language activation can vary according to context by examining phonetic productions in code-switching speech. Both spontaneous speech and scripted speech are analyzed. Follow-up perception

experiments are conducted to see if listeners are able to anticipate language switches, potentially due to the phonetic cues in the signal. Additionally, by focusing on early bilinguals who are L1 Spanish but English dominant, I am able to see what plays a greater role in cross-language activation, order of acquisition or language dominance. I find that speakers do have intermediate phonetic productions in code-switching contexts relative to monolingual contexts. Effects are larger and more consistent in English than Spanish. Similar effects are found in speech perception. Listeners are able to anticipate language switches from English to Spanish but not Spanish to English. Together these results suggest that language dominance is a more important factor than order of acquisition in cross-language activation for early bilinguals. Future models on bilingual language organization and access should take into account both context and language dominance when modeling degrees of cross-language activation.

# Chapter 1

## Introduction

Speakers of a language have a pool of sounds available to them to make words and form these words into utterances. For a bilingual speaker this task is more difficult. A bilingual speaker has two sets of sounds and words, and must be able to keep them appropriately tagged to a specific language. They must also be able to turn one of their languages “off” when producing or perceiving an utterance in the other language. Past research suggests that the separation between languages does not result in one language being completely turned off. Instead the “inactive” language is always available and activated at least at some low level. This dissertation will extend this line of research to see how a specific context – code-switching – can induce *different degrees* of cross-language activation, as manifested in phonetic productions. Namely, I will test if the porous separation between languages is dynamic, and can change from one context to the next, as one or both languages becomes more heavily activated. Contexts where both languages are heavily activated should result in greater cross-language activation relative to the baseline levels found in previous studies.

This chapter will present an overview of the topic of cross-language activation in bilinguals (Section 1.1). Effects in both speech production and perception will be

discussed, as well as how this can vary by the type of bilingual being studied. Focusing on phonetics, I will discuss past work on speech production and perception in early and simultaneous bilinguals (Section 1.2). I will also explain what code-switching is, as well as review past work on the phonetics of code-switching (Section 1.3). Finally, the chapter will conclude with an outline of the dissertation (Section 1.4).

## **1.1 Cross-language Activation in Bilinguals**

### **1.1.1 Inhibitory Control (IC) Model**

The Inhibitory Control (IC) model was originally proposed by Green (1986) and formalized by Green (1998). The model is based on the idea of “language task schemas”. These schemas include language-specific information, such as translations and implementations for word production. When a bilingual chooses a word to produce, they must choose the correct language task schema, however, all potential language task schemas are in simultaneous competition. There are three levels to the model: “first, one level of control involves language task schemas that compete to control output; second, the locus of word selection is the lemma level in Levelt et al.’s [1999] terms and selection involves the use of language tags; third, control at the lemma level is inhibitory and reactive” (Green, 1998, p. 68).

The first level, which involves competition between language task schemas, can be equated to two types of competing tasks operating at the same time. For example, during the Stroop task there is the competition between color identification and word identification. Difficulty in controlling language task schemas has been documented in aphasic bilinguals, some of whom have been found to be limited to only one language at a time in a given day (Green, 1986). This demonstrates that there is indeed cognitive separation of the languages, at least for early bilinguals. While in the context of the IC

model, this separation has been discussed mostly in regards to lexical access, the same idea should apply to other levels of language, including phonetics. In switching from one language task schema to another, a bilingual speaker must also modulate their speech production and perception.

Word selection within a given language task schema occurs on the second level. Green (1998) claims that every lemma is tagged to a specific language, and that this tagging is also connected to the conceptual representation of the word. For example, the English word “chair” will have both the language tag “English” and the concept FURNITURE; the Spanish word “*silla*” (“chair”) will also have the concept FURNITURE, but the language tag “Spanish”. Lemmas that share conceptual tags are linked across languages, such that when the word “chair” is activated so is the word “*silla*”. Evidence for this comes from tasks such as lexical decision, where bilinguals are given a word and need to say if it belongs to a given category or not. Bilinguals do not show a difference in speed for accepting or rejecting the word depending on if the category word (e.g. FURNITURE) is of the same language as the target word (e.g. “chair”) or a different language from the target word (e.g. “*silla*”), thus demonstrating that bilinguals have a shared semantic space across languages (Caramazza & Bories, 1980).

The third and final stage incorporates inhibitory control in correct lemma selection. To avoid producing the incorrect language item, the translation is suppressed through a mechanism of inhibitory control during lemma selection, allowing the speaker to choose the correct English-tagged word. There can be a delay in production though, as a previous suppression may need to be overcome to get to the desired word and language tag. For example, in picture naming, bilinguals are slower on switch trials (trials where the previous word was produced in a different language) than non-switch trials (Meuter & Allport, 1999). This delay in naming is believed to be due to the delay in reactivating the previously suppressed language.

Green (1998) also made specific predictions regarding language switching. He predicted that “[l]anguage switching may take time (1) because it involves a change in language schema for a given task, and (2) because any change of language involves overcoming the inhibition of the previous tags” (Green, 1998, p. 73). The IC model thus captures the fact that there is a time when both languages should be activated, and that switching can result in a delay. Dual-activation occurs both when a lemma is being selected (due to translation effects) and at the moment of switching between languages. The delay during switching occurs while a speaker moves from activation of one language task schema to another.

### **1.1.2 Implications for Speech Production and Perception**

The IC model predicts several effects, for both bilingual speech production and perception. In the original paper, Green (1998) stated that there should be a delay in production when switching occurs, and furthermore that this delay should be asymmetrical, such that there are larger delays in switching back into the L1 due to the earlier, greater effort needed to inhibit the L1. Indeed, this effect has been documented in picture naming tasks, where bilinguals are slower at naming a picture in their L1 after having named a picture in the L2, compared to the other direction of switching (L1 to L2) (Meuter & Allport, 1999; Schwieter & Sunderman, 2008; Schwieter, 2009). However, a lack of an asymmetrical cost has been found for more balanced bilinguals (Costa & Santesteban, 2004) or when switching is voluntary (Gollan & Ferreira, 2009). Thus, more balanced bilinguals, who have more experience at switching between language task schemas, may be able to reduce the cost of switching the language they are inhibiting. In fact the concept of inhibition is not without controversy. Bobb and Wodniecka (2013), in their review of past switching studies, suggest that there could be causes of the switch costs other than inhibition. For example, they propose that the presence of switch costs could

be determined by individual differences, such as switching abilities in non-linguistic tasks, for example the Stroop task (p. 581). They also discuss that if indeed this is a result of inhibition, we cannot know for certain which type of inhibition is being used: local (a brief, reactive form of inhibition) or global (a more sustained form of inhibition). This is an important distinction, as global inhibition is likely a better description of bilingual language access (if inhibition is indeed being used), and it appears that switching paradigms are accessing local inhibition.

Beyond just switching tasks, picture naming experiments have also shown other effects demonstrating active (but not complete) inhibition of one language. In unilingual picture naming studies, bilinguals are slower than their monolinguals peers (Roberts, Garcia, Desrochers, & Hernandez, 2002; Gollan, Montoya, Fennema-Notestine, & Morris, 2005; Kaushanskaya & Marian, 2007). This follows from the IC model, if each lemma selection requires suppression of the translation equivalent, regardless of whether that language is already being suppressed. However, not all researchers believe this slowing is due to interference. Gollan et al. (2005) argued that it was actually a frequency effect, where “being bilingual is analogous to having a lexicon full of lower frequency words, relative to monolinguals” (p. 1220). The frequency-based approach suggests that any delays are not due to interference from the other language, but instead a frequency-based search where bilinguals, by virtue of having more words across two languages, have a greater number of words with lower frequencies (Gollan, Montoya, Cera, & Sandoval, 2008; Gollan et al., 2011).

As a result, this slowing down is not necessarily due to interference, and thus should not be cast in such a negative light. Asymmetrical effects could then be due to other factors, such as living in an L1 or L2 dominant environment, or having more experience with a specific direction of switching (for review see, Bobb & Wodniecka, 2013). For example, if spontaneous code-switches from English to Spanish are more

common than Spanish to English for a certain population, that may be reflected as an asymmetry in picture naming. Indeed, having both languages activated does not always produce a negative effect. When some of the words to be named are cognates, bilinguals are faster at naming cognates compared to non-cognates, due to a boost in activation during retrieval from both languages (Costa, Caramazza, & Sebastian-Galles, 2000). Importantly though, both delays due to competition and cognate boosts provide evidence that there is constant low-level activation of the other language.

Both of these effects have been explored through tip of the tongue (TOT) effects in picture naming. A TOT is when a speaker knows the word associated with a certain image (or, in non-experimental settings, when they have a word in mind) but are unable to accurately retrieve it (Brown, 1991). In general, bilinguals have more TOTs than monolinguals, even in studies focusing on bilinguals with high proficiency in the language of testing (Gollan, Silverberg, & Silverberg, 2001). However, bilinguals have fewer TOTs for cognates than non-cognates. In fact, when comparing bilinguals and monolinguals only on cognate items, there is no difference between groups in TOT frequency (Gollan & Acenas, 2004). This is again further evidence that cross-language activation does not always produce a detrimental effect in speech production.

In perception, researchers have also found evidence of cross-language activation and inhibition. In eye-tracking experiments, bilinguals are distracted by phonological competitors across both languages, not just in the language of testing (Spivey & Marian, 1999; Marian & Spivey, 2003; Marian, Spivey, & Hirsch, 2003). Other tasks using orthographic perception have found similar effects to speech perception. For example, Colomé (2001) conducted a modified version of the phoneme monitoring task to test for degree of inhibition of the non-target language. Catalan-Spanish bilinguals were shown a picture and an orthographic representation of a single sound. Their task was to say whether the sound was in the Catalan name of the object or not. In trials where

“no” (not a sound in the Catalan name for the object) was the correct response, bilinguals were slower to reject when the sound would appear in the Spanish word for the object, compared to when it was not present in the object name for either language. For example, when presented with a picture of a table, “*taula*” in Catalan, the participant would be slower to reject [m], since it exists in the Spanish translation “*mesa*”, than [f], which is not present in either translation. Effects from lexical decision tasks also show slowdowns when “non-words” can be processed as real words in the unused language (de Groot, Delmaar, & Lupker, 2000). Finally, in tasks that require reading mixed-language texts, bilinguals show increased reading times compared to single-language texts (Kollers, 1966; Macnamara & Kushnir, 1971). Overall, this body of work demonstrates that bilinguals do show effects of cross-language activation and arguably also interference, both in speech production (e.g. picture naming) and speech perception (e.g. eye-tracking).

### 1.1.3 Effects of Type of Bilingual

While many of these effects are robust across different experiments and replications, the population of bilinguals must always be taken into consideration. As previously discussed, the asymmetrical language-switching effect in picture naming decreases or goes away for bilinguals with high proficiency in both languages (Costa & Santesteban, 2004). Bilingual populations can vary not only in regards to degree of proficiency in both languages, but also in terms of order and age of acquisition. This can therefore lead to a mismatch between L1 and dominant language, to be discussed further below.

Both early and simultaneous bilinguals are often defined as someone who has learned both languages before the age of six (Flege, 1991; Flege, Munro, & Mackay, 1995; Genesee, Paradis, & Crago, 2004; Gildersleeve-Neumann & Wright, 2010; Hamers & Blanc, 2000; Lee & Iverson, 2012; McLaughlin, 1978; Padilla & Lindholm, 1984; Poplack, 1980). However, in principle there can be differences between simultaneous

bilinguals, who learn two languages from birth, and early bilinguals, who learn one language at birth and another before the age of six. Indeed, researchers have found differences in how each group represents their two languages. Sebastián-Gallés, Echeverría, and Bosch (2005) tested simultaneous Catalan-Spanish bilinguals, early Catalan-Spanish bilinguals (bilinguals who were raised in a monolingual Catalan household, and did not receive extensive exposure to Spanish until school, around age four), and early Spanish-Catalan bilinguals (bilinguals who were raised in a monolingual Spanish household, and did not receive extensive exposure to Catalan until school, around age four) on a Catalan (word / non-word) lexical decision task, where items could differ by a vowel contrast present in Catalan but not Spanish (/e/ versus /ɛ/, Spanish only has /e/). On control items (those without the contrast), the simultaneous bilinguals outperformed both types of early bilinguals. However, for both types of experimental items (/e/ words and /ɛ/ words), simultaneous bilinguals were in between the two early bilingual groups, with Catalan-Spanish having the best performance and Spanish-Catalan the worst. This shows that even simultaneous bilinguals may have difficulty with a language-specific contrast, despite being exposed to it from birth.

Another type of early bilingual that poses additional questions is the heritage speaker. Heritage speakers are generally bilinguals who grow up with one language at home, but are dominant in the main language of their country of residence (the non-heritage language); heritage speakers retain varying degrees of proficiency in the heritage language (Valdés, 2000). Heritage speakers are an interesting population because their dominant language is not their first one (L1). Heritage speakers can be thought of as a unique bilingual population; indeed, in a translation task, heritage speakers were faster than low-proficiency bilinguals, but slower than high-proficiency bilinguals (Schwieter, 2008). Heritage speakers have been shown to maintain knowledge of their L1, including syntactic knowledge, but be impaired in pragmatic knowledge (Montrul, 2004).

Regarding speech production, heritage speakers of Western Armenian (now English dominant) were found to have vowel productions affected by English – however, only for those vowels that exist in both languages (Godson, 2004). Godson (2004) interpreted this to mean that the dominant language affects the L1, but only the phonetic categories that overlap with those in the L2.

Sometimes a speaker's L1 not only becomes the non-dominant language, but is lost entirely due to attrition. Attrition is when a speaker loses access to a language, resulting in a decrease in proficiency in the language over time (Andersen, 1982). This can occur as the result of international adoption, or in the context of a heritage speaker, when the L2 becomes dominant very early in life, and the input from the heritage language is scant. For example, Au, Oh, Knightly, Jun, and Romo (2008) tested speakers who grew up with Spanish, but reported having limited to no current proficiency, and were relearning Spanish as adults. Speakers with childhood exposure to Spanish were found to outperform typical L2-learners in terms of accent (how native-sounding their speech was). However, childhood speakers outperformed both childhood overhearers and typical L2-learners on grammaticality judgement tasks. Similar later-in-life benefits have been found for childhood Korean speakers in regards to phonetic production and perception (Oh, Jun, Knightly, & Au, 2003). These results demonstrate that childhood exposure to a language, even if later lost, can have lasting effects on speakers' knowledge and use of that language.

The final group of bilinguals that has received much discussion is late bilinguals. A late bilingual would be someone not falling into any of the above groups: someone who learns a language later in life, often with a cut-off of after age 14 (Lenneberg, 1967). Late bilinguals struggle to master native-like proficiency. Flege, Yeni-Komshian, and Liu (1999) found that as age of acquisition of English increased, speakers were rated as more accented; however, grammaticality judgements and morphosyntactic knowledge were

better predicted by variables such as education. Indeed, researchers have shown that when accounting for variables such as level of education, the decline is more linear, without a clear drop-off point (Hakuta, Bialystok, & Wiley, 2003). With extensive exposure to native speaker input, late L2 speakers can actually improve over time (Flege & Liu, 2001).

It is thus clear that the term “bilingual” can mean many different things, varying by factors such as age of acquisition, language dominance, and language availability. The present thesis will focus on high-proficiency, early Spanish-English bilinguals, or heritage bilinguals. They can be classified as heritage bilinguals as many grew up with Spanish at home, but are now English-dominant due to living in the United States. While some studies involving heritage speakers have included speakers with limited proficiency in their L1, the present study focuses on bilinguals who are still proficient users of both languages. Studying this group will inform the literature on early bilingualism, but also seek to disentangle often conflated factors of L1 and dominant language.

## **1.2 Past Work on Phonetic Speech Production and Perception in Simultaneous and Early Bilinguals**

### **1.2.1 Speech Production**

Early bilingual speakers’ ability to keep both languages separate in speech production has been well documented. Early, high-proficiency bilinguals are able to appropriately retrieve the correct language-specific realizations of sounds when producing words in one language or the other (Flege & Eefting, 1987). For example, a Spanish-English bilingual when producing the Spanish word “*perro*” (“dog”) will use the Spanish unaspirated [p], not the English aspirated [p<sup>h</sup>], at the beginning of the word. But despite

being very skilled overall at keeping the two languages separate, bilinguals do not exactly match their monolingual peers in speech production.

In voice onset time (VOT) studies, adult bilinguals show a range of effects compared to monolinguals. Sundara, Polka, and Baum (2006) compared French-English simultaneous bilinguals to monolinguals on the production of /d/ and /t/ within each language. In English, bilinguals had significantly shorter VOT values for /d/ than monolinguals, using negative (more French-like) VOT, whereas monolinguals used short-lag VOT; for /t/ in English the groups did not statistically differ. In French, bilinguals produced more heavily pre-voiced VOT for /d/ than monolinguals; no difference between bilinguals and monolinguals for /t/. Based on the results for English, it would appear that effects from French are moving the bilinguals' English /d/ productions closer to their French ones. However, bilinguals' greater amount of pre-voicing in French, relative to monolinguals, suggests divergence (moving apart of phonetic categories) over convergence (nearing of phonetic categories). Bilinguals even had a statistically significant difference between their /d/ categories in English and French, demonstrating they were not simply producing the same sound in each language.

Various effects have also been found for children during acquisition of stop categories. Children learning Arabic and English (simultaneous Arabic-English bilinguals) have been found to have difficulty with the Arabic pre-voicing category, but similar effects were also found for the monolingual Arabic-speaking children (Khattab, 2002). In a study with three groups of children (monolingual Korean, monolingual English, bilingual Korean-English) at two ages (five-years-old, ten-years-old), five-year-old Korean-English simultaneous bilingual children did not differ from monolinguals in production of Korean stops (Lee & Iverson, 2012). Ten-year olds however had significantly longer VOT productions than monolinguals for lenis and aspirated stops. In English, 5-year olds produced each category with shorter VOT, but 10-year olds only produced shorter VOT values

for voiceless stops. Simultaneous Spanish-German bilingual children (Spanish-speaking mother, German-speaking father) were found to show three patterns of VOT category acquisition, “1. Delay in the phonetic realization of voicing;...2. Transfer of voicing features;...and 3. No cross-language influence in the phonetic realization of voicing” (Kehoe, Lleó, & Rakow, 2004, p. 71). Delays appear as children take longer to acquire the voicing contrast relative to their monolingual peers, in this case the delay is realized as producing most stops as short-lag (which are more German-like). Transfer occurs when sounds from one language are used in the other, e.g. a high number of pre-voiced tokens in German as a result of Spanish influence. A lack of cross-language influence occurs when both languages’ categories are faithfully produced without effects from the other language. In some cases, hyper-category separation has also been found. For example, Flege and Eefting (1987) found that L1 Spanish-speaking children, who were exposed to English starting about age five to six, produced Spanish /p, t, k/ with even shorter VOT than Spanish monolingual children; effects from English would predict the opposite, potentially showing that children are making an extra effort to keep the English and Spanish realizations distinct. This is similar to the effect found by Sundara et al. (2006) for adults in their French.

While work on other consonants is more limited, similar results have been found. Simonet (2010) looked at Catalan-dominant and Spanish-dominant Catalan-Spanish bilinguals’ production of /l/. Both groups had been exposed to Catalan and Spanish by age six, but their dominant language was the only language they were exposed to at home for the first several years of life. Catalan has a darker (i.e., more velarized) /l/ than Spanish (Recasens, 2004; Recasens & Espinosa, 2005). Indeed, Simonet (2010) found that bilinguals produce in general darker tokens of /l/ in Catalan than Spanish. However, Catalan-dominant bilinguals produced darker tokens of /l/ than Spanish-dominant bilinguals in both Catalan and Spanish, despite maintaining the category difference across

languages. Similarly, Barlow, Branson, and Nip (2012) tested L1 Spanish speaking children who had been exposed to English by age six on their production on English and Spanish tokens of /l/ (English also has darker tokens of /l/ than Spanish). The bilingual children produced lighter, more Spanish-like tokens of /l/ in both languages, compared to monolingual English speaking children, while still maintaining the contrast across languages.

Regarding vowels, L1 Spanish early L2 English (by age 6) bilinguals maintain two separate inventories, but tend to have categories closer together than the same categories produced by monolingual speakers of each language (Grijalva, Piccinini, & Arvaniti, 2013). Context can also affect vowel productions. For example, Simonet (2014) found that when Catalan-Spanish bilinguals (a similar population to Simonet (2010)) produced Catalan words with the Catalan vowels /o/ and /ɔ/ in a session when also producing words in Spanish, both vowels were produced closer to the Spanish /o/, compared to in a session when only Catalan words were produced.

Overall these results show that early bilinguals tend to differ from monolinguals in their productions, either through convergence or divergence (or both). Despite these differences, bilinguals are still able to have language-specific productions for sounds that overlap across languages.

### 1.2.2 Speech Perception

In speech perception, bilinguals also show varied results compared to monolinguals. In tasks where listeners hear a continuum between two sounds (e.g. a VOT continuum between /b/ and /p/), bilinguals vary in where they perceive the boundary relative to monolinguals. For example, an early Spanish-English bilingual will categorize more tokens as /p/ than monolingual *English* speakers, but will categorize more tokens as /b/ than monolingual *Spanish* speakers (Flege & Eefting, 1987). Bilinguals have also

been found to change their boundary point between phonetic categories, depending on if they believe the stimuli are in English or Spanish (e.g. more tokens labeled as /b/ in English than Spanish); however, this effect varies by how balanced the bilingual is (Elman, Diehl, & Buchwald, 1977). Contrary effects have also been found, including those showing that bilinguals only perceive the sounds according to one language. This is true regardless of supposed language of the stimuli, and even when the L2 is learned as early as school-age (Williams, 1977).

Researchers have also shown speech perception differences based on language dominance. Cutler, Mehler, Norris, and Segui (1992) tested French-English bilinguals who were raised in a one-parent one-language environment on a speech segmentation task. Bilinguals segmented according to the properties of their dominant language when processing speech in their dominant language. When processing speech in their non-dominant language though, French-dominant bilinguals used English segmentation strategies in English, while English-dominant bilinguals carried over English segmentation strategies to French. Navarra, Sebastián-Gallés, and Soto-Faraco (2005) tested early Catalan-Spanish bilinguals on a syllable classification task, where they had to decide if the first syllable was /pu/ or /ti/; the second syllable was either /ke/ (/e/ being a phoneme in both Catalan and Spanish) or /kɛ/ (/ɛ/ being a phoneme in only Catalan). All bilinguals had been exposed to both languages by age three, but varied in whether their home language (and thus dominant language) was Catalan or Spanish. Despite the fact that attention to the second syllable was irrelevant to the task, in blocks where both /ke/ and /kɛ/ were present, Catalan-dominant bilinguals were slower to respond than if the block had only one type of final syllable. Spanish-dominant bilinguals did not show any difference depending on if the block was mixed or not. This result suggests that the Catalan-dominant bilinguals were actively processing the /e/-/ɛ/ contrast, as it is informative in Catalan, while the Spanish-dominant bilinguals were not. These language

dominance differences are present even for simultaneous bilinguals, as it appears that one language always wins out as dominant (Sebastián-Gallés et al., 2005).

In speech-in-noise tasks, early bilinguals have shown difficulty compared to monolinguals. In Rogers, Lister, Febo, Besing, and Abrams (2006), Spanish-English bilinguals who had acquired English before age six (and were judged to have no accent in English) listened to monosyllabic words in speech-shaped noise and with reverberation. The task was simply to repeat out loud the word they believed they heard. Bilinguals had more difficulty than the monolingual participants, even though their performance was the same in quiet conditions. The authors believe that this bilingual disadvantage results from the increased demand for attentional resources or increased processing demand. Despite the overall drop in scores, early bilinguals (those exposed to both languages before age six) are still able to take advantage of context in speech-in-noise, while late bilinguals are not (Mayo & Florentine, 1997).

Thus, in speech production and perception, early bilinguals differ from monolinguals, with differences varying based on language dominance and order of acquisition. Despite having language-specific phonetic categories, in speech production bilinguals show both effects of convergence and divergence relative to monolinguals. This can be influenced by language dominance, with categories in the non-dominant language showing an effect from the dominant language, leading to a form of convergence. In speech perception, bilinguals again appear to be biased by their dominant language. This is true both when stimuli are presented in their non-dominant language, and when a language-specific contrast is irrelevant to the task. Overall, this shows that despite being highly proficient speakers of two languages, early bilinguals still show nuanced differences relative to monolinguals; variation also exists within early bilinguals, depending on their language dominance profiles.

## 1.3 Code-switching

### 1.3.1 What is Code-switching?

To test effects of cross-language activation in bilinguals, this dissertation will look at the phonetics of code-switching. Code-switching is when proficient bilinguals switch languages, sometimes in the middle of a sentence (Gumperz, 1977; Bullock & Toribio, 2009). One classic example is the sentence “Sometimes I’ll start a sentence in Spanish *y termino en español*” (“Sometimes I’ll start a sentence in Spanish *and end in Spanish*”) from Poplack 1980. Here the speaker switches between English and Spanish in the middle of the sentence. This was a spontaneous production by a fluent Spanish-English bilingual, and examples like this are common in the speech of highly proficient bilinguals in bilingual settings.

Code-switching has been extensively studied regarding its sociolinguistic uses. Language switching has been documented in the form of the type presented above, and as single-word switches. One example of single-word switches is slang words being imported from one language to the other; for example, Basque-Spanish bilinguals will often insert Spanish slang words into their Basque, despite rarely using any other type of language switching (Lantto, 2014). Sometimes the difference between code-switching and borrowing (when a single word is imported into the language, often taking on the phonetics of that language) can be difficult to discern, as words can become lexicalized in both languages (Lipski, 2005). One example of this to be explored in the present dissertation is the discourse marker *like*, which is used in English, Spanish, and code-switching utterances. Code-switching can have pragmatic uses, such as a form of style-shifting from one topic to the next (Milroy & Gordon, 2003). It can also signal social identity, for example as a way of existing in two groups at once, or a form of “bivalency” as discussed by Woolard (1999).

There has also been extensive syntactic work on code-switching, examining where and why within an utterance a speaker switches languages. Researchers have looked at how speakers deal with the conflicting syntactic constraints of both languages (e.g. in English adjectives come before nouns, but in Spanish adjectives generally come after nouns), and if they incorporate both languages' syntactic structures in their code-switching productions (Pfaff, 1979; Sankoff & Poplack, 1981). To explain these patterns, and the potential conflict of the syntactic structures of two languages, theoretical frameworks have been developed that classify one language as the 'matrix language' – the language providing the overall structure – and one language as the 'embedded language' – the one being inserted into the matrix language during code-switches (Myers-Scotton, 2008). Speaker-specific variables have also been found to be important in determining where a switch occurs, such that more proficient bilinguals can switch at more positions in a sentence than speakers who are more heavily dominant in one of their two languages. In the present dissertation, I will analyze code-switching as it occurs freely in Chapter 2, and in pre- and post-predicate positions in Chapter 3.

### **1.3.2 Past Work on the Phonetics of Code-switching**

While there is a long tradition in linguistics of investigating the syntactic aspects of code-switching, work on the phonetics of code-switching is more recent. Similar to how bilinguals must navigate between the syntactic structures of two languages, during code-switching they must also switch their phonetic targets from one language to the other. Note that studying the phonetics of code-switching is different from comparing bilinguals to monolinguals, which seeks to see if bilinguals match monolinguals in phonetic productions or show effects from their other language. Here, effects of cross-language activation are being examined internal to a given bilingual speaker, to see if the speaker varies their productions between one context (monolingual utterances) and

another context (code-switching utterances). As with research comparing bilinguals to monolinguals, experiments on the phonetics of code-switching have largely focused on voice onset time (VOT) as the variable of investigation, with mixed results. Some researchers found no effect of code-switching on phonetic productions (Grosjean & Miller, 1994; López, 2012). Other researchers have found effects of code-switching, but not always in a consistent direction. Code-switching has been found to affect only one of the two languages, with evidence of phonetic categories moving towards the inactive language, i.e. convergence (Antoniou, Best, Tyler, & Kroos, 2011; D. J. Olson, 2013; Balukas & Koops, 2015). However, in other studies there was evidence of convergence for one language and divergence for the other language (Bullock, Toribio, González, & Dalola, 2006; Piccinini & Arvaniti, 2015). Finally, D. J. Olson (2016) found an effect of convergence for only one language for English-dominant Spanish-English bilinguals, but found convergence for both languages for Spanish-dominant speakers. A summary of these results can be found in Table 1.1. Fricke, Kroll, and Dussias (2015) also tested VOT in Spanish-English bilinguals, but only for English words, they also found a shortening of VOT by code-switching boundaries. Little work has moved beyond VOT as a variable for analysis (although see, D. Olson & Ortega-Llebaria, 2010; Piccinini & Garellek, 2014; Fricke et al., 2015). Doing so is one goal of this dissertation.

Comparing across code-switching studies can be difficult. In regards to population, the studies differed greatly in what type of bilinguals the researchers targeted. In terms of age of acquisition, some researchers tested late bilinguals (Grosjean & Miller, 1994; López, 2012; D. J. Olson, 2013; Bullock et al., 2006; D. J. Olson, 2016), whereas some tested early bilinguals (Antoniou et al., 2011; Balukas & Koops, 2015; Piccinini & Arvaniti, 2015; Fricke et al., 2015). Populations also differed in regards to language dominance, with some researchers testing L1-dominant bilinguals (Grosjean & Miller,

**Table 1.1:** Past work on the phonetics of code-switching. A summary of past research on the phonetics of code-switching, specifically VOT. Some papers found no effect of code-switching, some found effects of convergence but only for one of the two languages, some found asymmetrical effects, with convergence for one language and divergence for the other, and one study found convergence for both languages.

| <b>No effects</b>                                      | <b>Convergence for one language</b>                                                                                           |
|--------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------|
| Grosjean and Miller (1994)<br>López (2012)             | Antoniou et al. (2011)<br>D. J. Olson (2013)<br>Balukas and Koops (2015)<br>D. J. Olson (2016)<br>[English-dominant speakers] |
| <b>Asymmetrical effects for both languages</b>         | <b>Convergence for both languages</b>                                                                                         |
| Bullock et al. (2006)<br>Piccinini and Arvaniti (2015) | D. J. Olson (2016)<br>[Spanish-dominant speakers]                                                                             |

1994; López, 2012; Bullock et al., 2006; D. J. Olson, 2016), some L2-dominant bilinguals (Antoniou et al., 2011; D. J. Olson, 2013; Piccinini & Arvaniti, 2015), mixed dominance (Fricke et al., 2015), and for one study dominance was not specified (Balukas & Koops, 2015). Moreover, while most studies looked at scripted speech, three examined spontaneous speech (Balukas & Koops, 2015; Piccinini & Arvaniti, 2015; Fricke et al., 2015). The range of results could then be explained by population and methodological differences.

Research on the *perception* of code-switching is rather limited. One study on Cantonese-English bilinguals looked at the role of phonology in anticipating code-switches through a gating task, where listeners had to predict an upcoming word (Li, 1996). When the phonology matched the language being switched in to, listeners were better at predicting the upcoming word. Here ‘phonology’ meant there were two possible versions of the code-switch word, one produced with the phonology appropriate for the language that the word came from, and one produced with the phonology of the

language proceeding the word. For example, in the sentence “*Keoi ge flight jin-ci*” (“*he/she flight is delayed*”) the word “flight” could either be produced with English or Cantonese phonology. The English variant of “flight” was produced as /flat/, while the Cantonese variant was produced as /faɪ/. However, this study did not look at *intermediate* phonetic productions, instead having a full phonological switch from one language to the other. Thus, this study did not look at the phonetic characteristics of the target words. More recently, Fricke et al. (2015) used the visual world paradigm to test code-switching perception, and found that listeners can exploit low-level phonetic cues to anticipate a code-switch.

D. Olson and Ortega-Llebaria (2010) investigated the interaction of code-switching and intonation in signaling narrow focus. Narrow focus is when a specific aspect of the sentence is being highlighted, possibly because only one part of the sentence is new information to the listener. This is in contrast to broad focus, where no specific part is highlighted, and the entire sentence may contain new information (Ladd, 1986). They found a significant interaction of context (monolingual versus code-switching) and pitch range. When pitch was a clear indicator of narrow focus, the presence of a code-switch did not affect listeners’ reading of the sentence as having narrow or broad focus. But when pitch information was not informative, listeners were more likely to have a narrow-focus interpretation if the sentence included a code-switch.

### 1.3.3 The Benefit of Studying Code-switching

Cross-language activation is expected to be gradient, much like phonetic productions. Code-switching is a context in which both languages should be more heavily activated, and thus ideal to test for effects of increased cross-language activation. For example, both English and Spanish have the sound /i/, although it is produced slightly differently in each language. In code-switching speech, where degree of cross-language

activation should be increased, phonetic realizations of /i/ in both languages may be produced intermediate to the two language-specific variants. This result would show that different contexts can induce different degrees of cross-language activation, as manifested in phonetic productions.

If intermediate phonetic productions are found, as has been documented in some past studies of the phonetics of code-switching, this could affect how speech is perceived and processed by listeners. The term “intermediate phonetic productions” is defined as phonetic productions that do not directly map on to the average phonetic characteristics of a phoneme in either language. The presence of these productions could be beneficial to listeners. Intermediate phonetic productions before a code-switching could serve as a cue to listeners that the speaker is about to switch languages. These cues would then alleviate some of the processing costs of having a speaker switch languages. This result could explain why past psycholinguistic work on language switching has shown it to be a detriment when unexpected in picture naming (Meuter & Allport, 1999; Schwieter & Sunderman, 2008; Schwieter, 2009), in reading (Kolars, 1966; Macnamara & Kushnir, 1971), and in electrophysiological studies (Chauncey, Grainger, & Holcomb, 2008; Moreno, Federmeier, & Kutas, 2002; Proverbio, Leoni, & Zani, 2004), while also explaining why code-switching is nonetheless common in bilingual communities (Pfaff, 1979; Poplack, 1980, 1987; Woolford, 1983; Belazi, Rubin, & Toribio, 1994; Myers-Scotton, 2008). As discussed, research on this aspect of code-switching is largely lacking.

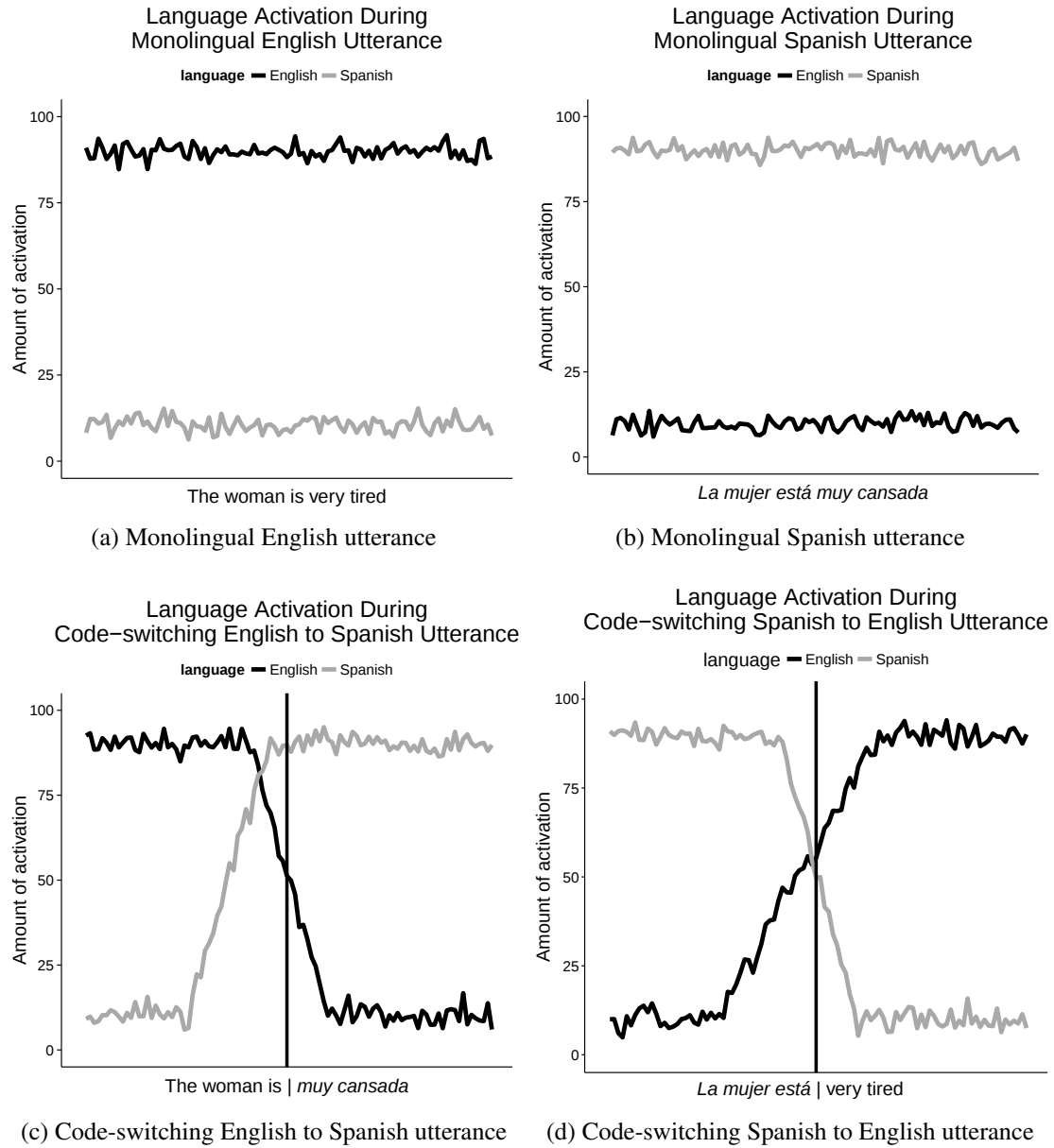
Code-switching thus is a perfect test case to examine cross-language activation, as it: 1) represents a context where both languages should be more heavily activated, and 2) could better explain how bilingual speech is actually processed when language switches occur.

### 1.3.4 Implications for Theories of Bilingualism

This dissertation will expand on current theories of bilingual language organization and activation in two ways: 1) showing that context can induce different degrees of cross-language activation for a given speaker, and 2) attempting to disentangle how effects may differ according to current dominant language versus L1.

Regarding (1), while theories currently account for cross-language activation in a general sense, the present dissertation will push that assumption further, to show that degree of cross-language activation can vary within a bilingual. The case study here is monolingual versus code-switching utterances. If indeed bilinguals always have both languages somewhat activated, even in monolingual contexts, then the degree to which both languages are activated should also vary depending on context. If intermediate phonetic productions are found in code-switching contexts (more than in monolingual contexts), that would demonstrate that code-switching is a time when both languages are more heavily activated, and thus there can be different degrees of cross-language activation depending on context. Figures 1.1a - 1.1d illustrate this difference. In both of the monolingual contexts (Figures 1.1a and 1.1b) there is high activation of the language in use, but also a consistent low-level activation of the language not in use. In the code-switching contexts (Figures 1.1c and 1.1d) a clear change happens, as one language becomes more activated and the other less activated through suppression. What is important though is that at the code-switching boundary, both languages are heavily activated. This high activation of both languages will result in intermediate phonetic productions, relative to the monolingual contexts.

In this dissertation, “context” refers to a very specific time in speech production: the moment, and surrounding time, of transitioning from one language to another. However, “context” can be further expanded. For example, when a bilingual is speaking with someone who they know is also bilingual, they may preemptively have both languages



**Figure 1.1:** Language activation in different utterance types. Activation levels of English and Spanish in different utterance types. Note that, near switches, there is more activation of both languages. This in turn should yield intermediate phonetic productions.

more heavily activated, knowing that their interlocutor may code-switch. Conversely, if they are speaking with someone who is monolingual they may work harder to suppress the language not use, since it is less beneficial to have both languages more heavily activated. In this way, having both languages more or less activated can facilitate speech perception, depending on context. Other contexts where it could be beneficial to have both languages more heavily activated include learning a third language and listening to accented speech, among others.

If bilinguals do in fact have varying, gradient degrees of cross-language activation, and if such activation varies by external context, this may explain some past psycholinguistic results that showed bilinguals having difficulty with tasks such as language-switching (e.g., Meuter & Allport, 1999; Kolers, 1966). However, this effect can be reduced or go away entirely when switches are predictable and there is a shared word order across languages (Declerck & Philipp, 2015). Indeed, these past, more negative results could be due to the fact that bilinguals are not situated in the appropriate context to anticipate language switches. As such, these results may overestimate the difficulty bilinguals have in switching from one language to the other. In more natural speech perception, if listeners are able to use phonetic cues to anticipate language switches, this could alleviate some of the processing difficulties found in these psycholinguistic studies. This work implies that theories of language activation and organization need to be able account for different degrees of cross-language activation, and furthermore that bilinguals can use these different degrees to their advantage in both speech production and perception.

While it is predicted that external contexts affect the degree to which both language are activated, internal effects such as language dominance and L1 can also play a role. Language dominance and L1 have often been difficult to tease apart, as in past studies bilinguals' dominant language was often also their L1. The population studied here is ideal to see which of these variables has a greater effect, as it consists of speakers

who are L1 Spanish but now English dominant. Language-switching studies have not only shown that there is a cost to go from one language to the next, but also that this cost is asymmetrical, and can impact switches from the non-dominant to the dominant language more than the reverse (Meuter & Allport, 1999). Specifically, the theory is that it takes more energy to suppress the dominant language, and thus it takes longer to switch back into it after a switch. However, this assumes a match between dominant language and L1. The current dissertation will test for effects of direction of the switch. Will speakers show greater difficulties moving from English to Spanish or from Spanish to English in speech production and perception? If more intermediate phonetic productions are found in English, and if listeners have greater difficulty predicting switches from Spanish to English, this would suggest that the dominant language is more affected by language switching. If the reverse is found, and there are more intermediate phonetic productions in Spanish, with greater difficulty predicting switches from English to Spanish, that would show the L1 is actually the more important variable. The former prediction is illustrated in Figure 1.1c and 1.1d, as English takes longer to be reactivated, thus having less of an effect on Spanish productions, but the fast reactivation of Spanish results in an effect on English productions. Disentangling these two variables will impact how we model bilingual language activation in future work.

## **1.4 Overview of Dissertation**

In summary, this dissertation examines the phonetic properties of code-switching to determine whether specific contexts can induce different degrees of cross-language activation in bilinguals. From the point of view of speech production, I tested whether code-switching results in greater cross-language activation, which thus results in intermediate phonetic productions, which would support the idea that there is greater

cross-language activation in code-switching versus monolingual utterance. I also tested whether listeners can anticipate switches, which would support the hypothesis that listeners use intermediate phonetic productions to their advantage. In Chapter 2, I study spontaneous code-switching, focusing on the production of the discourse marker *like* in monolingual and code-switching contexts. In Chapter 2 I also test the perception of code-switching speech, to see if listeners can anticipate upcoming language switches. Then in Chapter 3, I examine three different phonetic variables, /l/-clarity in different syllabic positions, lenition of stops to fricatives of word-initial voiced stops, and voice onset time (VOT) of word-initial voiceless stops in scripted speech. These three sets of experiments will expand our knowledge of both the phonetics of code-switching in speech production and perception, and have implications for theories of bilingualism more generally.

### 1.4.1 Phonetic Features to be Studied

In Chapter 2, data was collected from pairs of early Spanish-English bilinguals having conversations about various topics. Speakers were free to use English or Spanish, as well as switch back and forth between languages (code-switching). I analyzed the phonetic properties of the discourse marker *like*, which was used in monolingual contexts, both English and Spanish, and in code-switching contexts, as the word directly between a switch from English to Spanish or Spanish to English. The phonetic properties analyzed included: 1) duration of the /laɪ/, 2) /k/ closure and burst duration and realization, 3) formant values of the /l/, the /aɪ/, and the /laɪ/ as a single production. These were chosen because they were predicted to be different in English and Spanish, and thus potentially in between both languages in the code-switching contexts.

Duration was measured because it may be a cue to vowel quality of the diphthong, which has two vowel targets within a syllable (Ladefoged, 2001). Thus in the diphthong

/aɪ/, the two vowels make up the vowel in one syllable, in contrast to when /a/ and /ɪ/ are in different syllables. On a phonological level English and Spanish are supposed to differ in their phonetic representation of the diphthong in /laɪ/. English /aɪ/ is thought to end with a phonetic target that is closer to /ɪ/ (note that /i/ versus /ɪ/ is a phonemic contrast in the English) (e.g. in Aiello, 2008). However, in Spanish the diphthong /aɪ/ is thought to end with a phonetic target that is more peripheral (more /i/-like), perhaps because Spanish has only phonemic /i/ and not /ɪ/ (Martínez-Celdrán, Fernández-Planas, & Carrera-Sabaté, 2003). However, English may actually end with something more like a glide, and could have a shorter duration than the vowel /ɪ/ would (Lehiste & Peterson, 1961). Spanish on the other hand may be produced with two full vowels, resulting in a longer duration (Roca, 1997). Regardless of phonological representation, if English /aɪ/ ends with a more centralized target (/ɪ/ or its glided version) than Spanish, then we might expect durational differences because /ɪ/ (as a stand-alone vowel) is shorter than /i/ (in English). Given this, the duration of the syllable /laɪ/ may be a cue to how English and Spanish differ, and then how code-switching tokens differ as well.

The second part of *like* analyzed was the realization of the /k/, studying both the closure and the burst. The closure is the period of time during which the tongue is in contact with the palate, whereas the burst refers to the moment (or interval) of release of the tongue from the palate (Ladefoged, 2001). Immediately after the closure is the burst, or the puff of air that leaves the mouth after the release of the stop. Whether or not the burst is present is potentially interesting, as English word-final stops are often unreleased (Byrd, 1993). This could mean that the closure is present but that there is no clear burst, or that the stop closure was not formed at all, such that the speaker moved directly from the /aɪ/ of *like* to the next word. The unreleasing of word-final stops has not been documented in Spanish, so one may expect fully realized tokens of /k/ in Spanish, but not English, with code-switching tokens showing variation. Since this is a binary

distinction, code-switching tokens may be released less often than in Spanish, but more often than in English. Durations of the closure and burst were also measured as a means of potentially distinguishing between /k/ in monolingual versus code-switching contexts.

The final analysis of *like* was a formant analysis of the whole /laɪ/ sequence over time, as well as summary values of the /l/ and two points in the /aɪ/. Focusing first on the /l/, the production of an /l/ is often discussed in terms of its “darkness” or velarization. In a light /l/ (phonetically [l]) the tongue body is forward (Recasens & Espinosa, 2005). In a dark /l/ (phonetically [ɫ] or [ɭ]) the tongue body is retracted and raised towards the velum, thus velarization as the process of an /l/ darkening (Huffman, 1997). Variations in /l/ darkness are seen in its formant structure; with darker /l/ tokens having in particular lower F2 values than lighter /l/ tokens (Sproat & Fujimura, 1993). This measurement of darkness is often quantified as a difference between F2 and F3, given that F3 varies less as a function of darkness. A small F3 minus F2 difference is predicted for light tokens of /l/ and a large difference for dark tokens of /l/. English is found to have a darker /l/ than Spanish (Huffman, 1997; Simonet, 2010). In code-switching tokens, we expect the /l/-clarity (how light or dark the /l/ is) to fall somewhere in between the two languages.

Formant values of the vowel were also examined, as F1 and F2 can be an indicator of height and front-backness respectively. Low F1 values correlate with high vowels, and high F1 values with low vowels. Low F2 values correlate with back vowels, and high F2 values correlate with front vowels. As already discussed, instances of *like* in English versus Spanish are expected to end in slightly different vowels, /ɪ/ and /i/, which differ in the height dimension (/ɪ/ is produced lower in the mouth than /i/, and should thus show differences in F1). A front-backness difference can also be predicted as indicated by F2 values, /ɪ/ is produced lower in the mouth than /i/. While the first part of the diphthong, /a/, is the same in both languages, in general Spanish has a more backed vowel space than English (A. R. Bradlow, 1995; Grijalva et al., 2013). As a result, an F2 difference

can also be predicted at the beginning of the diphthong due to vowel space differences. By conducting a time course analysis, one can see how code-switching tokens differ in their relation to each of the types of monolingual tokens over time.

In Chapter 3, data of scripted speech was collected of early Spanish-English bilinguals reading sentences in one language (monolingual) and sentences that included a language switch (code-switching). Scripted speech was used to allow for a more controlled analysis, as well as to include more variables in the study. Three variables were chosen for investigation: 1) /l/-clarity in different syllabic positions, 2) lenition of stops to fricatives of word-initial voiced stops, and 3) voice onset time (VOT) of word-initial voiceless stops. These variables were chosen to expand our knowledge of code-switching beyond VOT, the most commonly studied variable. Two of the features also have the added element of language-specific allophonic contrasts, which I describe below.

The first variable examined is /l/-clarity in different syllabic positions. As previously discussed, English has darker realizations of /l/ than Spanish. However, English has the added phonological difference of having two /l/ allophones, one for syllable-initial position and one for syllable-final position. In syllable-initial position, English tends to have a light /l/ (but still darker than Spanish /l/), while in syllable-final position, it is classified as an even darker /l/ (Sproat & Fujimura, 1993); note this is not a categorical distinction, but a gradient one along a continuum (Yuan & Liberman, 2011). In Spanish, /l/ does not vary much in clarity as a function of its position (Simonet, 2010). This can have implications for what happens in code-switching as: 1) English tokens of /l/ may become lighter while Spanish tokens of /l/ become darker, and 2) the phonetic difference in /l/-clarity between onset and coda /l/ in English may reduce due to the effect of the general lightening in English from Spanish.

The second variable under investigation is rooted in a phonological effect from

Spanish, lenition of stops to fricatives. Spanish stops become fricatives or approximates (lenition) after nonhomorganic consonants (such as laterals, rhotics, approximates, and fricatives) and vowels (this alternation can also be treated as fortition of fricatives; see, Bakovic, 1994). For example, in the word “*dato*” (“date”), the initial phoneme in the word is produced as a stop, [d], when preceded by the determiner “*un*” (“a”), and thus the phoneme /n/. However, when “*dato*” is preceded by the determiner “*ese*” (“that”), and thus the phoneme /e/, the initial phoneme is produced as something closer to a fricative [ð] (Bakovic, 1994). This is a well-attested phonological process across Spanish varieties, though specific varieties differ as to the phonological environments in which fricatives are found (Canfield, 1981; Lipski, 1994). The Spanish stop-fricative alternation is phonetically categorical (presence vs. absence of stop closure), and thus differs from the gradient F2 variation seen for English /l/-clarity differences. In terms of code-switching, again, two predictions can be made: 1) there will be more lenition of stops to fricatives in English code-switching contexts relative to English monolingual contexts, and less lenition in Spanish code-switching contexts relative to Spanish monolingual contexts, and 2) the effect of cross-language activation may be more apparent in Spanish than English, as Spanish already has variation between stops and fricatives.

The final variable being studied lacks any systematic allophonic variation in either language, but still has implications for both English and Spanish in code-switching: voice onset time (VOT) of word-initial stops. VOT is defined as “the interval between the release of the stop and the onset of glottal vibration, that is, voicing” (Lisker & Abramson, 1964, p. 398). VOT is frequently contrasted in the world’s languages as a way to differentiate two or more stops sharing the same place of articulation (Cho & Ladefoged, 1999). However, how languages make use of the VOT continuum may differ. An initial distinction can be made between voiced and voiceless stops. In a voiced stop, voicing begins before the release of the stop, while in voiceless stops voicing begins after

the stop's release. VOT for voiced stops is quoted as a negative value; for voiceless stops a positive one. Spanish /b, d, g/ are voiced, while English /b, d, g/ are usually voiceless word-initially, especially at phrasal onsets (Lisker & Abramson, 1967). Within voiceless stops, further distinctions can be made based on the duration of the interval between the release and onset of voicing following the release of the stop. The most common distinction is between short-lag (a relatively short VOT) and long-lag (a longer VOT). This distinction is also sometimes classified as unaspirated (in that the VOT is close to zero) versus aspirated (where there is a substantial duration). However, in Cho and Ladefoged (1999) VOT productions from 18 languages were compared, and voiceless stops were classified into four categories: 1) unaspirated stops, 2) slightly aspirated stops, 3) aspirated stops, and 4) highly aspirated stops. English has a two-way voiceless stop contrast word-initially, /b, d, g/ is often phonetically realized as voiceless unaspirated ([p, t, k]), while /p, t, k/ is usually realized as voiceless aspirated ([p<sup>h</sup>, t<sup>h</sup>, k<sup>h</sup>]), whereas Spanish has only voiceless unaspirated stops for /p, t, k/. English and Spanish thus have different VOT realizations of word-initial /p, t, k/. In English they are realized with a long-lag VOT, while in Spanish they are realized with short-lag VOT. Regarding code-switching, it can then be predicted that in code-switching contexts VOT of English word-initial /p, t, k/ will get shorter (more Spanish-like) while Spanish word-initial /p, t, k/ will get longer (more English-like).

### 1.4.2 Dissertation Plan

The current dissertation will examine the production and perception of code-switching speech, to see if speakers produce intermediate phonetic productions in code-switching contexts. If so, this would support the idea that code-switching is a context in which there is greater activation of both languages. This will be tested in both spontaneous speech (Chapter 2) and scripted speech (Chapter 3). I will also test if

listeners can anticipate upcoming language switches, which may be due to their ability to use the intermediate phonetic productions in speech perception (Chapter 2). If the predicted effects are found, they will imply that different contexts can induce different degrees of cross-language activation in bilinguals. Further, by looking at each language in turn, and effects of the direction of the switch, we can see if language dominance or L1 is more important in predicting the degree to which both language is suppressed in speech production and perception.

## Chapter 2

# Code-switching in Spontaneous Speech

### Abstract

Research has shown that bilinguals have constant activation of both languages, which results in one language influencing another in terms of how words are accessed in each language. The present study investigates how degree of cross-language activation can vary by context at the phonetic level by specifically investigating the production and perception of the discourse marker *like* in Spanish-English code-switching by L1 Spanish but English dominant bilinguals. Speakers produce *like* in code-switching contexts differently than in comparable monolingual (English, Spanish) contexts, such that they are phonetically in between the two monolingual productions. In two language continuation categorization tasks, listeners can anticipate whether a language switch is about to occur or not, however in most cases only for switches from their dominant language (English) to their non-dominant language (Spanish). This could be interpreted as evidence that listeners take advantage of this phonetic information to anticipate upcoming language switches. These results support past studies on bilingual language activation and switching, while demonstrating that there are repercussions of the activation effects at the phonetic level. Furthermore, in the perception studies, the degree of activation

is affected by current language dominance, thus suggesting that language dominance may be more important than order of acquisition for predicting switch costs in highly proficient, early bilinguals.

## 2.1 Introduction

Current theories of language access in bilinguals have largely come to support the Inhibitory Control (IC) model (Green, 1986, 1998). In the IC model, both languages are always somewhat activated, and where the *degree* to which a given language is activated varies depending on whether it is in use or not. This constant (at least low-level) activation of both languages results in cross-language interference, which has been found in a variety of experimental paradigms both in speech production and perception. Bilinguals are faster at naming cognates than non-cognates, which is attributed to the fact that if both languages are activated, cognates get retrieved more quickly because there is activation coming from both languages (Costa et al., 2000). In picture naming studies where bilinguals need to change the language they used to name a picture, bilinguals show asymmetrical switching costs, being faster at naming pictures in their L1 / dominant language than their L2 / non-dominant language in non-switch trials, but faster in their L2 than their L1 in switch trials (Meuter & Allport, 1999). However, other researchers have found that this effect can differ according to how balanced the bilingual is in their two languages, where more balanced bilinguals do not show the asymmetrical cost (Costa & Santesteban, 2004; Schwieter, 2008). When switching is voluntary instead of cued, bilinguals sometimes even show a benefit for switching compared to staying in the same language (Gollan & Ferreira, 2009). Evidence for cross-language activation has also been found in speech perception. Using the visual world paradigm, bilinguals are distracted by phonological competitors both within- and between-languages (Marian & Spivey, 2003;

Marian et al., 2003; Spivey & Marian, 1999).

While this line of research has been hugely important in better understanding lexical access in bilinguals, most studies have not further explored the porous nature of language separation. For example, researchers have not looked at how context can induce different degrees of cross-language activation. Context here is defined as language situations where the amount both languages are in use varies, e.g. when speaking to a monolingual versus when speaking to another bilingual. Furthermore, psycholinguistic studies of language switching have focused on a categorical level of language access, namely lexical retrieval. Another area that has received far less attention is phonetic activation. Phonetics is a promising domain of language to examine different degrees of cross-language activation in bilingual language organization, because it is gradient in both time and space (or degree). While picture naming studies have relied on reaction times as their continuous measure, one can directly test the degree to which the language “not in use” is indeed activated, in the form of gradient phonetic productions that exist between the two languages (e.g. vowel productions). Similarly, in perception, one can test if an intermediate phonetic production leads to greater activation of the language not in use. Recently there has been some examination of phonetics in picture naming studies to see how variables such as language switching and cognate status affects phonetic productions (D. J. Olson, 2013; Goldrick, Runnqvist, & Costa, 2014).

Code-switching offers an interesting context in which to study bilingual language activation as it represents a time when both languages should be heavily activated. Code-switching is when a speaker switches languages during a conversation, sometimes mid-utterance, and is a common practice among fluent bilinguals (Gumperz, 1977; Bullock & Toribio, 2009). As such, one would predict intermediate phonetic productions not just between monolinguals and bilinguals, but internal to a bilingual speaker. For example, a vowel that phonetically differs between English and Spanish may, in a code-

switching context, be produced with formant values that fall between both of the vowels. Examining the phonetics of code-switching thus allows researchers to see how having both languages more heavily activated affects gradient intermediate phonetic realizations. Additionally, most studies have found switching to induce a detrimental cost, but the presence and exploitation of phonetic cues could explain why code-switching is so easy and prevalent in highly proficient bilinguals in speech perception.

Code-switching has been previously studied from several perspectives including sociolinguistics (Gumperz, 1977; Milroy & Gordon, 2003; Woolard, 2004; Lipski, 2005), syntactic constraints (Pfaff, 1979; Poplack, 1980, 1987; Woolford, 1983; Belazi et al., 1994; Myers-Scotton, 2008), and the electrophysiological consequences of code-switching (Chauncey et al., 2008; Moreno et al., 2002; Proverbio et al., 2004). However, work on the phonetics of code-switching is rather lacking. Previous work has focused on segments, usually examining voice onset time (VOT) in monolingual utterances compared to code-switching utterances. Results have been mixed, with some finding no differences in VOT depending on if a word was produced in a monolingual or code-switching context (Grosjean & Miller, 1994; López, 2012), and others finding differences, but which vary depending on the direction of the switch and proficiency of the speakers (Bullock et al., 2006; Antoniou et al., 2011; D. J. Olson, 2013; Balukas & Koops, 2015; Piccinini & Arvaniti, 2015). In studies where effects were found, there was sometimes evidence of convergence, or intermediate phonetic productions, for one language but not the other (Antoniou et al., 2011; D. J. Olson, 2013; Balukas & Koops, 2015), and other times there was evidence for convergence for one language but *divergence* for the other language (Bullock et al., 2006; Piccinini & Arvaniti, 2015).

There has been some limited psycholinguistic work on code-switching phonetics in speech perception as it relates to predicting code-switches, which showed listeners do use phonetic information to anticipate code-switches to some extent (Li, 1996). However,

in this study, a word was either produced with entirely English phonetics or entirely Cantonese phonetics in a code-switching context. Thus the *gradient* nature of phonetics was not exploited. However, more recent work with the visual world paradigm has started to examine perception of more gradient phonetics (Fricke et al., 2015).

The present study seeks to answer the question, can different *contexts* affect the *degree* of cross-language activation? To test this the phonetics of code-switching was examined, as this represents a time when there should be greater activation of both languages, and thus greater effects of cross-language activation. The current study includes three experiments with the goal of answering two research questions: 1) In *production*, do Spanish-English bilinguals produce code-switching utterances with intermediate phonetic productions compared to in monolingual utterances?, and 2) In *perception*, do Spanish-English bilinguals use the intermediate productions in code-switching utterances to anticipate language switches?

The first question was tested by first collecting a corpus of spontaneous code-switching to conduct acoustic analyses on code-switching versus monolingual (non-code-switching) tokens. The discourse marker *like* was chosen for study as it was found to be used in both English and Spanish utterances and thus did not seem to be only an English lexical item. As the speakers were all from Southern California it would not be surprising if the discourse marker has been lexicalized as a Spanish word as well as an English word. If the word has been lexicalized in both English and Spanish, different predictions can be made for how the word will be produced on a phonetic level in each language. While phonetic work specifically on diphthongs is rather lacking for both English and Spanish, some work has shown that the end of the English diphthong (the /ɪ/) is closer to a glide than a vowel, ending less high and fronted compared to the monophthong /ɪ/ (Lehiste & Peterson, 1961). Conversely, one phonological analysis of Spanish falling diphthongs (for example /ai/) suggests that they are two fully produced vowels, instead

of a vowel plus a glide as in English (Roca, 1997). Thus, it can be predicted that the Spanish diphthong will be longer in duration than the English diphthong, if indeed it is produced as two full vowels. Additionally it is predicted that the diphthong will end higher and more fronted in Spanish than English, being closer to an /ɪ/ or an /i/ than a glide. Regarding general vowel space differences, the Spanish vowel space tends to be more backed than the English vowel space (A. R. Bradlow, 1995; Grijalva et al., 2013), so the diphthong may be in general more backed in Spanish than English, at least at the beginning of the diphthong. Effects are also expected for the /l/. English has been found to have a darker /l/ than Spanish (Huffman, 1997; Simonet, 2010), even for bilinguals (Barlow et al., 2012). Finally, differences are expected for the realization of the /k/ at the end of the word. English is known to not always release word final stops (Byrd, 1993), while the same is not documented for Spanish.

In addition to using *like* in fully English and Spanish utterances, speakers also used *like* as a boundary word in between languages at the exact point of a switch. If code-switching does induce a context where both languages are more heavily activated than in monolingual utterances, there should be phonetic differences between the realization of *like* in code-switching versus monolingual contexts.

The second question was tested by giving a new group of early Spanish-English bilinguals utterances up until the discourse marker *like* and asking them to predict the upcoming language. If listeners are aware of these phonetic cues they should be able to correctly guess whether a code-switch is about to occur or not.

By examining phonetic effects of the production and perception of spontaneous code-switching one can test current theories of bilingual language activation while using a naturalist context that more closely replicates switching in everyday life. If the expected production results are found, that would provide support for the IC model's predictions that degree of activation is gradient and manifested by intermediate phonetic

productions, especially at switches. If the predicted perception results are found, that would suggest that bilinguals can use cross-language activation to their advantage in anticipating language switches. This would counter past psycholinguistic studies on switches which have found a cost to switching languages. Instead, perhaps with ample warning of a switch through phonetic information, these costs are lessened in actual switching comprehension.

## 2.2 Experiment 1: Production

Experiment 1 tested the predictions of the theory that in spontaneous code-switching speakers will have more intermediate phonetic productions in code-switching than in monolingual utterances. The phonetics of the discourse marker *like* was examined since it is used freely in monolingual (English-*like*-English, Spanish-*like*-Spanish) and code-switching (English-*like*-Spanish, Spanish-*like*-English) utterances.

### 2.2.1 Method

Early Spanish-English bilinguals of Mexican-American heritage were recorded in pairs while conversing on topics particular to Mexican and Mexican-American culture, both with and without a distractor (the completion of jigsaw puzzles during conversation).

#### Materials

Prompts based on Mexican-American culture were chosen with the help of a Mexican-American Spanish-English bilingual undergraduate researcher; the prompts were selected to be culturally appropriate and thus elicit as natural a conversation as possible. Three conversational prompts and accompanying pictures were used to elicit spontaneous speech: *Quinceañera*, a girl's 15th birthday party that marks an important

milestone in Mexican-American culture; *Chavo del 8*, a popular Mexican TV show also shown in the United States on Spanish TV channels; and *Día de los Muertos* or Day of the Dead, an important holiday in Mexican and Mexican-American culture to honor and celebrate the dead. Prompts asked speakers to talk about their thoughts on the topic and posed specific questions about their experiences. Written versions of the prompts were provided on a piece of paper in both English and Spanish; Spanish was at the top of the page with the English translation below it. The Spanish text was presented first as a way to help speakers to get into a bilingual mode and thus facilitate code-switching during the conversation. On a second piece of paper speakers were provided with a picture related to the prompt (for *Día de los Muertos*, speakers were given two pictures). If the speakers were two females, *Quinceañera* and *Chavo del 8* were used; if the speakers were two males or one female and one male *Chavo del 8* and *Día de los Muertos* were used, as males would have less to talk about for the *Quinceañera* prompt. There were no male-male pairs. As a result of this set-up no dyad had both the *Quinceañera* and *Día de los Muertos* prompts; nevertheless, prompts were evenly used across tasks (except that *Chavo del 8* was used four times in the task without distraction and three times in the task with distraction).

In one of the tasks, jigsaw puzzles were used as a form of distraction. There were four puzzles in total, each consisting of twelve 2 inch  $\times$  2 inch pieces. Each puzzle was of a different animal one would find at the zoo; all puzzles were designed for children ages three and older. The puzzles were deliberately selected to be easy, as the aim was only to provide a mild distraction.

## Speakers

Five pairs (10 speakers in total) of Spanish-English bilinguals of Mexican-American heritage participated in the experiment; three pairs were female-female and

two female-male (total 8 females, 2 males). The speakers' average age was 19.8 years ranging from 18 to 24 years. They were UCSD undergraduates who were given course credit in exchange for participation. They all self-identified as fluent speakers of both languages; they said they were exposed to both languages before the age of six, and continued to use both languages in everyday life.

Before participating in the experiment speakers filled out a modified version of the Language Experience and Proficiency Questionnaire (LEAP-Q; Marian, Blumenfeld, & Kaushanskaya, 2007) in English, answering questions about their language background and uses of both Spanish and English. When asked if English was their first or second language, five said it was their first and five their second; when asked if Spanish was their first or second language, eight marked it was their first and two their second; speakers were allowed to say both languages were their first language. None marked anything but English or Spanish for their first and second languages. Seven out of ten speakers reported English as their dominant language, three Spanish as their dominant language. All speakers marked Hispanic for ethnicity, except one who declined to answer. None reported any speaking or hearing disorders. Ages of acquisition and current exposure are reported in Table 2.1. Self-reported proficiency measures are reported in Table 2.2.

**Table 2.1:** Speakers' ages of acquisition and current exposure. Language profiles of speakers including average age of acquisition, age of full fluency in understanding and speaking, and current exposure to both English and Spanish. All speakers were exposed to English before age 6 even if they did not fully "acquire" it by that age. Any remaining percentage in current exposure was a language other than English or Spanish.

|                                              |                | English    | Spanish    |
|----------------------------------------------|----------------|------------|------------|
| <b>Age acquired (years)</b>                  | <i>Average</i> | 3.9        | 0.9        |
|                                              | <i>Range</i>   | 0 to 14    | 0 to 2     |
| <b>Age fluent (years)</b>                    | <i>Average</i> | 6.7        | 4.5        |
|                                              | <i>Range</i>   | 1 to 16    | 1 to 12    |
| <b>Current exposure (percentage of time)</b> | <i>Average</i> | 67.4%      | 32.4%      |
|                                              | <i>Range</i>   | 49% to 90% | 10% to 50% |

**Table 2.2:** Speakers' proficiency scores. Speakers' average self-reported proficiency in speaking, understanding, and reading in English and Spanish, based on questions in the LEAP-Q. Scores out of 10. Note, giving a high score for one language did not preclude giving a high score for another language. This is evident from the column showing the absolute value of the difference in ratings for the two languages; generally the difference is only about 1.

|                      |                | English | Spanish | English–Spanish<br>(absolute value) |
|----------------------|----------------|---------|---------|-------------------------------------|
| <b>Speaking</b>      | <i>Average</i> | 8.0     | 8.0     | 1.2                                 |
|                      | <i>Range</i>   | 5 to 10 | 6 to 10 | 0 to 4                              |
| <b>Understanding</b> | <i>Average</i> | 8.4     | 8.3     | 0.7                                 |
|                      | <i>Range</i>   | 8 to 10 | 6 to 10 | 0 to 4                              |
| <b>Reading</b>       | <i>Average</i> | 8.4     | 7.3     | 1.1                                 |
|                      | <i>Range</i>   | 7 to 10 | 4 to 9  | 0 to 5                              |

## Procedure

The study included two tasks: 1) directed conversation (henceforth referred to as the Conversation Task), and 2) directed conversation with distraction (henceforth the Conversation with Puzzle Task, or Puzzle Task for short); the distraction was the requirement that speakers complete individually the four jigsaw puzzles mentioned above while holding a conversation. All speakers were greeted in English and completed the language questionnaire in English before participating in the study. Speakers were given one of the three conversational prompts with accompanying picture(s) and told to read the prompt and discuss it using the pictures (different prompts were used for the two tasks of each dyad of speakers). Prompts and task order were counterbalanced between dyads of speakers, to the extent that gender-related requirements permitted (see Section 2.2.1). In the Puzzle Task speakers were instructed to independently complete each of the four puzzles while talking about the prompt. Speakers were given no restrictions regarding turn-taking or about which language to use, and were not directed or interrupted by the experimenter until the end of the task. All conversations took place in the sound booth of

the UCSD Phonetics Lab. The experimenter was not present for the conversations. For the Conversation Task, after 15 minutes passed, the experimenter went into the sound booth and told the speakers to end their conversation (the average duration of conversations from the point when speakers started discussing the prompt to the point when the experimenter returned to the sound booth was 14.93 minutes [standard deviation 0.07 minutes]). For the Puzzle Task, conversation ended when both speakers had completed all four puzzles, at which point they alerted the experimenter (the average duration of conversations from the point when speakers started discussing the prompt to their leaving the sound booth to get the experimenter was 8.71 minutes [standard deviation 1.51 minutes]).

All speakers knew their partner before the experiment. This was deliberate, as a pilot study showed that speakers would not code-switch unless they were already familiar with their partner. Conversations were recorded using Praat (Boersma & Weenink, 2009) and an A-to-D converter (at a sampling rate of 48 kHz with a quantization rate of 16-bit). The recordings were in stereo using two Earthworks SR77 microphones.

### **Annotations and Measurements**

All conversations were transcribed in standard orthography using the annotation facility in Praat. Four transcription tiers were used, two per speaker with one for English orthographic transcription and one for Spanish orthographic transcription (two speakers  $\times$  two languages). This was done to keep productions by each speaker and each language separate. Rough utterance boundaries were annotated in Praat by the author, who is a native speaker of English and an L2 Spanish speaker. If the author was unsure about the language an utterance belonged to, it was marked on both tiers and checked with a second transcriber (a native speaker of Spanish). Once all utterance boundaries were annotated, all English utterances were transcribed by the author. Spanish utterances were transcribed by either the author or a native speaker of Spanish; any Spanish transcription by the author

was double checked by one of three native Spanish speakers. All tokens of *like* were segmented as described below to test for predicted differences. If the preceding word ended in an /l/ the token was not included. Any cases deemed too difficult to segment for various reasons (reduction, preceding context) were not included. For transcription of the conversations the stereo file was not split, however it was split for all phonetic annotation and analysis.

Phonetic differences were predicted for: 1) the overall duration of the /laɪ/, 2) the realization of the /k/, both in regards to presence and duration of the closure and burst, and 3) the formant structure of the /laɪ/. Duration of the /laɪ/ was chosen as a variable to investigate because if indeed Spanish diphthongs are produced as two full vowels, then they should have a longer duration compared to English diphthongs, and thus a longer /laɪ/ production. To test this prediction all tokens of the word *like* were segmented from the onset of the /l/ to the offset of the vowel (the /laɪ/) and the duration of this production was measured.

The /k/ analyses are due to the fact that in English whether word-final stops are released or not has been shown to be variable (Byrd, 1993), whereas the same prediction is not made for Spanish. Two additional segmentations were made: 1) from the offset of the vowel to the beginning of the /k/ burst (the /k/ closure), and 2) from the onset of the /k/ burst to the end of the /k/ burst (the /k/ burst). It was first coded if the /k/ closure and burst were present, and if it was, the duration was measured between the appropriate segmentation points. If the word following a token began with a stop, the burst was considered the beginning of the next word, not the final /k/ of the token, however the closure was counted as the closure of the *like* token. Some tokens ended in /h/ instead of /k/, these were considered tokens where no burst was present.

Finally, formant analyses of the /laɪ/ were conducted. First, the /l/ and /aɪ/ were analyzed separately to see if predicted differences affected the segmental targets (/l/ dark-

ness, maximal jaw opening of diphthong nucleus, and diphthongal offset). Segmentation between the /l/ and the /aɪ/ was based on visual inspection of the waveform (abrupt rise in amplitude between the /l/ and the vowel) and the spectrogram (particularly rises in F2). For both the /l/ and the /aɪ/, F1, F2, and F3 values were taken at 1% installments from 0-100% of the segment. Since durations were not always the same across tokens, percentages were used instead of increases in absolute time for formant extraction to make sure tokens could be comparable to one another. For the analysis of the /l/, average F1, F2, and F3 values were computed after outlier removal. For the /aɪ/, two values were computed after outlier removal: 1) for the 25-75% portion of the vowel the maximum F1 was found and accompanying F2 and F3 values, and 2) for the 76-100% portion of the vowel maximum F2 was found and accompanying F1 and F3 values. For (1) 25-75% was chosen as the target should be in roughly the middle portion of the diphthong. For (2) 76-100% was chosen as this coincided with roughly the offset of the diphthong. To examine the entire shape of the /laɪ/, F1, F2, and F3 values were taken in 5% installments from 0-100% of the token resulting in 21 measurements per token. Praat scripts were used to extract all formant values; different settings were used for female and male speakers. Outliers were defined as values that were two standard deviations from the mean for a given speaker at that specific percentage. One additional outlier was removed when the data was inspected with a scatterplot; it was not caught as an outlier initially because this speaker had very few tokens and thus a large standard deviation.

All *like* tokens were coded on three dimensions: 1) language context of production, 2) language preceding the token, and 3) grammatical function of *like*. Language contexts included monolingual and code-switching (a Spanish token was considered different from a code-switching token if *like* was both preceded and followed by Spanish). Examples of the two monolingual contexts (English-*like*-English and Spanish-*like*-Spanish) are provide in (1) and (2) below. Code-switching tokens were when *like* was immediately

between two languages with less than 300 ms between the preceding or following language and the token. Code-switching contexts included both when English was the language preceding the token (code-switching English-Spanish) and when Spanish was the language preceding the token (code-switching Spanish-English) contexts; in all code-switching cases the word *like* was at the boundary point between languages. Examples of the two code-switching contexts are provided in (3) and (4) below.

**1. Context = monolingual, Language preceding token = English**

He would just act *like*, I don't know.

**2. Context = monolingual, Language preceding token = Spanish**

Me acuerdo uno es que *like* no sé quien.

GLOSS: I remember one that *like* I don't know who.

**3. Context = code-switching, Language preceding token = English**

One of those barrels and *like* estaba adentro.

GLOSS: One of those barrels and *like* he was in it.

**4. Context = code-switching, Language preceding token = Spanish**

Yo me acuerdo que tenía que ir *like* before having mine...

GLOSS: I remember that I had to go *like* before having mine...

Tokens were also coded according to their grammatical function. It was found by Drager (2009) that different grammatical uses of *like* can differ in duration and formant values, particularly for F2. Since the greatest differences were between the grammatical types and discourse marker types of the word *like*, only discourse marker types were

used for the present study. Specific coding categories were used as described by D'Arcy (2007). The two codings used for this study were: 1) discourse marker and particle, and 2) quotative complementizer. The discourse marker and particle categories have been collapsed together as they are often difficult to clearly label as separate categories. Example sentences from D'Arcy (2007) are presented in (5) and (6). The word *like* when used as a verb or any other grammatical context was not included. Example segmentations and codings are provided in Figures 2.1a and 2.1b.

### 5. Discourse Marker and Particle

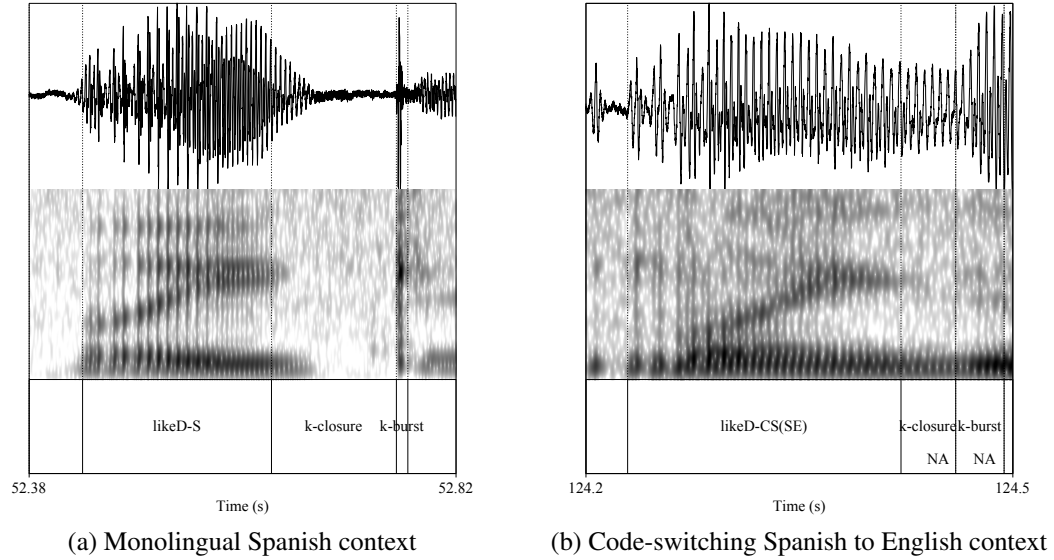
Marker: Nobody said a word. *Like* my first experience with death was this Italian family.

Particle: Well you just cut out *like* a girl figure and a boy figure and then you'd cut out *like* a dress or a skirt or a coat, and *like* you'd color it.

### 6. Quotative Complementizer

And we were *like*, "Yeah but you get to sleep *like* three-quarters of your life." He was *like*, "That's an upside."

Table 2.3 includes summary counts of the tokens. The number of tokens was very unbalanced, with far more monolingual English tokens than anything else. However, the number of monolingual Spanish and code-switching tokens of both types were comparable.



**Figure 2.1:** Example segmentations of two tokens of *like*. Segmentations for the /laɪ/ and following /k/ separated by closure and burst. The “D” codes the tokens as discourse marker or particle; quotative complementizer was coded “DQ”. The “S” coded the token as monolingual Spanish, the “CS(SE)” coded the token as a code-switching from Spanish to English; the other two language codings were “E” for monolingual English and “CS(ES)” for code-switching from English to Spanish. Note, for the code-switching example the /k/ segmentations are placeholders and marked with “NA”, as both the closure and burst were not produced.

**Table 2.3:** Counts of *like* tokens. Summary counts of tokens by context, language preceding the token, and grammatical coding.

|                                    | English |    | Spanish |    | TOTAL |
|------------------------------------|---------|----|---------|----|-------|
|                                    | ML      | CS | ML      | CS |       |
| <b>Discourse Marker / Particle</b> | 420     | 20 | 42      | 31 | 513   |
| <b>Quotative Complementizer</b>    | 39      | 11 | 1       | 1  | 52    |
| <b>TOTAL</b>                       | 459     | 31 | 43      | 32 | 565   |

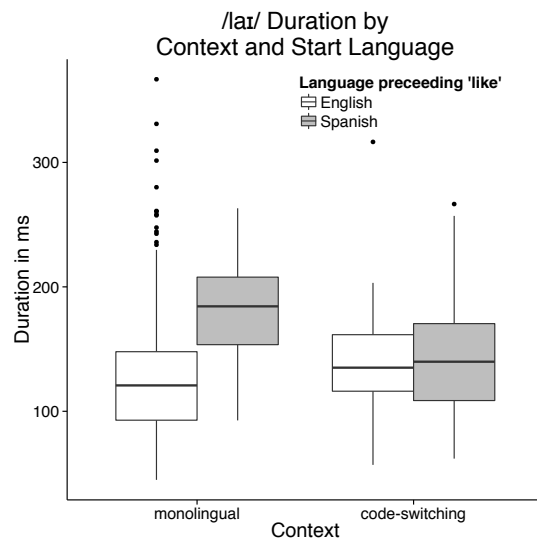
## 2.2.2 Results

### Duration of /laɪ/

To test for significant effects a linear mixed effects regression model was run in R (R Development Core Team, 2013) with the lme4 package (Bates, Mächler, Bolker, &

Walker, 2015). Duration of the /laɪ/ was the dependent variable. Context (monolingual, code-switching), language preceding the token (English, Spanish), task (Conversation, Puzzle), and grammatical function (discourse marker and particle, quotative complementizer) were included as fixed effects; context, language preceding the token, and task were included as interactions, all possible two-way interactions and the three-way interaction. All variables were coded with contrast coding. Speaker was included as a random slope by context, language preceding the switch, and task. No other random effects were included (e.g. “Item” or “Word”) as only one word was analyzed, *like*. This was the maximal uncorrelated random effects structure that converged. Significance was tested using model comparison. Alpha was set to 0.05.

Neither of the main effects of interest (context, language preceding the token) were significant, but the interaction of context and language preceding the token was significant [ $\beta = -59.96$ ,  $SE = 13.79$ ,  $\chi^2(1) = 17.24$ ,  $p < 0.001$ ]. Follow up simple regressions found that for monolingual tokens Spanish tokens had significantly longer durations than English tokens [ $\beta = 52.67$ ,  $SE = 7.29$ ,  $r = 0.30$ ,  $p < 0.001$ ]; there was no difference though for code-switching tokens. Within language, for tokens preceded by English, code-switching tokens had longer durations than monolingual tokens [ $\beta = 17.73$ ,  $SE = 8.50$ ,  $r = 0.08$ ,  $p < 0.05$ ], and for tokens preceded by Spanish, code-switching tokens had shorter durations than monolingual tokens [ $\beta = -37.35$ ,  $SE = 10.90$ ,  $r = -0.36$ ,  $p < 0.01$ ]. No other main effects or interactions were significant. This suggest that 1) English and Spanish tokens of *like* are phonetically different and, 2) code-switching tokens are distinct from both monolingual English and monolingual Spanish tokens but not from each other in regards to /laɪ/ duration. See Figure 2.2 for a summary of these results.



**Figure 2.2:** Duration of /laɪ/ separated by context and language preceding the token. The whiskers extend from the first or third quartile (Q1, Q3) to the largest value within 1.5 times the inter quartile range. Any dots outside of the whiskers represent outliers.

### Closure and Burst

In addition to analyzing the /laɪ/ portion of *like*, the closure and burst of the /k/ were also examined. The first set of analyses tested for if the presence or lack of a closure or burst was affected by context and proceeding language. To test for significant effects logistic mixed effects regression models were run. Presence of the closure or burst were the dependent variables. For the model on closure presence, context (monolingual, code-switching) and language preceding the token (English, Spanish) were included as fixed effects and as an interaction; the model would not converge with additional variables. Speaker was included as a random slope by context. This was maximal uncorrelated random effects structure that would converge. For the model on burst presence, context (monolingual, code-switching), language preceding the token (English, Spanish), task (Conversation, Puzzle), and grammatical function (discourse marker and particle, quotative complementizer) were included as fixed effects; context and language preceding the token were included as interactions, the model would not converge with

additional interactions. Speaker was included as a random slope by context and task. This was the maximal uncorrelated random effects structure that would converge. For both analyses, no other random effects were included (e.g. “Item” or “Word”) as only one word was analyzed, *like*. All variables for both models were coded with contrast coding. Significance was tested using model comparison. Alpha was set to 0.05.

The model on closure presence found a significant interaction of context and language preceding the token [ $\beta = -29.71$ ,  $SE = 55.04$ ,  $\chi^2(1) = 8.25$ ,  $p < 0.01$ ]. However, follow up simple logistic regressions did not find any significant differences of context or language preceding the token. The model on burst presence did not have any significant main effects or interactions.

Duration analyses were also conducted for both the closure and burst for all tokens in which the duration was not 0 (i.e. there was a closure or burst present). Regarding fixed effects the models were the same as the model for /laɪ/ duration. For both models, speaker was included as a random slope by context, language preceding the switch, task, and grammatical function. No other random effects were included (e.g. “Item” or “Word”) as only one word was analyzed, *like*. In no model were interactions included in the random slope. For both the closure duration model and burst duration model no main effects or interactions were significant.

In summary, it appears that closure and burst, both presence and duration, were minimally affected by context or language preceding the token.

### **Average Formants of /l/**

In order to reduce speaker specific effects, the F1 and F2 values were normalized using the Bark Difference Metric (Syrdal & Gopal, 1986; Thomas & Kendall, 2007). First F1, F2, and F3 are converted to Bark. Then the height measurement is computed with  $F3_{bark} - F1_{bark}$ , and the front-backness metric with  $F3_{bark} - F2_{bark}$ . To test for

effects on the /l/ specifically two linear mixed effects models were run, one with average F1 bark normalized as the dependent variable and one with average F2 bark normalized as the dependent variable. The fixed effects were context (monolingual, code-switching) and language preceding the token (English, Spanish); context and language preceding the token were included as an interaction. All variables were coded with contrast coding. Task and grammatical function were not included as they were not significant in any of the other previous analyses. Speaker was included as a random slope by the interaction of context and language preceding the token. No other random effects were included (e.g. “Item” or “Word”) as only one word was analyzed, *like*. This was the maximal uncorrelated random effects structure that converged. Significance was tested using model comparison. Alpha was set to 0.05.

For both the model of average F1 bark normalized values and the model of average F2 bark normalized values there were no significant effects for any of the main effects or the interaction. This suggests that the /l/ in *like* does not differ in average clarity according to language context.

### **Formants of /aɪ/**

To test for effects on the /aɪ/ specifically four linear mixed effects models (two models at two points in the vowel) were run. The first point was the nucleus of the vowel, defined by the point where the F1 maximum occurred between 25% and 75% into the vowel; a model was run both for F1 bark normalized and F2 bark normalized at this point. The second was the offglide of the vowel, defined by the point where the F2 maximum occurred between 76% and 100% into the vowel, a model was run both for F1 bark normalized and F2 bark normalized at this point. The fixed effects were context (monolingual, code-switching) and language preceding the token (English, Spanish); context and language preceding the token were included as an interaction. All

variables were coded with contrast coding. Speaker was included as a random intercept and a random slope by context and language preceding the token uncorrelated with the random intercept for the analysis of the nucleus for both the F1 and F2 models. For the offglide analyses speaker was included as a random slope only by language preceding the token for both the F1 and F2 models. No other random effects were included (e.g. “Item” or “Word”) as only one word was analyzed, *like*. These was the maximal uncorrelated random effects structure that converged. Significance was tested using model comparison. Alpha was set to 0.05.

For all four analyses (nucleus F1, nucleus F2, offglide F1, offglide F2) there were no significant effects. This suggests that vowel targets do not differ by language context.

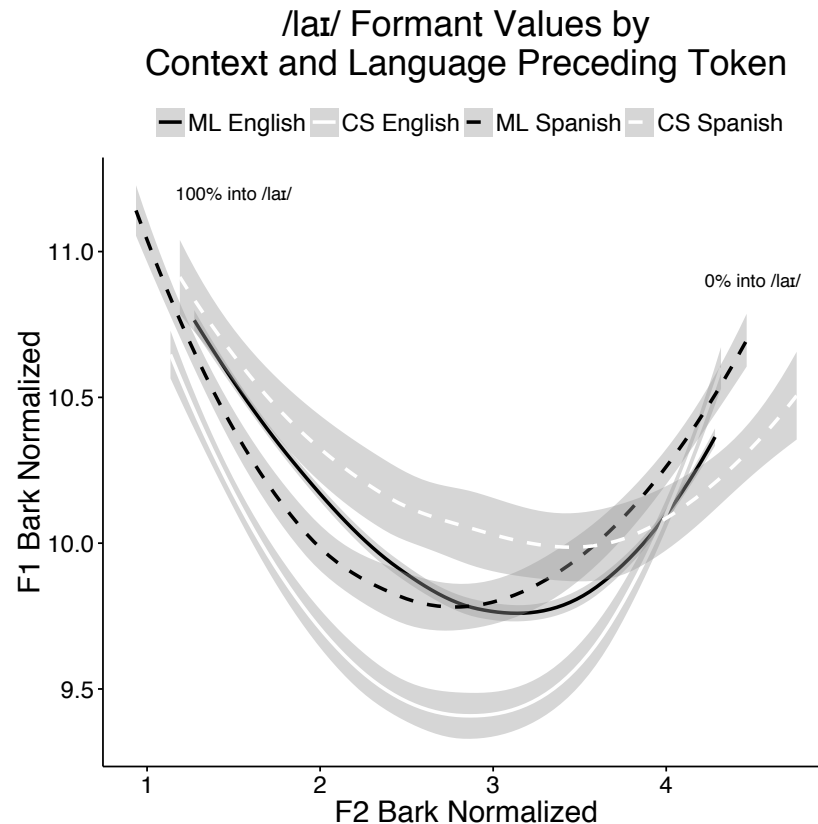
### **Formants of /laɪ/**

The final analyses were conducted on the formant values of the entire /laɪ/. To test for significant effects on the whole /laɪ/ production two linear mixed effects models were run, one with F1 bark normalized as the dependent variable and one with F2 bark normalized as the dependent variable. The fixed effects were context (monolingual, code-switching), language preceding the token (English, Spanish), and percentage into the token (0 – 100% in 5% steps); context, language preceding the token, and percentage were included as all possible two-way interactions and the three-way interaction. All variables were coded with contrast coding. For the F1 model, speaker was included as a random slope by context and language preceding the token. For the F2 model, speaker was included as a random slope by the interaction of context and language preceding the token. No other random effects were included (e.g. “Item” or “Word”) as only one word was analyzed, *like*. This was the maximal uncorrelated random effects structure that converged. Significance was tested using model comparison. Alpha was set to 0.05.

For the model of F1 bark normalized values, there was a significant effect of

percentage, where the farther into the utterance the higher the /laɪ/ is produced [ $\beta = 0.003$ ,  $SE = 0.0004$ ,  $\chi^2(1) = 68.18$ ,  $p < 0.001$ ]. There were also three significant interactions, context by percentage [ $\beta = -0.002$ ,  $SE = 0.0009$ ,  $\chi^2(1) = 7.11$ ,  $p < 0.01$ ], language preceding token by percentage [ $\beta = 0.004$ ,  $SE = 0.0009$ ,  $\chi^2(1) = 23.44$ ,  $p < 0.001$ ], and context by language preceding token by percentage [ $\beta = 0.005$ ,  $SE = 0.002$ ,  $\chi^2(1) = 7.75$ ,  $p < 0.01$ ]. Follow-up simple regressions found that monolingual English tokens ended significantly higher than they started [ML-E:  $\beta = 0.004$ ,  $SE = 0.0003$ ,  $r = 0.14$ ,  $p < 0.001$ ], but there was no difference for code-switching English tokens. Both Spanish monolingual and code-switching tokens ended higher than they started [ML-S:  $\beta = 0.01$ ,  $SE = 0.001$ ,  $r = 0.19$ ,  $p < 0.001$ ; CS-S:  $\beta = 0.01$ ,  $SE = 0.001$ ,  $r = 0.20$ ,  $p < 0.001$ ].

The F2 bark normalized analysis found a significant effect context, with speakers producing more backed productions for code-switching tokens [ $\beta = 0.33$ ,  $SE = 0.08$ ,  $\chi^2(1) = 10.60$ ,  $p < 0.01$ ]. There was also a significant effect of percentage, with the tokens ending more fronted than they started [ $\beta = -0.04$ ,  $SE = 0.0004$ ,  $\chi^2(1) = 5432.40$ ,  $p < 0.001$ ]. There were three significant interactions, context by percentage [ $\beta = -0.003$ ,  $SE = 0.001$ ,  $\chi^2(1) = 6.93$ ,  $p < 0.01$ ], language preceding token by percentage [ $\beta = -0.005$ ,  $SE = 0.001$ ,  $\chi^2(1) = 23.21$ ,  $p < 0.001$ ], and context by language preceding token by percentage [ $\beta = 0.004$ ,  $SE = 0.002$ ,  $\chi^2(1) = 5.26$ ,  $p < 0.05$ ]. Follow-up simple regressions found that all types of tokens ended significantly more fronted than they began, the most fronted being monolingual Spanish, then code-switching Spanish, then code-switching English, then monolingual English [ML-S:  $\beta = -0.04$ ,  $SE = 0.001$ ,  $r = -0.85$ ,  $p < 0.001$ ; CS-S:  $\beta = -0.04$ ,  $SE = 0.001$ ,  $r = -0.81$ ,  $p < 0.001$ ; CS-E:  $\beta = -0.04$ ,  $SE = 0.001$ ,  $r = -0.78$ ,  $p < 0.001$ ; ML-E:  $\beta = -0.04$ ,  $SE = 0.0004$ ,  $r = -0.74$ ,  $p < 0.001$ ]. Both the F1 and F2 results demonstrate that *like* tokens do differ by both context and language preceding token in regards to formant values. See Figure 2.3 for formant plot.



**Figure 2.3:** Formant values of /laɪ/ separated by context and language preceding the token over time. Note, the beginning of the token (0%) is the far right and the end of the token (100%) is the far left).

### 2.2.3 Discussion

The results of the production experiment demonstrate: 1) that *like* is produced differently in English and Spanish and is not a direct borrowing from English (“borrowing” here refers to when a single word from a language is inserted into another language, but maintains the original language’s phonetics), but instead matches the expected phonetic characteristics of Spanish, and 2) code-switching tokens of *like* do not directly map onto one language or the other, but instead are produced between both languages. This was found in regards to /laɪ/ duration (English shortest, Spanish longest, code-switching in between) and formant values (Spanish begin and end more fronted and end higher than English, code-switching productions in between), but not in regards to /k/ realization.

Analyses of specific segments, the /l/ and two points during the /aɪ/, did not reveal any effects of context or language preceding the token. This suggests that the effects found cannot be tied to a specific point in time, but instead are a global difference happening throughout the production of the /laɪ/.

However, as discussed earlier, these analyses are on a very unbalanced data set with very few tokens for several categories. Follow-up production data would be needed to make any truly strong claims about the data. These results were enough to warrant a follow-up perception experiment to test if bilinguals are able to perceive these acoustic differences in the signal, and furthermore use them to anticipate upcoming language switches.

## 2.3 Experiment 2: Code-switching Detection

After finding that there are indeed gradient differences in code-switching productions of *like*, the next goal was to determine if these cues are salient to Spanish-English bilingual listeners during speech perception. To test this, a perception experiment was conducted which engaged listeners in a metalinguistic task requiring them to indicate when they thought a language switch was about to occur.

### 2.3.1 Method

#### Materials

All stimuli were taken from the previous production experiment. Only productions from the Conversation Task were used; 85% of the tokens of *like* were discourse marker or particle tokens while the other 15% were quotative complementizer tokens. Given the lack of differences between the two types of tokens in the production analysis, the different proportions for the contexts should not be an issue. Half of the stimuli were

code-switches and half were not; half began in English and half in Spanish. For a full breakdown of the stimuli by context and *like* grammatical coding see Table 2.4.

**Table 2.4:** Counts of *like* tokens in perception experiments. Breakdown of number of stimuli in each context and *like* grammatical coding.

|                                    | English   |           | Spanish   |           | TOTAL |
|------------------------------------|-----------|-----------|-----------|-----------|-------|
|                                    | <i>ML</i> | <i>CS</i> | <i>ML</i> | <i>CS</i> |       |
| <b>Discourse Marker / Particle</b> | 9         | 6         | 10        | 9         | 34    |
| <b>Quotative Complementizer</b>    | 1         | 4         | 0         | 1         | 6     |

The monolingual utterances had *like* at some point in the middle of the utterance; code-switching utterances had *like* at the switch point between languages. For all stimuli listeners heard the utterance only up to and including *like*. A total of 40 stimuli were used for testing: 10 English-*like*-English (monolingual), 10 Spanish-*like*-Spanish (monolingual), 10 English-*like*-Spanish (code-switching), and 10 Spanish-*like*-English (code-switching). Four additional stimuli (one per context) were used at the beginning of the experiment for practice.

## Listeners

To be included in the study, listeners had to call at least one fourth of stimuli a code-switch. They did not have to have *correctly* identify one fourth of code-switches, simply give that response at least a fourth of the time. This cutoff was chosen because most listeners instead chose to call almost all stimuli monolingual. Listeners were 29 Spanish-English bilinguals of Mexican-American heritage, 28 female and 1 male. Listeners' average age was 19.9 years ranging from 18 to 23 years old. Listeners were UCSD undergraduates who were given course credit in exchange for participation. All listeners self-identified as fluent speakers of both languages and said they were exposed to both languages from birth.

Like the speakers in the production experiment, all listeners filled out the LEAP-Q before participating in the experiment. When asked if English was their first or second language, six said it was their first and 23 their second; when asked if Spanish was their first or second language 25 said it was their first and four their second; listeners were allowed to say both languages were their first language. None marked anything but English or Spanish for their first and second languages. Regarding dominant language, 27 listeners reported English as their dominant language and two Spanish as their dominant language. All speakers marked Hispanic as their ethnicity. None reported any speaking or hearing disorders. Ages of acquisition and current exposure are reported in Table 2.5. Self-reported proficiency measures are reported in Table 2.6.

**Table 2.5:** Perception experiment #1 listeners' ages of acquisition and current exposure. Language profiles of listeners, including average age of acquisition, age of full fluency in understanding and speaking, and current exposure to both English and Spanish. All listeners were exposed to English before age 6 even if they did not fully "acquire" it by that age. Any remaining percentage in current exposure was a language other than English or Spanish.

|                                              |                | <b>English</b> | <b>Spanish</b> |
|----------------------------------------------|----------------|----------------|----------------|
| <b>Age acquired (years)</b>                  | <i>Average</i> | 3.8            | 1.2            |
|                                              | <i>Range</i>   | 0 to 6         | 0 to 3         |
| <b>Age fluent (years)</b>                    | <i>Average</i> | 5.6            | 4.9            |
|                                              | <i>Range</i>   | 1 to 10        | 2 to 15        |
| <b>Current exposure (percentage of time)</b> | <i>Average</i> | 67.0%          | 32.5%          |
|                                              | <i>Range</i>   | 25% to 90%     | 10% to 75%     |

## Procedure

The experiment was presented to listeners in the program SuperLab Pro 4.5 (Cedrus Corporation, 2011). Listeners were told that they were going to hear half of a sentence either in English or Spanish, and their task was to determine what language they

**Table 2.6:** Perception experiment #1 listeners' proficiency scores. Listeners' average self-reported proficiency in speaking, understanding, and reading in English and Spanish, based on questions in the LEAP-Q. Scores out of 10. Note, giving a high score for one language did not preclude giving a high score for another language. This is evident from the column showing the absolute value of the difference in ratings for the two languages; generally the difference is only about 1.

|                      |                | English | Spanish | English-Spanish<br>(absolute value) |
|----------------------|----------------|---------|---------|-------------------------------------|
| <b>Speaking</b>      | <i>Average</i> | 9.0     | 7.6     | 1.4                                 |
|                      | <i>Range</i>   | 8 to 10 | 4 to 10 | 0 to 5                              |
| <b>Understanding</b> | <i>Average</i> | 9.3     | 8.5     | 0.9                                 |
|                      | <i>Range</i>   | 7 to 10 | 5 to 10 | 0 to 3                              |
| <b>Reading</b>       | <i>Average</i> | 9.1     | 7.6     | 1.7                                 |
|                      | <i>Range</i>   | 7 to 10 | 3 to 10 | 0 to 6                              |

believed the next word was in. For example, for the utterance “One of those barrels and *like* estaba adentro” listeners only heard “One of those barrels and *like*”. Listeners began with four practice items in randomized order: one English-*like*-English, one Spanish-*like*-Spanish, one English-*like*-Spanish, and one Spanish-*like*-English. A fixation cross was presented on the screen while a stimulus played. Once the stimulus was finished the computer displayed a message prompting the listeners to press “z” if they thought the utterance continued in English and “m” if they thought the utterance continued in Spanish. For the original set of listeners having “z” or “m” correspond to English was counterbalanced; with the cutoff of calling one fourth of stimuli a code-switch 13 participants used “z” for English and 16 “m” for English. The keys “z” and “m” were used since they were easy to find on the keyboard being at opposite ends of the bottom row of letters on a United States English keyboard. After each practice item, the listener heard the entire utterance and found out if they were correct or not. After hearing the four practice items, listeners were told they were about to begin the experiment and would not receive any feedback on their responses. The 40 stimuli were randomized and presented with a block design over four blocks. A given listener heard each stimulus four times,

once per block, for a total of 160 responses per listener. Response type (monolingual or code-switch) was recorded.

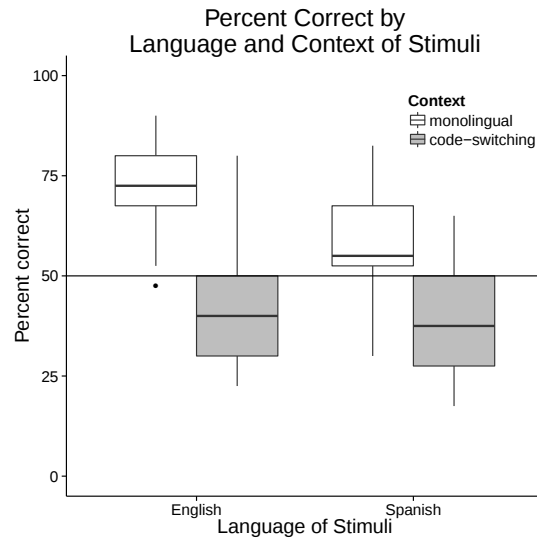
### 2.3.2 Results

**Table 2.7:** Perception experiment #1 percent responses by language and context.

|                    | <b>English stimuli</b> |                   | <b>Spanish stimuli</b> |                   |
|--------------------|------------------------|-------------------|------------------------|-------------------|
|                    | <i>ML Context</i>      | <i>CS Context</i> | <i>ML Context</i>      | <i>CS Context</i> |
| <b>ML Response</b> | 72%                    | 58%               | 58%                    | 61%               |
| <b>CS Response</b> | 28%                    | 42%               | 42%                    | 39%               |

To test for significant effects of accuracy a logistic mixed effects regression model was run. Accuracy (correct, incorrect) was the dependent variable. Language of stimuli (English, Spanish), and context (monolingual, code-switching) were included as fixed effects and as an interaction. All variables were coded with contrast coding. Block was not included as initial testing found it did not significantly improve the model. Listener was included as a random slope by language of stimuli and context as an interaction. Item was also included as a random intercept. Significance was tested using model comparison. Alpha was set to 0.05. The main effect of language was significant, with listeners performing worse on the Spanish stimuli than the English stimuli [ $\beta = -0.40$ ,  $SE = 0.16$ ,  $\chi^2(1) = 5.89$ ,  $p < 0.05$ ]. There was a significant main effect of context, with listeners performing worse on the code-switching stimuli than the monolingual stimuli [ $\beta = -1.10$ ,  $SE = 0.22$ ,  $\chi^2(1) = 21.35$ ,  $p < 0.001$ ]. The interaction of language of stimuli and context was not significant. See Figure 2.4 for summary of results.

In addition to testing general accuracy, one question was, when listeners called an utterance a code-switch were they applying the label at random, or were they more likely to apply it correctly (when the utterance actually was a code-switch) than incorrectly

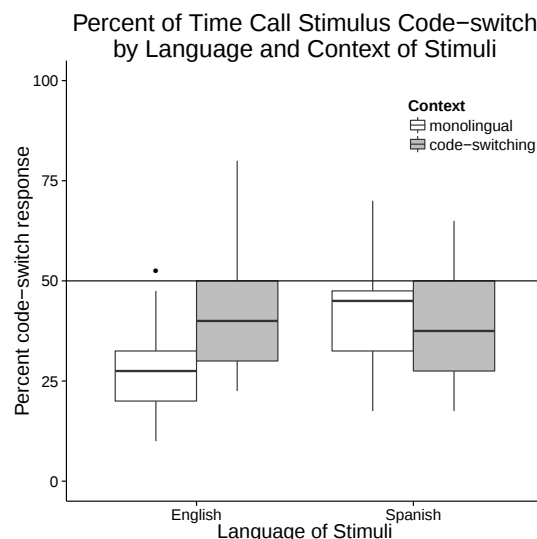


**Figure 2.4:** Perception experiment #1 accuracy on task by language and context. Accuracy on task by language and context. Chance is marked at 50%. The whiskers extend from the first or third quartile (Q1, Q3) to the largest value within 1.5 times the interquartile range. Any dots outside of the whiskers represent outliers.

(when it was not a code-switch).  $d'$  scores were calculated for each listener for each language separately; a hit was defined as correctly identifying a code-switch and a false alarm was incorrectly labeling a stimulus as a code-switch. An ANOVA was run with the  $d'$  score as the dependent variable and language of stimuli as the independent variable included as a within-subject factor. There was a significant effect of language, such that listeners had higher  $d'$  scores for English stimuli than Spanish stimuli [ $F(1, 28) = 42.54$ ,  $p < 0.001$ ].

However, it is still unclear whether listeners treat the contexts differently within language. To answer this question an additional logistic mixed effects regression model was run, but instead of correct or incorrect as the dependent variable, listener response (monolingual or code-switch) was the dependent variable. All other aspects of the model were the same as for the accuracy analysis. The main effects of language of stimuli and context were not significant, however there was a significant interaction of language of stimuli and context [ $\beta = -0.79$ ,  $SE = 0.32$ ,  $\chi^2(1) = 5.54$ ,  $p < 0.05$ ]. Follow up simple

regressions found that the context effect was significant for English stimuli [ $\beta = 0.61$ ,  $SE = 0.00$ ,  $z = 6.89$ ,  $p < 0.001$ ], but not Spanish stimuli. A summary of results is presented in Figure 2.5. Note, the key difference between Figure 2.4 and Figure 2.5 is what is represented on the y-axis. In Figure 2.4 percent correct is plotted, so if listeners gave perfect responses all four boxes would be 100%. In Figure 2.5 percentage of time giving a code-switching response is plotted, so if listeners gave perfect responses the first and third boxes (monolingual stimuli) would be at 0% for never giving a code-switch response, and the second and fourth boxes (code-switching stimuli) would be at 100% for always giving a code-switch response.



**Figure 2.5:** Perception experiment #1 percent call stimulus code-switch by language and context. Percent call stimulus a code-switch by language and context. Chance is marked at 50%. The whiskers extend from the first or third quartile (Q1, Q3) to the largest value within 1.5 times the inter quartile range. Any dots outside of the whiskers represent outliers.

### 2.3.3 Discussion

The perception study found that listeners do treat monolingual and code-switching utterances differently and that stimuli language affects responses. While there was a

clear bias for listeners to call stimuli monolingual, listeners did not apply the code-switch label at random. If listeners applied the code-switch label to a stimulus, it was generally applied correctly. However, this effect was specific to switches from English to Spanish, demonstrating that the direction of the switch matters. For Spanish utterances, both monolingual and code-switching, listeners were at chance.

## **2.4 Experiment 3: Code-switching Forced Categorization**

The results of the first perception experiment found that there was some evidence that listeners could predict code-switches (at least from English). However, there was a bias by listeners to call all stimuli monolingual across both languages. To see how results would change when this bias was eliminated, a second perception study was run where listeners were required to equally sort utterances, such that half had to be labeled as monolingual and half as code-switches. Additionally language mode (such as the language a listener is spoken to when entering the lab) was added as a manipulation, as this has found to be important in past studies (Grosjean, 2001).

### **2.4.1 Method**

#### **Materials**

Materials were the same as those used in Experiment 2. Half of stimuli were monolingual and half were code-switches.

## Listeners

Listeners were 40 Spanish-English bilinguals of Mexican-American heritage, 33 female, 7 male. Listeners' average age was 20 years, ranging from 18 to 29 years old. Listeners were UCSD undergraduates who were given course credit in exchange for participation. All listeners self-identified as fluent speakers of both languages and said they were exposed to both languages from birth.

As for the other experiments, all listeners filled out the LEAP-Q before participating in the experiment. When asked if English was their first or second language, 11 said it was their first language and 29 their second; when asked if Spanish was their first or second language, 34 marked it was their first and six their second; listeners were allowed to say both languages were their first language. None marked anything but English or Spanish for their first and second languages. Regarding dominant language, 29 marked English as their dominant language and 11 Spanish. All speakers marked Hispanic for ethnicity. None reported any speaking or hearing disorders. Ages of acquisition and current exposure are reported in Table 2.8. Self-reported proficiency measures are reported in Table 2.9.

**Table 2.8:** Perception experiment #2 listeners' ages of acquisition and current exposure. Language profiles of listeners, including average age of acquisition, age of full fluency in understanding and speaking, and current exposure to both English and Spanish. All listeners were exposed to English before age 6 even if they did not fully "acquire" it by that age. Any remaining percentage in current exposure was a language other than English or Spanish.

|                                              |                | English    | Spanish    |
|----------------------------------------------|----------------|------------|------------|
| <b>Age acquired (years)</b>                  | <i>Average</i> | 3.4        | 1.4        |
|                                              | <i>Range</i>   | 0 to 10    | 0 to 3     |
| <b>Age fluent (years)</b>                    | <i>Average</i> | 5.9        | 3.5        |
|                                              | <i>Range</i>   | 1 to 15    | 1 to 7     |
| <b>Current exposure (percentage of time)</b> | <i>Average</i> | 66.9%      | 32.8%      |
|                                              | <i>Range</i>   | 10% to 90% | 10% to 90% |

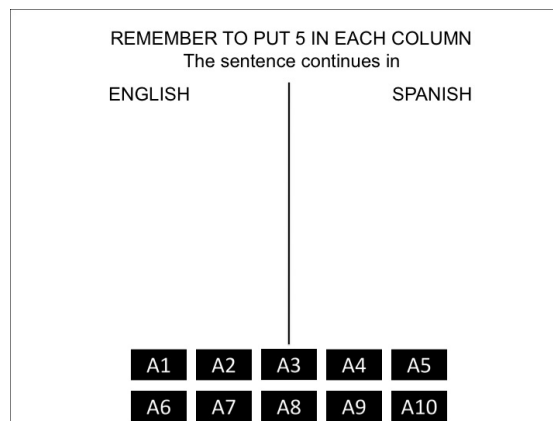
**Table 2.9:** Perception experiment #2 listeners' proficiency scores. Listeners' average self-reported proficiency in speaking, understanding, and reading in English and Spanish, based on questions in the LEAP-Q. Scores out of 10. Note, giving a high score for one language did not preclude giving a high score for another language. This is evident from the column showing the absolute value of the difference in ratings for the two languages; generally the difference is only about 1.

|                      |                | English | Spanish | English–Spanish<br>(absolute value) |
|----------------------|----------------|---------|---------|-------------------------------------|
| <b>Speaking</b>      | <i>Average</i> | 9.1     | 8.0     | 1.3                                 |
|                      | <i>Range</i>   | 7 to 10 | 5 to 10 | 0 to 5                              |
| <b>Understanding</b> | <i>Average</i> | 9.5     | 8.6     | 1.0                                 |
|                      | <i>Range</i>   | 7 to 10 | 5 to 10 | 0 to 5                              |
| <b>Reading</b>       | <i>Average</i> | 9.1     | 7.8     | 1.5                                 |
|                      | <i>Range</i>   | 7 to 10 | 4 to 10 | 0 to 5                              |

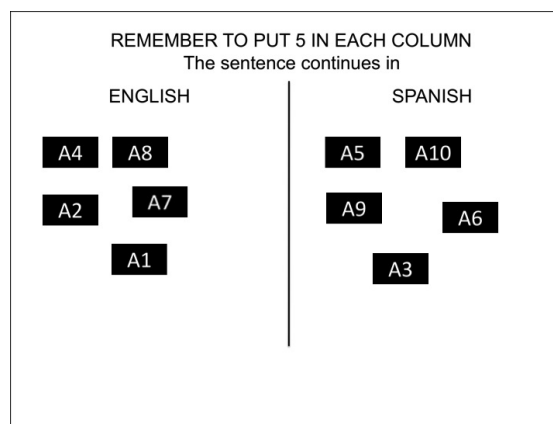
## Procedures

Listeners were presented with four PowerPoint slides using the Ladder and Free Classification paradigms (Clopper, 2008; A. Bradlow, Clopper, Smiljanic, & Walter, 2010). On each slide there were ten sound files displayed as black boxes labeled with letters and numbers. The sound files were either English utterances up to the discourse marker *like*, or Spanish utterances up to the discourse marker *like*; half of the sound files continued in the same language (monolingual) and half continued in the other language (code-switch). Listeners did not hear the continuation of the utterance beyond the word *like*. Listeners were asked to double-click on the sound files to listen to them, and then to sort all ten sound files into the two columns “ENGLISH” or “SPANISH” to mark what language the utterance continued in. Listeners were instructed that they must put five sound files in each column, thus labeling half of them as monolingual and half as code-switches. Listeners could listen to the sound files as many times as they liked and could change the sorting of the ten files until they were satisfied with the final sorting. The first slide was a slide with stimuli that began in English, whereas the second slide

began in Spanish. The third and fourth slides repeated this order, resulting in two English slides and two Spanish slides. An example of a slide with unsorted stimuli is presented in Figure 2.6; a slide with sorted stimuli is presented in Figure 2.7.



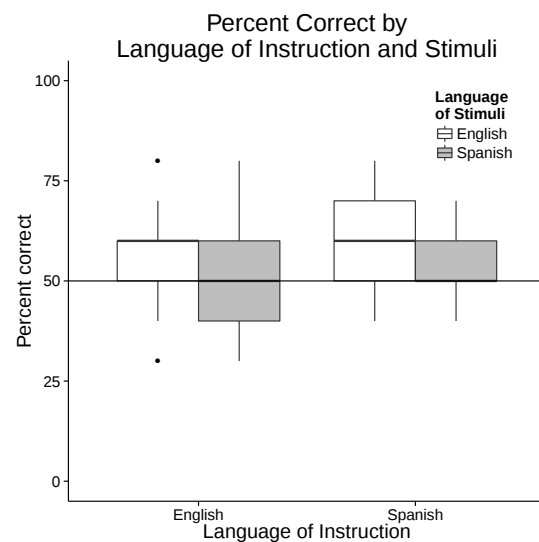
**Figure 2.6:** Perception experiment #2 example slide at the beginning of the experiment, with unsorted stimuli.



**Figure 2.7:** Perception experiment #2 example slide at the end of the experiment, with sorted stimuli.

Half of the listeners received instructions in English and half in Spanish. Listeners filled out the LEAP-Q in the language of instruction of the experiment before participating in the experiment. There were no significant differences between the two groups in regards to either L1 or dominant language.

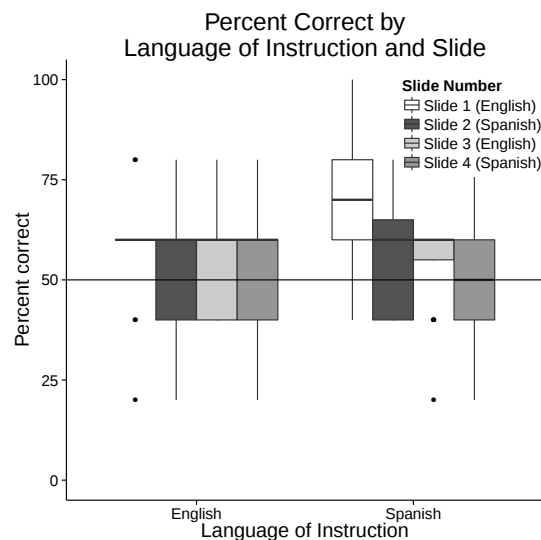
## 2.4.2 Results



**Figure 2.8:** Perception experiment #2 results by language of stimuli and language of instruction. Results are presented by language of stimuli and language of instruction. Chance is marked at 50%. The whiskers extend from the first or third quartile (Q1, Q3) to the largest value within 1.5 times the inter quartile range. Any dots outside of the whiskers represent outliers.

Initial tests were run to see if results differed by the language of the stimuli. Binomial tests were conducted within each language of stimuli for each language of instruction group with random chance set to 0.5 to see if listeners performed above chance on categorizing the sound files. Alpha was set to 0.05. Listeners who received instructions in English performed above chance on stimuli that began in English [ $p < 0.05$ ], but not for stimuli that began in Spanish. Listeners who received instructions in Spanish performed above chance for stimuli that began in English [ $p < 0.05$ ], but not for stimuli that began in Spanish. See Figure 2.8 for a summary of these results.

To test if the difference between languages was significant, a logistic mixed effects regression model was run. The dependent variable was correct or incorrect for a given stimulus. Language of instruction and slide language were included as fixed effects with contrast coding. Listener was included as a random intercept and a random slope



**Figure 2.9:** Perception experiment #2 results by slide, language of stimuli, and language of instruction. Results are presented by slide, language of stimuli, and language of instruction. Boxes in slide order of appearance. Chance is marked at 50%. The whiskers extend from the first or third quartile (Q1, Q3) to the largest value within 1.5 times the inter quartile range. Any dots outside of the whiskers represent outliers.

by language of slide. Stimulus was not included as a random effect due to convergence issues. This was the maximal uncorrelated random effects structure that converged. Note, context (monolingual or code-switching) was not included as a fixed effect as the nature of the experimental design was such that there would be no difference between those categories, as an error in one context necessarily led to an error in the other context. The two contexts are thus not independent due to the task, and including context as a fixed effect would violate model assumptions of independence. Significance was tested using model comparison. The main effect of language was significant, with listeners performing better on the English stimuli than the Spanish stimuli [ $\beta = -0.27$ ,  $SE = 0.11$ ,  $\chi^2(1) = 5.17$ ,  $p < 0.05$ ]. There was no effect of language of instruction and no significant interaction.

Since the experimental design not only required detection of switching within a given slide, but also between slides, a second analysis was conducted separated by

each slide to see if the switching back and forth between English and Spanish stimuli affected categorization of code-switches. To correct for multiple hypothesis testing the alpha was reduced to 0.025 using Bonferroni correction. The binomial test found that listeners who received instructions in English were trending above chance for Slide 1 (stimuli beginning in English) [ $p = 0.03$ ] and trending above chance for Slide 3 (stimuli beginning in English) [ $p = 0.06$ ], but were at chance for Slides 2 or 4 (stimuli beginning in Spanish). Listeners who received instructions in Spanish were significantly above chance for the first slide (stimuli beginning in English) [ $p < 0.025$ ] and trending above chance for Slide 2 (stimuli beginning in Spanish) [ $p = 0.03$ ], but there were no significant effects for Slides 3 or 4 (Slide 3: stimuli beginning in English; Slide 4: stimuli beginning in Spanish). See Figure 2.9 for a summary of these results.

To test if the difference between slides was significant, a logistic mixed effects regression model was run. Language of instruction and slide number (1 to 4) were included as fixed effects; language of instruction was coded with contrast coding and slide number was included as a numeric variable from 1 to 4. Listener was included as a random intercept and a random slope by slide number. Stimulus was included as a random intercept. This was the maximal uncorrelated random effects structure that converged. Significance was tested using model comparison. Language of instruction was significant, with listeners who received instructions in Spanish getting higher scores than those who received instructions in English [ $\beta = 0.82$ ,  $SE = 0.34$ ,  $\chi^2(1) = 5.43$ ,  $p < 0.025$ ]. Slide number not was significant.

### 2.4.3 Discussion

Overall, the results of the second perception study confirm those from the first perception study. Bilinguals are able to detect switches to some extent, however they are better at predicting switches from English to Spanish than Spanish to English. This can

be somewhat mitigated by language of instruction. When listeners received instructions in Spanish, they were more likely to be able to detect switches from Spanish to English than if they received instructions in English.

It should also be noted that for the listeners who received instructions in Spanish, skills deteriorated throughout the task, even though it was a very short task overall. Perhaps the switching made it harder to keep track of which sounds were out of place and thus cued a switch. Another possibility is that listeners simply became bored with the task. However, since the task took about 15 minutes this seems unlikely.

## 2.5 General Discussion

The present study sought to determine if degree of bilingual language activation affects phonetic production and perception in code-switching speech. Specifically, I tested if in code-switching contexts, the discourse marker *like* is produced phonetically intermediate to English *like* and Spanish *like* in monolingual contexts. Follow-up perception experiments tested if listeners could anticipate language switches, which could suggest that they are able to use phonetic cues to their advantage in speech perception.

The results of the production experiment found that speakers did produce intermediate phonetic productions in code-switching contexts both in regards to duration of the /laɪ/ and the formant values. Effects were not found for /k/ realization. There were no effects of the formant values of the target of the /l/ or the /aɪ/. However, effects were found in a more global sense for the entire /laɪ/ production. First, it was found that English and Spanish tokens of *like* are indeed different, both in terms of duration and formant structure. These results match predictions that Spanish diphthongs are produced with two full vowels while English diphthongs are produced with something closer to a vowel and a glide, resulting in Spanish tokens having longer durations. It is unclear at this

point if the longer duration is specifically tied to the /l/ or the diphthong (and furthermore, which part of the diphthong). Future work can try and more clearly pinpoint the locus of this effect. The duration results also explain the formant results, as the fuller vowel at the end of the diphthong for Spanish would result in a higher and more fronted offset for Spanish compared to English. However, this effect was not found when analyses were conducted at specific points in the /aɪ/.

Second, it was found that code-switching tokens of *like*, both English to Spanish and Spanish to English, did not directly map onto one language or the other, but instead were intermediate productions between each language. In regards to duration, code-switching tokens of *like* were significantly shorter than Spanish tokens of *like*, although not to the same extent as English tokens of *like*. The analysis of formant structure found code-switching tokens to be different from both English and Spanish tokens. Consistent interactions showed that code-switching tokens did not directly map onto the language preceding the token, and instead changed which monolingual realization it most closely matched throughout the production.

These results have implications for models of bilingual language activation, in that they show the degree of activation can be affected by context. As discussed, studies have shown that it takes bilinguals longer to switch from one language to the next in picture naming (Meuter & Allport, 1999). In this study it was found that phonetic realization of a lexical item can be affected by switching, not just reaction times for retrieval. Past studies on the phonetics of code-switching examining VOT have been limited by the fact that a given lexical item was tagged to a specific language. The discourse marker *like* is a useful testing ground for what happens when a word is not tagged to a specific language, as for this population it is a lexical item in both English and Spanish. In code-switching then, it can be argued that *like* is not specific to either language, or potentially belongs to both simultaneously. Indeed the phonetic analysis of the formant values did show a

gradient switch from the phonetics of one language to the other throughout the switch, as well as demonstrating that the tokens never fully mapped on to either language. The fact that productions show properties of both languages can be taken as evidence that there are contexts when bilinguals have both languages heavily activated at the same time.

The follow-up perception experiments tested if this increased activation of both languages can be exploited in speech perception. By using code-switching stimuli, listeners were tested on their ability anticipate language switches, potentially due to the phonetic information of an utterance. In the first experiment, results showed that listeners have a bias to say a switch has not occurred. However, when they do label a stimulus as a code-switching they are generally correct. In the second experiment, when listeners were required to equally sort stimuli as code-switching or monolingual, they were found to be above chance at predicting switches in some language contexts. For both of these experiments, the direction of the switch did matter, such that listeners could only predict switches from English to Spanish but not Spanish to English. This effect can be somewhat mitigated by having listeners be in a Spanish mode.

This asymmetrical effect of predicting switches matches past results on reaction times of picture naming (Meuter & Allport, 1999). Bilinguals are slower at switching from their L2 into their L1 than from their L1 into their L2. This was proposed to be because it takes more energy to suppress the L1 and thus more time later to reactivate it and switch into it. Note that for these studies generally the L1 is the dominant language and the L2 is the non-dominant language. This explanation could apply to the results of the present study. While for most listeners Spanish is the L1, it is now the non-dominant language. Listeners have more trouble predicting switches from their non-dominant language (Spanish) into their dominant language (English), thus mirroring the reaction time results for picture naming. Having both languages activated to some degree may allow listeners to detect phonetic attributes of the language not in use in an utterance,

and thus anticipate a switch. However, if it takes more energy to suppress the dominant language, then listeners may have it activated to a lower degree at the beginning of the utterance and not be able to detect the phonetic attributes of the language following the switch. The fact that this can be somewhat mitigated by conducting the experiment in the non-dominant language warrants additional study, both in future phonetic studies of language switching and future picture naming studies of the previously attested asymmetrical switching cost effect. Future studies on bilingual language activation should take into account the results of the present study by attempting to directly model degree of cross-language activation given the effects of context and direction of the switch.

## 2.6 Conclusion

Bilingual language activation was examined with the production and perception of the discourse marker *like* in Spanish-English code-switching. Regarding speech production, it was found that early Spanish-English bilinguals do produce intermediate phonetic realizations of the discourse marker *like* in Spanish-English code-switching. In terms of speech perception, it was found that listeners are able to anticipate language switches, although this is largely limited to switches from their dominant to their non-dominant language. One possible explanation for this is that they are using the gradient phonetic information in speech production to anticipate these switches. Future work on bilingual language activation should incorporate results from phonetic studies in predicting how degree of language activation can vary according to language context.

## Chapter 3

# Code-switching in Scripted Speech

### Abstract

Past research has shown that bilinguals produce intermediate phonetic categories in code-switching contexts. However, further understanding of code-switching phonetics is limited by previous researchers' focus on one phonetic dimension (VOT), and to differences in populations. In particular, language dominance versus order of acquisition have been difficult to tease apart. The current study extends this research by investigating three phonetic features: 1) /l/-clarity in different syllabic positions, 2) lenition of word-initial voiced stops to fricatives, and 3) VOT of word-initial voiceless stops. In addition to testing multiple phonetic features, bilinguals whose L1 was Spanish but who are now English-dominant were recruited, to test for effects of language dominance versus order of acquisition. Results found a significant effect of code-switching for /l/-clarity and VOT. For /l/-clarity, while in English effects were found in both pre- and post-switch position, in Spanish the effect was limited to post-switch position. For VOT, effects were only found for English pre-switch position. No effects were found regarding code-switching for lenition of voiced stops to fricatives. These results demonstrate that code-switching does in fact result in intermediate phonetic categories, and that the range of effects

can vary by specific phonetic features. Additionally, the results support the theory that language dominance is a better indicator than order of acquisition in predicting degree of cross-language activation for this population.

### 3.1 Introduction

The phonetics of code-switching has begun to receive greater interest and attention in the bilingualism literature, with most recent work focusing on voice onset time (VOT) as the variable of interest. VOT, particularly of word-initial voiceless stops with initial stress, has been a useful phonetic parameter, as many languages contrast pairs of sounds on this dimension. For example, both English and Spanish have /b, d, g/ and /p, t, k/ word initially, but while English contrasts short-lag VOT ([p, t, k]) with long-lag VOT ([p<sup>h</sup>, t<sup>h</sup>, k<sup>h</sup>]), Spanish contrasts negative VOT (or pre-voicing) ([b, d, g]) with short-lag VOT ([p, t, k]) (Lisker & Abramson, 1964). Several phonetic studies of code-switching have compared VOT productions of language pairings like English and Spanish in monolingual versus code-switching contexts to test for convergence of phonetic categories (Grosjean & Miller, 1994; Bullock et al., 2006; Antoniou et al., 2011; López, 2012; D. J. Olson, 2013; Balukas & Koops, 2015; Piccinini & Arvaniti, 2015; Fricke et al., 2015). While studies of VOT have been useful, they have produced mixed results, with some finding no effect of code-switching (Grosjean & Miller, 1994; López, 2012), some finding effects limited to only one of the two languages (Antoniou et al., 2011; D. J. Olson, 2013; Balukas & Koops, 2015), and finally some finding effects for both languages but with one language converging and one diverging (Bullock et al., 2006; Piccinini & Arvaniti, 2015). ‘Convergence’ here refers to the moving together of phonetic categories, such that they are closer but not completely overlapping.

Work on other phonetic variables has been rather limited. It would be useful to

look at phonetic variables beyond VOT, as obviously, such studies only deal with one phonetic variable. However, there is reason to believe that other types of variables will not behave the same way, for example, potentially due to language-specific allophonic variation. There has been some additional work on the phonetics of code-switching in regards to prosody (D. Olson & Ortega-Llebaria, 2010; Piccinini & Garellek, 2014). In addition to VOT, Fricke et al. (2015) also examined at speech rate, and found slower speech rate in code-switching utterances relative to monolingual utterances. In Chapter 2 new segmental variables were examined in the discourse marker *like*, /l/-quality, vowel quality, and final /k/ realization. Results in both cases showed evidence of intermediate phonetic productions in code-switching contexts relative to monolingual contexts. Here intermediate phonetic productions refers to variables having phonetic realizations somewhere in between both languages, i.e. a form of convergence.

While the results of Chapter 2 are useful in expanding our knowledge of the phonetics of code-switching beyond one phonetic feature (VOT), it suffers from certain drawbacks in further extending the results to code-switching in a more global sense. One, the result of intermediate phonetic productions is limited to one specific word, the discourse marker *like*. It is unclear if this is a general effect that would apply to any word beginning with /laɪ/. Also, the word *like* was a very specific case, existing in both English and Spanish and thus not clearly tagged to either language in the code-switching contexts examined. It remains to be seen if intermediate phonetic productions will still be found when words in code-switching contexts are tagged to a specific language, for example the English word “life”. Two, the data came from spontaneous speech. While this does pose many benefits, including speech being produced as it would be in a more natural environment, it also means the data is less controlled for other potential variables that could affect productions (e.g. prosody). Finally, while new phonetic features have been analyzed, it still leaves several phonetic differences between English and Spanish to

explore.

In this chapter, three phonetic variables will be examined: 1) /l/-clarity, 2) lenition of word-initial voiced stops to fricatives, and 3) VOT of word-initial voiceless stops. This will allow several phonetic features to be examined in a single, controlled experiment. Additionally, these specific variables can be useful to further explore allophonic variation in code-switching contexts, as English has an allophonic alternation for /l/-clarity and Spanish for lenition of stops to fricatives. These variables can also be used to see how language dominance and order of acquisition interact with the direction of a switch. This study will both add to the literature in a descriptive nature, by increasing the number of phonetic variables investigated in code-switching speech, and in a theoretical nature, by adding to our knowledge of bilingualism more generally. Each variable and predictions made for its phonetic behavior are discussed in turn.

English and Spanish differ in how /l/ is realized. English tends to have a “darker” or more velarized /l/ (closer to [ɫ]), while the Spanish /l/ is clearer (closer to [l]) (Huffman, 1997; Simonet, 2010). Furthermore, /l/ exhibits allophonic variation in English depending on its location within the syllable, as discussed by Barlow et al. (2012). English has lighter instantiations of /l/ in onset compared to coda position: for example the /l/ in “lake” /leɪk/ is lighter than the /l/ in “kale” /keɪl/. Spanish does not have this allophonic variation, such that /l/ in both the words “*lago*” (“lake”) and “*gel*” (“gel”) are equally light (Simonet, 2010). As a result, in a monolingual context, one would predict an interaction of language and phonological position, with English having a significant difference in /l/-clarity between the two positions, but Spanish not. This has implications for code-switching realizations as well. If code-switching represents a time when both languages are more heavily activated, there should be a general lightening of English /l/ and a general darkening of Spanish /l/. There should also be a reduction in the effect of phonological position for English, as both onset and coda /l/ lighten due to stronger

activation of Spanish. The allophonic difference may not go away entirely, but it could decrease due to the general lightening of /l/. This would be an effect specific to English, as Spanish does not show the effect of position in a monolingual context. These predicted effects are summarized in Table 3.1.

On the other hand, Spanish has lenition of stops /b, d, g/ to fricatives [β, ð, ɣ] following a vowel or a heterorganic consonant (as strengthening see, Bakovic, 1994). For example, the word “*dato*” (“date”) in isolation is produced as [d̪ato], (with /d̪/ being realized as a voiced stop). But when preceded by a vowel (e.g. “*ese*” “that”), /d̪/ is realized as a lenited fricative or approximant (“[ð]-*ato*” or approximant “[ɰ]-*ato*”) (Bakovic, 1994). English does not have this pattern. One might predict then that in code-switching contexts, the frequency of lenition in Spanish would decrease due to effects from English. A general increase in lenition may also be predicted for English, but possibly to a lesser degree since word-initial /b, d, g/ in English are often voiceless, and may thus be less likely to lenite to voiced fricatives. This is similar to the /l/-clarity variable, where a decrease in positional effects is only predicted for English. Note, this variable is also interesting from a descriptive perspective, as (with the exception of the /k/ analysis in Chapter 2) all analyses on the phonetics of code-switching have been conducted on continuous variables, while this will be on a categorical variable, stop versus fricative. A summary of the predictions for voiced stop lenition can be found in Table 3.2.

The final phonetic variable under investigation is VOT of word-initial voiceless stops. This analysis will function more as another data point for past literature. This study adds to the literature on VOT in code-switching contexts by focusing on a specific population of bilinguals (predominantly L1 Spanish, English dominant). It also can be used as a point of comparison to Piccinini and Arvaniti (2015), who examined the effect of code-switching on VOT of word-initial voiceless stops in the same population

(same general demographics, at the same university) but in spontaneous speech. Additionally, the VOT measure can be compared to the /l/-clarity analysis. Both measures are continuous, but while /l/-clarity has the allophonic effect of position in English, VOT production of voiceless stops in word-initial position does not vary allophonically in either language. The effect of having both languages more heavily activated should equally affect English and Spanish VOT productions, though in different directions. English VOT is predicted to get shorter (more Spanish-like), while Spanish VOT is predicted to get longer (more English-like). A summary of the predictions for voiced stop lenition can be found in Table 3.3. Note, as previously discussed, this prediction only matches part of the literature, which has found a range of results. The current study then focuses on one English-specific allophonic variable (/l/-clarity in different positions), one Spanish-specific allophonic variable (lenition of stops to fricatives), and one language-neutral variable (VOT of word-initial voiceless stops).

Two additional effects could interact to produce language-specific results: 1) language dominance versus order of acquisition, and 2) the direction of the switch (English to Spanish versus Spanish to English). In picture naming switching studies, the dominant language shows a greater cost than the non-dominant language (Meuter & Allport, 1999). Specifically in switch trials, where speakers change the language they use to name a picture, they are slower when they switch from their non-dominant to their dominant language. However, on non-switch trials, they are faster at naming pictures in their dominant language. The argument is that it takes more energy to suppress the dominant language, and thus more time to switch back into it (Meuter & Allport, 1999). This result has been shown to be affected by other factors, such as how balanced the bilinguals are (Costa & Santesteban, 2004; Schwieter, 2008), or whether switching is voluntary or not (Gollan & Ferreira, 2009). These results suggest that, phonetically, the non-dominant language may have a greater effect on productions in the dominant

language than vice versa.

However, one problem with many of these studies is that dominant language and L1 are often the same. So it is not clear whether it takes more energy to suppress the dominant language, or if it takes more energy to suppress the L1. The population under investigation in this dissertation offers an interesting opportunity to disentangle these two effects, as generally this population's L1 is Spanish, but their dominant language is English. If greater influences of Spanish on English are found (than English influence on Spanish), this would suggest that language dominance plays a larger role in language organization and access than order of acquisition. English (as the dominant language) takes more energy to suppress, and thus can be affected by Spanish. However, if the reverse effect is found (more influence of English on Spanish), this would demonstrate that a speaker's L1 has lasting effects on how they produce language, even if their L1 is no longer their dominant language. In this scenario, Spanish (as the L1) takes more energy to suppress, and thus can be affected by English. The perception results from Chapter 2 suggest language dominance is more important, as listeners had more trouble predicting switches back into their dominant language (Spanish to English) than into their non-dominant language (English to Spanish).

The above discussion refers to global, entire utterance, effects of code-switching, but language dominance may play a role in where specifically in the utterance effects are found, in regards to the direction of the switch. In Chapter 2, evidence was given that there are phonetic cues to a code-switch before the switch occurs. However, I also predict that there are carryover effects after the switch, due to a delay in deactivating the pre-switch language, and in fully activating the post-switch language. In Bullock et al. (2006)'s study of VOT in code-switching, the authors looked at tokens in three positions, pre-switch (a few words before the switch), switch (the word directly after the switch), and post-switch (a few words after the switch). For example, in the sentence "*Todos*

*mis amigos* talked Spanish as kids”, the /t/ “*todos*” was the pre-switch token, the /t/ in “talked” the switch token, and the /k/ in “kids” the post-switch token. They found effects at the pre-switch and switch positions relative to monolingual productions, but not at the post-switch position. This suggests that there can be both anticipatory and carryover effects, but that the carryover effects are limited in how far they extend. This perhaps could be due to segmental coarticulation effects, which have found more right-to-left coarticulation than left-to-right coarticulation (Sharf & Ohde, 1981). This could also be of interest for the /l/-clarity analysis, as in pre-switch position a coda-/l/ is closer to the switch than an onset-/l/, while in post-switch position it is the reverse. For example, in the sentence “I call *un hombre*” (“I call a man”) the /l/ in “call” is closer to the code-switch than the /l/ in “lock” in the sentence “I lock *una puerta*” (“I lock a door”); conversely, the /l/ in “lock” is closer to the code-switch in the sentence “*Yo tengo* a lock” (“I have a lock”) than the /l/ in “call” in the sentence “*Yo hago* a call” (“I make a call”).

I predict that in code-switching utterances there will be evidence of increased activation of both languages as seen by the presence of intermediate phonetic productions relative to productions in a monolingual utterance. This is illustrated in Figures 3.1a and 3.1c. In the first part of the monolingual English utterance, “The woman is”, activation of Spanish is very low, but in that same portion of the code-switching utterance, Spanish activation increases. This increase results in greater cross-language activation as manifested in the phonetic productions. In addition to these global effects of code-switching (monolingual versus code-switching utterances) there will also be differences between the two type of code-switching utterances due to the effect of language dominance. In pre-switch position, I predict effects of Spanish on English but not English on Spanish. Take for example the first half of Figures 3.1c and 3.1d, the pre-switch area. In the English-to-Spanish switch, Spanish is activated very quickly since it is the non-dominant language and took less energy to initially suppress. As a result there should be an effect

of Spanish on English productions. In the Spanish-to-English switch, English is activated more slowly, because it is the dominant language and should take more energy to suppress initially; as a result English does not have a very large effect on Spanish pre-switch productions. In post-switch position effects of English on Spanish and Spanish on English are predicted. In both Figures 3.1c and 3.1d, it takes a while for the pre-switch language to be activated. This results in carryover effects onto the post-switch productions. See Tables 3.1, 3.2, 3.3 for predictions based on the direction of the switch in addition to general predictions.

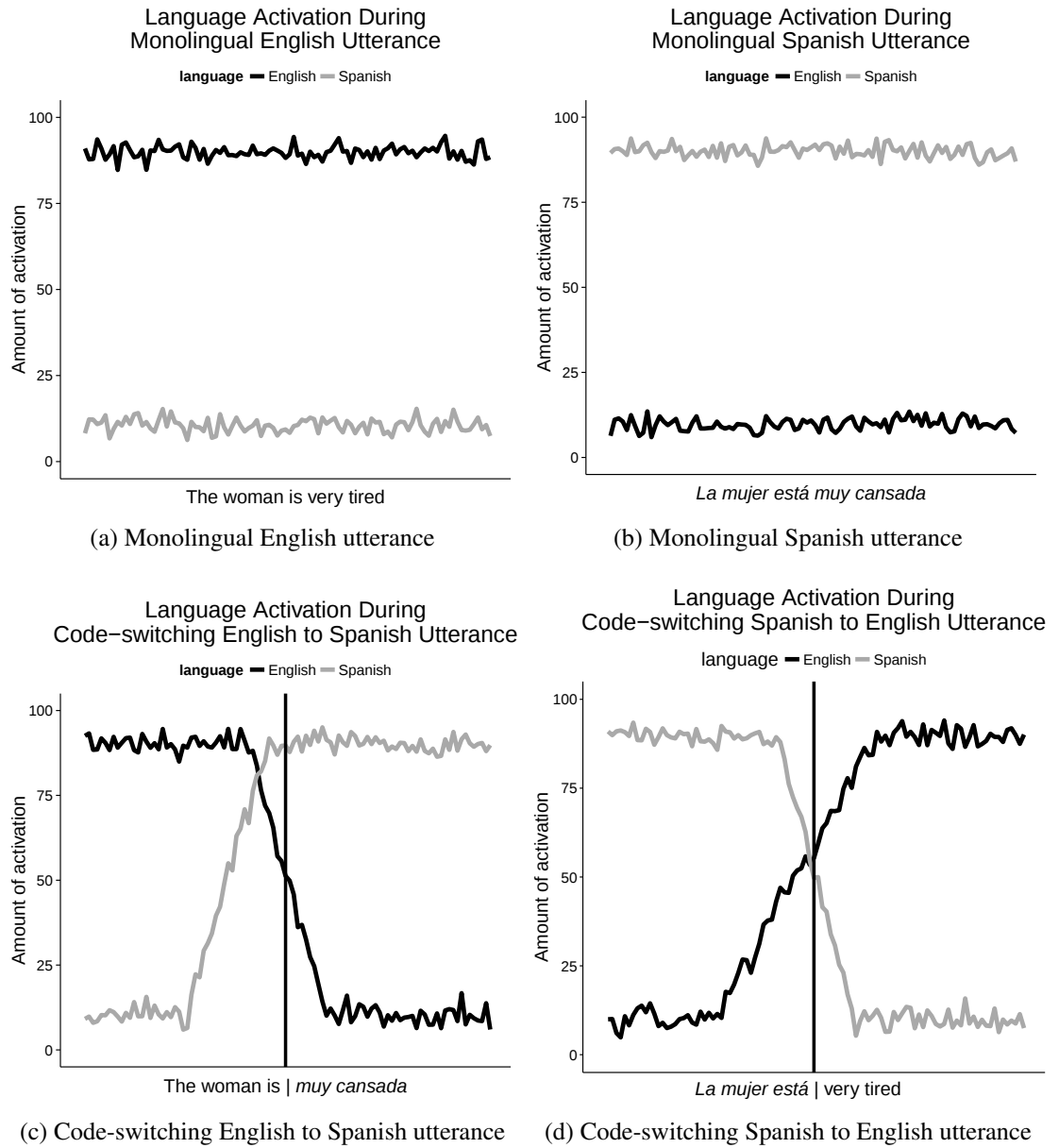
**Table 3.1:** Predictions for /l/-clarity. A summary of the predictions for /l/-clarity in onset and coda position, both in general and for code-switching stimuli separated by the direction of the switch.

| <b>GENERAL<br/>EFFECTS</b> | <b>Monolingual<br/>(baseline)</b> |             | <b>Code-switching<br/>(effect of CS)</b> |             |
|----------------------------|-----------------------------------|-------------|------------------------------------------|-------------|
|                            | <i>Onset</i>                      | <i>Coda</i> | <i>Onset</i>                             | <i>Coda</i> |
| <i>English</i>             | dark /l/                          | darkest /l/ | lightening                               | lightening  |
| <i>Spanish</i>             | light /l/                         | light /l/   | darkening                                | darkening   |

| <b>CS DIRECTIONAL<br/>EFFECTS</b> | <b>English to Spanish</b> |             | <b>Spanish to English</b> |             |
|-----------------------------------|---------------------------|-------------|---------------------------|-------------|
|                                   | <i>Onset</i>              | <i>Coda</i> | <i>Onset</i>              | <i>Coda</i> |
| <i>English</i>                    | lightening                | lightening  | lightening                | lightening  |
| <i>Spanish</i>                    | darkening                 | darkening   | –                         | –           |

Thus, the current study will examine three phonetic features: 1) /l/-clarity in onset and coda position, 2) lenition of word-initial voiced stops to fricatives, and 3) VOT of word-initial voiceless stops. By studying these three phonetic variables we will be able to expand our knowledge of the phonetics of code-switching beyond just one phonetic feature, while also testing the role of language dominance versus order of acquisition in bilingual language organization. Global effects of code-switching are predicted, with



**Figure 3.1:** Language activation in different utterance types. Activation levels of English and Spanish in different utterance types. In (a) and (b), there is little phonetic influence of the language not in use because activation is low. In (c) and (d), the language to be switched into increases in activation during the switch, thus influencing the language still in use. The speed of the increase in activation is larger in (c) than (d) since Spanish is the non-dominant language and took less energy to initially suppress.

**Table 3.2:** Predictions for lenition of word-initial voiced stops. A summary of the predictions for lenition of word-initial voiced stops, both in general and for code-switching stimuli separated by the direction of the switch.

| <b>GENERAL EFFECTS</b> | <b>Monolingual (baseline)</b> | <b>Code-switching (effect of CS)</b> |
|------------------------|-------------------------------|--------------------------------------|
| <i>English</i>         | stop                          | more lenition                        |
| <i>Spanish</i>         | fricative                     | less lenition                        |

| <b>CS DIRECTIONAL EFFECTS</b> | <b>English to Spanish</b> | <b>Spanish to English</b> |
|-------------------------------|---------------------------|---------------------------|
| <i>English</i>                | more lenition             | more lenition             |
| <i>Spanish</i>                | less lenition             | –                         |

**Table 3.3:** Predictions for VOT of word-initial voiceless stops. A summary of the predictions for VOT of word-initial voiceless stops, both in general and for code-switching stimuli separated by the direction of the switch.

| <b>GENERAL EFFECTS</b> | <b>Monolingual (baseline)</b> | <b>Code-switching (effect of CS)</b> |
|------------------------|-------------------------------|--------------------------------------|
| <i>English</i>         | long-lag VOT                  | shortening                           |
| <i>Spanish</i>         | short-lag VOT                 | lengthening                          |

| <b>CS DIRECTIONAL EFFECTS</b> | <b>English to Spanish</b> | <b>Spanish to English</b> |
|-------------------------------|---------------------------|---------------------------|
| <i>English</i>                | shortening                | shortening                |
| <i>Spanish</i>                | lengthening               | –                         |

code-switching productions differing from monolingual productions. This would be found in the form of lighter English tokens of /l/ and darker Spanish tokens of /l/, more lenition of stops to fricatives for English and less for Spanish, and shorter VOTs for English but longer for Spanish. However, the effect of position on /l/-clarity will be greater in English than Spanish since it is an allophonic alternation in English, and the lenition of stops to fricatives will be greater in Spanish than English since it is an allophonic alternation in Spanish. Direction of the switch is also predicted to vary for each

language, as it interacts with language dominance. Code-switching effects in English are expected to be equally large in both English-to-Spanish and Spanish-to-English switches. Conversely, code-switching effects in Spanish are expected to be larger in English-to-Spanish switches. If these predictions are verified, it will demonstrate that language dominance is more important than order of acquisition in how early, high-proficiency bilinguals organize and access their two languages in speech production.

## 3.2 Method

### 3.2.1 Materials

Materials included sentences in four contexts: 1) monolingual English (ML-E), 2) monolingual Spanish (ML-S), 3) code-switching English to Spanish (CS-ES), and 4) code-switching Spanish to English (CS-SE). Each sentence included target words chosen to elicit specific sounds in English and Spanish. The sounds were: word-initial /l/ and word-final /l/ to examine /l/-clarity in different positions, word-initial voiced stops (/b, d, g/) to examine lenition of stops to fricatives, and word-initial voiceless stops (/p, t, k/) to examine VOT differences. Words always bore stress on the syllable that included the target sound; e.g. in the word “peaches” stress is on the first syllable /pi/ which includes the target sound /p/. As a result, all words were disyllabic, with the exception of English /l/-final words which were monosyllabic, e.g. the word “meal” which is monosyllabic and ends in an /l/. The vowel following the target sound (or in the case of /l/-final words the vowel proceeding) was /i, a/ for English words and /i, a/ for Spanish words, e.g. for English “peaches” and “pocket” and for Spanish “*pinzas*” and “*pato*”. While English and Spanish do not have exactly the same vowel inventories, these two vowels were chosen because they are close in quality across the two languages; they also occur frequently in both languages. Words always began (or ended, for /l/-final words) with CVC structure,

glides were not counted as consonants; e.g. the English word “kiwi” was not included as the second consonant /w/ is a glide. Attempts were made to choose high-frequency words. Frequencies for both English and Spanish words were obtained from the CLEARPOND Database (Marian, Bartolotti, Chabal, & Shook, 2012). There were two target words per vowel, for a total of 64 words, or 32 words per language ( $8 \text{ target sounds} \times 2 \text{ language} \times 2 \text{ vowels} \times 2 \text{ tokens} = 64$ ). In some cases it was not possible to fully complete the paradigm. For example, there are no well-known English words beginning with /gi/, so instead of having two /gi/-initial words and two /ga/-initial words, there were instead four English /ga/-initial words. Pronunciations are based on typical Californian English and Mexican Spanish productions. It was also difficult to find Spanish /di/ words that met the requirements and could be easily used in a semantically meaningful sentence. As there were also no further useful /da/ words available, /de/ was used instead. As a result the number of vowels was not perfectly matched. The final totals were: English /i/ = 14, English /a/ = 18, Spanish /i/ = 14, Spanish /a/ = 16, Spanish /e/ = 2. None of the words were English-Spanish cognates, meaning a word and its translation equivalent could not have the same first two sounds. For English words, the vowels could not be the same as the closest Spanish vowel. For example, I excluded cases where a Spanish word began with /pi/, such as the Spanish word “*pilar*”, and the English translation equivalent began with /pɪ/ (“pillar”). All words were reviewed by two Spanish-English bilinguals of Mexican-American heritage to ensure that they were commonly used words in their dialects of Californian English and Mexican Spanish.

Each test sentence contained two target words, e.g. “peaches” and “locker”. To control as much as possible for potential coarticulatory effects, /l/-initial words and /p/-initial words were paired together, /l/-final words and /b/-initial words were paired together, /t/-initial and /g/-initial words were paired together, and /k/-initial words and /d/-initial words were paired together. This was done for two reasons: (a) having velar

test words in the same sentences as /l/ test words could affect /l/-darkness, and (b) having words with the same place of articulation could affect voicing of either category. I did not control for the place of articulation of other words in the sentence, due to difficulties in the construction of semantically meaning sentences. Each target word appeared four times: once as the first target word in a monolingual sentence, once as the second target word in a monolingual sentence, once as the first target word in a code-switching sentence, and once as the second target word in a code-switching sentence. As a result, each word appeared in three contexts, twice in the appropriate monolingual context and once in each of the code-switching contexts (CS-ES and CS-SE). An example with the English target word “peaches” is presented in (1) - (4).

1. ML-E – Target Word 1: The peaches in the bag fill the locker completely.
2. ML-E – Target Word 2: The loket from her grandmother was with the peaches in a bowl.
3. CS-ES – Target Word 1: The peaches I bought | *están al lado del lápiz amarillo.*

GLOSS: The peaches I bought | *are next to the yellow pencil.*

4. CS-SE – Target Word 2: *Las latas preservaron* | the ripe peaches for winter.

GLOSS: *The cans preserved* | the ripe peaches for winter.

The two target words (pre- and post-switch) never appeared together in more than one sentence, and did not have the same vowel following the target sound, as much as possible based on the final breakdown of vowels used (e.g. “peaches” and “leases”, both /i/ words, were never paired together) . For example in (1) “peaches” was paired with “locker”, in (2) it was paired with “loket”, in (3) it was paired with “*lápiz*”, and in (4) it was paired with “*latas*”. This produced 128 unique test sentences, 32 per context.

Sentence structure was generally “The TARGET\_WORD1 PREPOSITIONAL \_PHRASE VERB the TARGET\_WORD2 ADVERB / ADJECTIVE (for Spanish)”. Deviations from this pattern occurred as necessary to construct semantically meaningful sentences. The target words were never the first or final words of the sentence. Sentences were always at least 10 syllables long. The number of syllables was held as constant as possible to control for prosody: average number of syllables ML-E = 14.0 (s.d. 1.3), ML-S = 14.8 (s.d. 2.4), CS-ES = 14.8 (s.d. 1.9), CS-SE = 14.6 (s.d. 2.0). Code-switches always occurred in between the two target words, counterbalanced for either being pre-verbal or post-verbal switches, such that one target word was in English and one in Spanish. Sentences were counterbalanced for being in the present or past tense. For additional syllable count information about the code-switching stimuli, see Table 3.4.

**Table 3.4:** Code-switching stimuli syllable information. Number of syllables in code-switching stimuli, separated by pre- and post-verbal switches.

|                    |                 | <b>Target Word 1<br/>to CS</b> | <b>CS to<br/>Target Word 2</b> | <b>Pre-switch</b> | <b>Post-switch</b> |
|--------------------|-----------------|--------------------------------|--------------------------------|-------------------|--------------------|
| <b>Pre-verbal</b>  | <i>Avg.</i>     | 3.4                            | 3.8                            | 6.5               | 8.7                |
|                    | <i>St. Dev.</i> | 1.0                            | 1.6                            | 1.1               | 1.7                |
| <b>Post-verbal</b> | <i>Avg.</i>     | 3.6                            | 2.9                            | 6.6               | 7.6                |
|                    | <i>St. Dev.</i> | 1.5                            | 1.5                            | 3.1               | 5.0                |

### 3.2.2 Speakers

A total of 37 early Spanish-English bilinguals of Mexican-American heritage were original recorded. Speakers who did not meet the disfluency requirement were excluded (13 speakers), coming a final count of 24 speakers, 19 female and 5 male. Of the final 24 speakers included, speakers’ average age was 19.9 years ranging from 18 to 26 years old. All were undergraduates at UCSD who participated in the experiment

for course credit. All were required to have been exposed to both English and Spanish before the age of six, so that they fit the definition of an early bilingual. Proficiency and dominance were assessed by administering the Multilingual Naming Test (MINT; Gollan, Weissberger, Runnqvist, Montoya, & Cera, 2012), as well as a modified version of the Language Experience and Proficiency Questionnaire (LEAP-Q; Marian et al., 2007), and finally the Bilingual Dominance Scale (Dunn & Fox Tree, 2009).

When asked if English was their first or second language, 14 said it was their first and 10 their second; when asked if Spanish was their first or second language 18 said it was their first and six their second; speakers were allowed to say both languages were their first language. Regarding dominant language, 13 speakers reported English as their dominant language, one Spanish as their dominant language, and 10 said they were equally proficient in both. All speakers marked Hispanic as their ethnicity. None reported any speaking or hearing disorders. Ages of acquisition and current exposure are reported in Table 3.5. MINT and self-reported proficiency measures are reported in Table 3.6. Regarding the Bilingual Dominance Scale, the average score was 13.7 (s.d. 5.6); this suggests that speakers were on average English dominant.

**Table 3.5:** Speakers' ages of acquisition and current exposure. Language profiles of speakers, including average age of acquisition and current exposure to both English and Spanish. All speakers were exposed to English before age 6 even if they did not fully "acquire" it by that age. Any remaining percentage in current exposure was a language other than English or Spanish.

|                                              |                | English    | Spanish   |
|----------------------------------------------|----------------|------------|-----------|
| <b>Age acquired (years)</b>                  | <i>Average</i> | 3.3        | 1.3       |
|                                              | <i>Range</i>   | 0 to 10    | 0 to 5    |
| <b>Current exposure (percentage of time)</b> | <i>Average</i> | 70.3%      | 28.8%     |
|                                              | <i>Range</i>   | 10% to 95% | 5% to 95% |

**Table 3.6:** Speakers' proficiency scores. Speakers' MINT scores and average self-reported proficiency in speaking, understanding, and reading in English and Spanish, based on questions in the LEAP-Q. For the MINT scores are for percentage correct of uncued responses. For the LEAP-Q measures, scores are out of 10. Note, giving a high score for one language did not preclude giving a high score for another language. This is evident from the column showing the absolute value of the difference in ratings for the two languages; generally the difference is only about 1 for the self proficiency ratings.

|                      |                | English     | Spanish    | English-Spanish<br>(absolute value) |
|----------------------|----------------|-------------|------------|-------------------------------------|
| <b>MINT</b>          | <i>Average</i> | 90.2%       | 71.9%      | 19.1%                               |
|                      | <i>Range</i>   | 81% to 100% | 51% to 94% | 0% to 44%                           |
| <b>Speaking</b>      | <i>Average</i> | 9.4         | 8.2        | 1.6                                 |
|                      | <i>Range</i>   | 7 to 10     | 5 to 10    | 0 to 5                              |
| <b>Understanding</b> | <i>Average</i> | 9.6         | 9.3        | 0.5                                 |
|                      | <i>Range</i>   | 7 to 10     | 7 to 10    | 0 to 3                              |
| <b>Reading</b>       | <i>Average</i> | 9.5         | 8.4        | 1.4                                 |
|                      | <i>Range</i>   | 7 to 10     | 5 to 10    | 0 to 4                              |

### 3.2.3 Procedure

Speakers first were administered the Multilingual Naming Test (MINT; Gollan et al., 2012) to assess their language proficiency. I counterbalanced whether the English or Spanish portion of the MINT was administered first. Speakers then did the experiment. The four sentence lists were blocked such that speakers saw only one type of sentences at a time (e.g. only ML-E followed by only ML-S); additionally, speakers were always given the two monolingual contexts followed by the two code-switching contexts, or vice versa. Which set came first was counterbalanced, and within each set which list was presented first coming to a total of eight possible orderings. See Table 3.7 for summary.

Speakers were given the first list of sentences and the opportunity to read over the sentences and ask clarification questions before beginning the experiment. Once they were comfortable with the sentences, the experimenter left them in the sound booth alone. Sentences were presented on a computer screen using the program PsychoPy v1.8

**Table 3.7:** Ordering of eight conditions for experiment. Orderings separated into monolingual and code-switching blocks and within block by language specific lists.

| <b>Ordering</b> | <b>Block 1</b> |               | <b>Block 2</b> |               |
|-----------------|----------------|---------------|----------------|---------------|
|                 | <i>List 1</i>  | <i>List 2</i> | <i>List 1</i>  | <i>List 2</i> |
| 1               | ML-E           | ML-S          | CS-ES          | CS-SE         |
| 2               | ML-E           | ML-S          | CS-SE          | CS-ES         |
| 3               | ML-S           | ML-E          | CS-ES          | CS-SE         |
| 4               | ML-S           | ML-E          | CS-SE          | CS-ES         |
| 5               | CS-ES          | CS-SE         | ML-E           | ML-S          |
| 6               | CS-ES          | CS-SE         | ML-S           | ML-E          |
| 7               | CS-SE          | CS-ES         | ML-E           | ML-S          |
| 8               | CS-SE          | CS-ES         | ML-S           | ML-E          |

(Peirce, 2007). The experiment was self-paced. Each sentence was presented twice, but in a block design such that the speaker did not see a sentence for a second time until they had seen all sentences at least once. After completing the first list, the speaker retrieved the experimenter, was familiarized with the second list, and then followed the same procedure to record the second list of sentences. This was repeated for the other two lists of sentences. This resulted in a total of 256 test sentences (64 per context). Regarding specific sounds, each sound was produced 64 times (16 per context), with the exception of /t/ in monolingual Spanish sentences, as an error was found after participant recruitment started where “*copa*” had been used instead of “*taza*” for one of the sentences.

After reading all four lists, speakers completed a language background questionnaire. The language background questionnaire included an abbreviated version of the Language Experience and Proficiency Questionnaire (LEAP-Q; Marian et al., 2007) and the Bilingual Dominance Scale (Dunn & Fox Tree, 2009). With the exception of the Spanish portion of the MINT, the entire experiment was carried out in English.

### 3.2.4 Annotation and Measurements

Before beginning segmentation, sentences were coded for presence of disfluencies. Within-language pauses of 150 ms or more were categorized as disfluencies. At code-switching points, pauses of 300 ms or more were categorized as disfluencies, following Piccinini and Arvaniti (2015). A longer pause was allowed for code-switches as it was anticipated that even very fluent code-switchers may have a slight delay at code-switching points. Fricke et al. (2015) in fact found slower speech rates in syllables proceeding a code-switch than in matched monolingual utterances. Tokens from disfluent sentences were not included in the analysis. To be included in the analysis, a speaker needed to have at least half non-disfluent tokens in all cells of the analysis (e.g. for /l/-clarity, language  $\times$  context  $\times$  target word number  $\times$  /l/ position). Two speakers were included who did not meet this requirement.<sup>1</sup> This requirement were put in place to be more conservative in the analysis, and be sure effects were really due to code-switching and not other factors such as pausing.

Three variables were examined: 1) /l/-clarity, 2) lenition of word-initial voiced stops to fricatives, and 3) VOT of word-initial voiceless stops. All segmentation was done in Praat (Boersma & Weenink, 2009) and values were extracted with Praat scripts.

For the /l/ analysis, first the /l/ was segmented from the surrounding sounds. When the proceeding sound was voiceless, the beginning of voicing was used to segment the onset of the /l/. When the proceeding sound was voiced, formant transitions and a drop in waveform amplitude were used to segment the onset of the /l/. Changes in formant structure and/or a rise or drop in amplitude (depending on if the following sound was more or less sonorous) were used to determine the offset of the /l/. When both

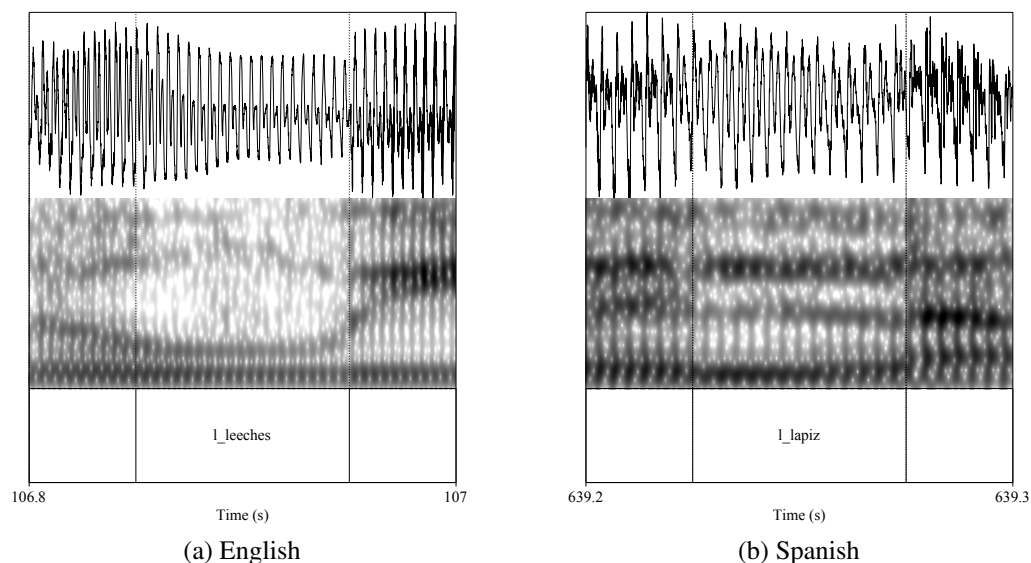
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<sup>1</sup>Of the two speakers who did not meet the requirements, one had two fewer tokens than required for Spanish, monolingual, Target word 1 for the VOT analysis, and one too few tokens for English, code-switching, Target word 1, onset position for the /l/-clarity analysis. The other speaker had two fewer tokens than required for Spanish, monolingual, Target word 2 for the VOT analysis, and one too few tokens for Spanish, code-switching, Target word 2, onset position for the /l/-clarity analysis.

correlates could be used, they were; otherwise, I used whichever cue was a clearer maker of the offset of the /l/ for segmentation. Average F2 and F3 were then extracted and subtracted from one another (F3-F2) to get a measure of /l/ darkness. Darker /l/ has a lower F2, so as darkness increases, so should F3-F2 (Sproat & Fujimura, 1993). See example segmentations in Figures 3.2a and 3.2b.

Before beginning analysis, outliers resulting from potential errors in the script's extraction of formant values were hand-corrected. For each speaker within language, the mean and standard deviation of F3-F2 was calculated after removing disfluent tokens. Any token greater or less than two standard deviations above or below the mean was labeled an outlier. Outliers were then corrected by hand checking F2 and F3; F3-F2 was then recalculated. The first three non-outlier tokens were also hand checked to be sure the script was in general extracting the correct values.

Linear mixed effects models were run, one for English data and one for Spanish data to test for significant effects. The dependent variable was F3-F2 in Hz. The fixed effects were context (monolingual, code-switching), target word number ("one" – pre-switch, "two" – post-switch), and position (onset, coda); fixed effects were included as a three-way interaction and all possible two-way interactions. All fixed effects were coded with contrast coding. The analysis was split by language, and two separate analyses were run to avoid the potential four way interaction of language  $\times$  context  $\times$  target word number  $\times$  position. The random effects were speaker (included as a random intercept and as a random slope by the interaction of context, target word number, and /l/ position uncorrelated with the intercept), word (included as a random intercept and as a random slope by context and target word number uncorrelated with the intercept), and sentence (included as a random intercept). This was the maximal uncorrelated random effects structure that would converge. Significance was assessed via model comparison with alpha set to 0.05.

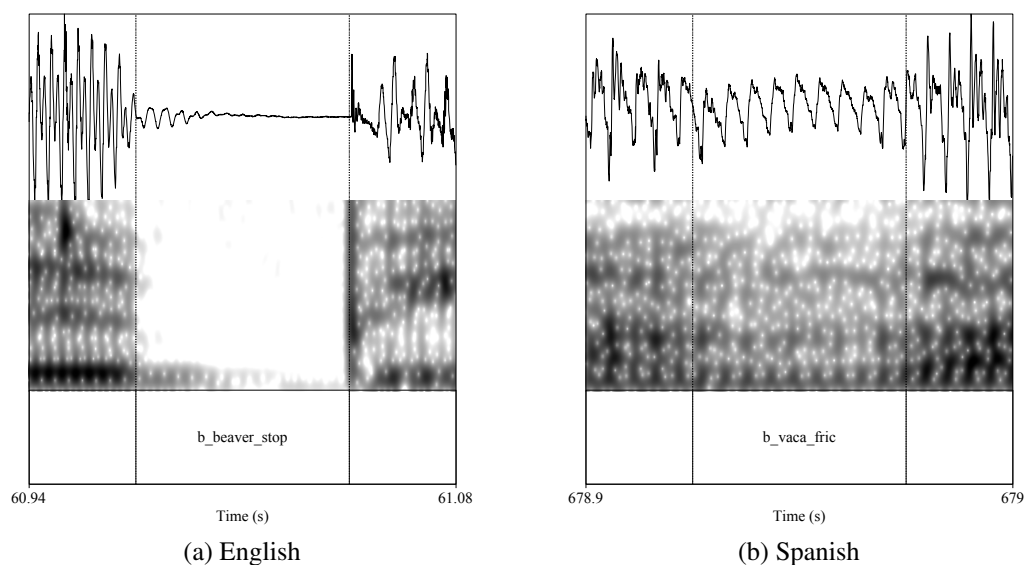


**Figure 3.2:** Example /l/-clarity segmentations in English and Spanish. Boundaries were assigned based on formant transitions and amplitude changes.

For voiced stops, visual inspection of spectrograms and waveforms was used to categorize a given token as a stop or a fricative / approximant (no distinction between fricatives and approximant was made). A stop was defined by the presence of a closure (with no formant structure) and a following burst. A fricative / approximant was defined by a drop in energy from the previous sounds when applicable (e.g. vowels), with strong voicing with concurrent formant structure, and with no burst. See example segmentations in Figures 3.3a and 3.3b.

A generalized linear mixed effects model was run to test for significant effects. Due to speakers almost exclusively using stops in English, the analysis was only conducted on Spanish productions. The dependent variable was presence of a fricative (1 for a fricative, 0 for a stop). The fixed effects were context (monolingual, code-switching) and target word number (“one” – pre-switch, “two” – post-switch); they were included as a two-way interaction. All fixed effects were coded with contrast coding. The random effects were speaker (included as a random intercept and as a random slope by context

and target word number uncorrelated with the intercept), word (included as a random intercept and as a random slope by target word number uncorrelated with the intercept), and sentence (included as a random intercept). This was the maximal uncorrelated random effects structure that would converge. Significance was assessed via model comparison with alpha set to 0.05.

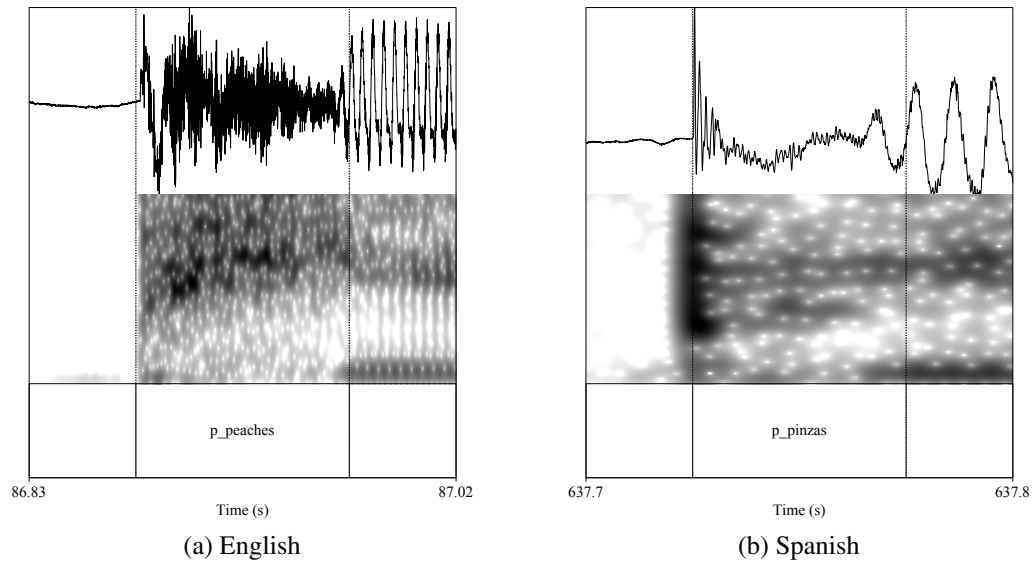


**Figure 3.3:** Example lenition segmentations of word-initial voiced stops to fricatives in English and Spanish. Category of production, stop or fricative, is noted in the TextGrid. Boundaries were based on lack of formant structure (a) and a drop in energy (b).

To measure VOT of voiceless stops, durations were taken from the onset of the burst to the onset of voicing. The onset of the burst was defined as the transient in the spectrogram, i.e. the point at which there was a sudden spike of high amplitude energy in the waveform. The onset of voicing was defined as the presence of glottal pulses in the waveform and spectrogram. The duration between these points was extracted for analysis. See example segmentations in Figures 3.4a and 3.4b.

A linear mixed effects model was run to test for significant effects. The dependent variable was VOT in milliseconds (log-transformed). A log transform was used to

give the data a more normal distribution given the long right tail, and to be maximally comparable to Piccinini and Arvaniti (2015). The fixed effects were language (English, Spanish), context (monolingual, code-switching), and target word number (“one” – pre-switch, “two” – post-switch); fixed effects were included as a three-way interaction and all possible two-way interactions. All fixed effects were coded with contrast coding. The random effects were speaker (included as a random intercept and as a random slope by the interaction of language, context, and target word number uncorrelated with the intercept), word (included as a random intercept and as a random slope by context and target word number uncorrelated with the intercept), and sentence (included as a random intercept). This was the maximal uncorrelated random effects structure that would converge. Significance was assessed via model comparison with alpha set to 0.05.

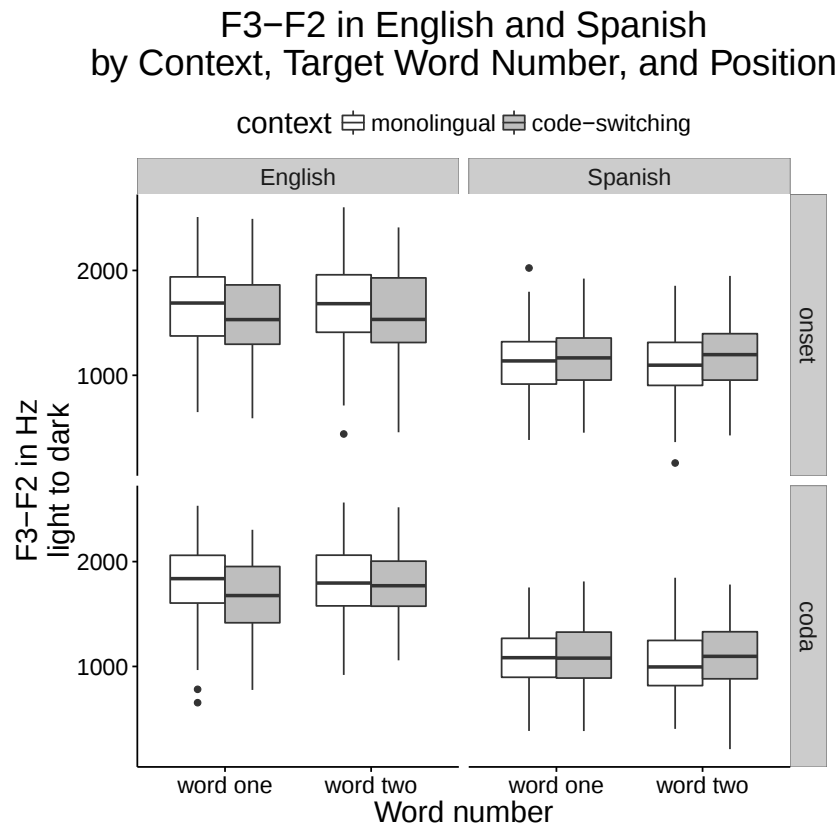


**Figure 3.4:** Example VOT segmentations of word-initial voiceless stops in English and Spanish. Boundaries were based on onset of burst to beginning of voicing.

### 3.3 Results

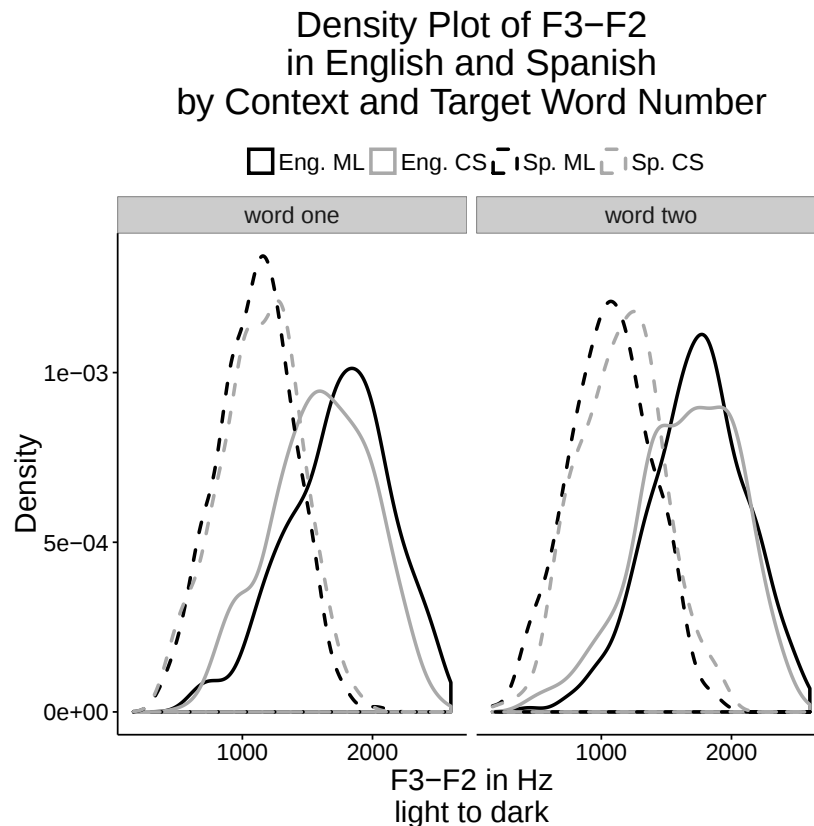
#### 3.3.1 /l/-clarity in Onset and Coda Position

The results are summarized in Figure 3.5. Starting with English, there was a significant effect of context, such that F3-F2 decreased (i.e., the /l/ was lighter) in the code-switching context [ $\beta = -116.35$ ,  $SE = 40.62$ ,  $\chi^2(1) = 5.77$ ,  $p < 0.05$ ]. Additionally, although between-language effects were not tested, it does appear that the English code-switching English-to-Spanish /l/ is still darker than the monolingual Spanish /l/. For Spanish, there was a significant effect of context, such that F3-F2 increased (i.e., the /l/ was darker) in the code-switching context [ $\beta = 61.63$ ,  $SE = 21.24$ ,  $\chi^2(1) = 5.94$ ,  $p < 0.05$ ]. There was a significant interaction of context and target word number [ $\beta = 69.13$ ,  $SE = 32.93$ ,  $\chi^2(1) = 3.93$ ,  $p < 0.05$ ]. Follow-up simple linear regressions found that there was no effect of context in Target word 1 position, but there was for the second target word [ $\beta = 84.11$ ,  $SE = 25.27$ ,  $r = 0.13$ ,  $p < 0.001$ ]. No other main effects or interactions were significant.



**Figure 3.5:** Results for /l/-clarity by language, context, word number, and syllabic position. F3–F2 of /l/ in onset and coda position separated by language, context, and target word number. The whiskers extend from the first or third quartile (Q1, Q3) to the largest value within 1.5 times the inter quartile range. Any dots outside of the whiskers represent outliers.

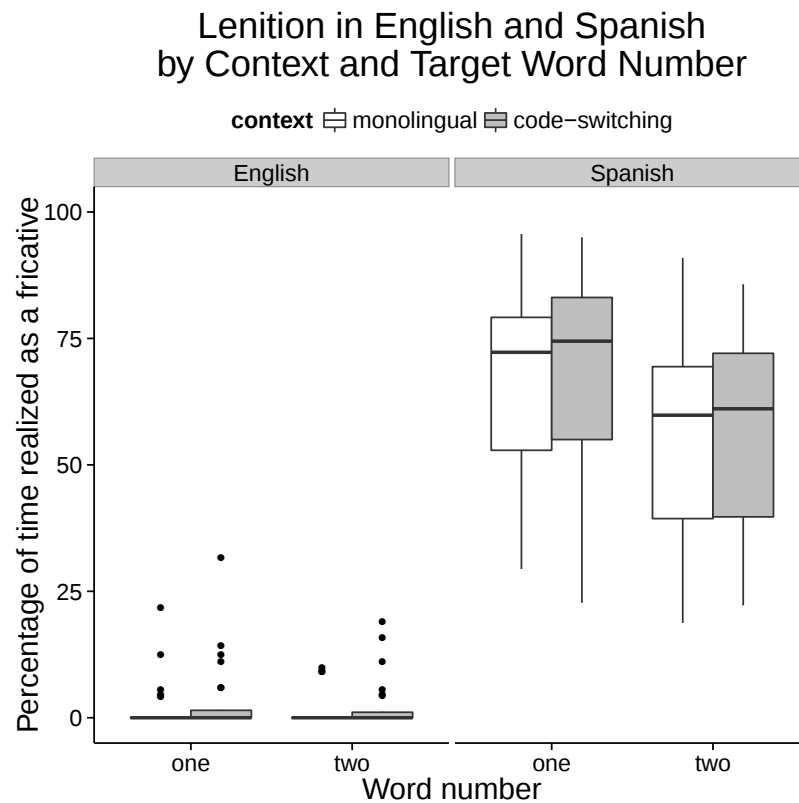
To be sure that the effect of context was really due to intermediate productions and not simply a bimodal distribution of English-like and Spanish-like productions, the three way interaction was plotted as density plots in Figure 3.6. As one can see, the distributions are normal and not bimodal, suggesting that code-switching productions are indeed produced intermediate to both languages, and do not simply map on to one language or the other half of the time.



**Figure 3.6:** Results for /l/-clarity by language, context, and word number as a density plot. F3–F2 of /l/ in separated by language, context, and target word number.

### 3.3.2 Lenition of Voiced Stops to Fricatives

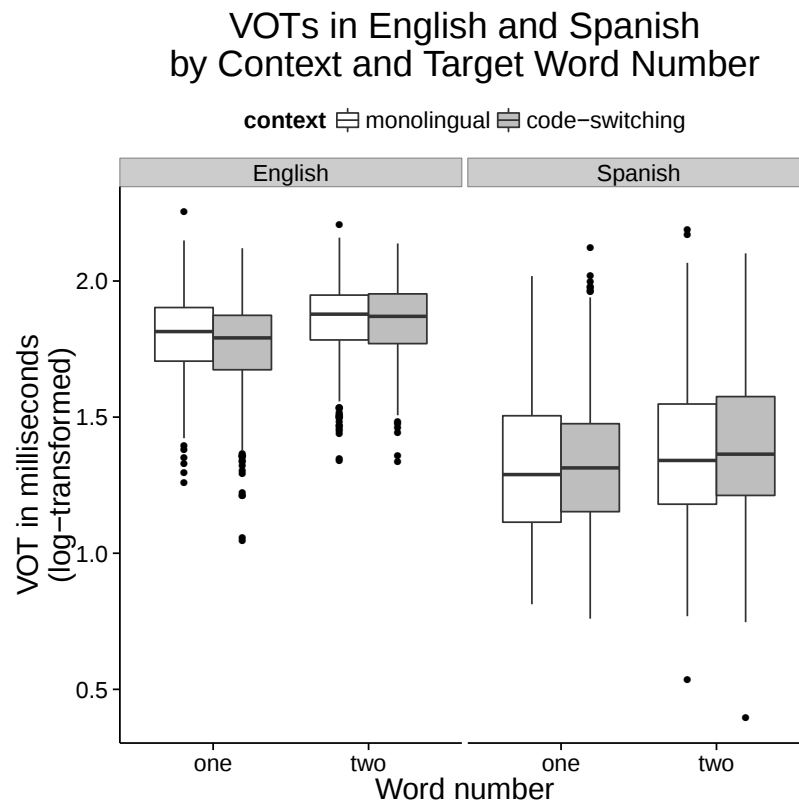
The results are summarized in Figure 3.7. Due to floor effects in English of almost entirely stop productions, no analysis was conducted on the English data. English data is included for sake of completeness. In Spanish, there was a significant effect of target word number, with speakers producing fewer fricatives for the second target words than the first [ $\beta = -0.73$ ,  $SE = 0.33$ ,  $\chi^2 = 4.37$ ,  $p < 0.05$ ]. The main effect of context and the interaction of context and target word number were not significant.



**Figure 3.7:** Results for word-initial lenition of voiced stops by language, context, and word number. Frequency of lenition of word-initial voiced stops separated by language, context, and target word number. The whiskers extend from the first or third quartile (Q1, Q3) to the largest value within 1.5 times the inter quartile range. Any dots outside of the whiskers represent outliers.

### 3.3.3 VOT of Word-initial Voiceless Stops

The results are summarized in Figure 3.8. There was a significant effect of language, such that (as expected) Spanish tokens had significantly shorter VOT than English tokens [ $\beta = -0.46$ ,  $SE = 0.06$ ,  $\chi^2(1) = 29.11$ ,  $p < 0.001$ ]. There was a significant effect of target word number, such that tokens Target word 2 had longer VOT than tokens of Target word 1 [ $\beta = 0.06$ ,  $SE = 0.01$ ,  $\chi^2(1) = 24.72$ ,  $p < 0.001$ ]. There was also a significant interaction of language by context by target word number [ $\beta = -0.05$ ,  $SE = 0.02$ ,  $\chi^2(1) = 4.77$ ,  $p < 0.05$ ]. No other main effects or interactions were significant.

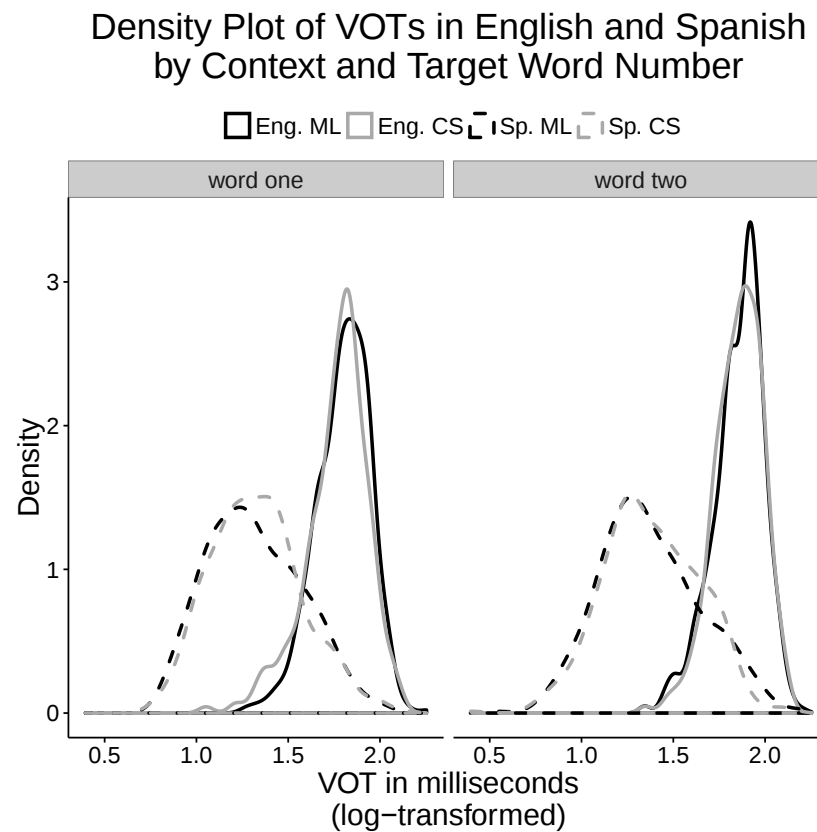


**Figure 3.8:** Results for word-initial voiceless VOT productions by language, context, and word number. Productions of word-initial voiceless VOT separated by language, context, and target word number. The whiskers extend from the first or third quartile (Q1, Q3) to the largest value within 1.5 times the inter quartile range. Any dots outside of the whiskers represent outliers.

To better understand the three-way interaction, follow-up simple linear regressions were conducted to test for an effect of context within language and target word number. For the first target words in English, there was a significant effect of context, such that code-switching tokens had shorter durations than monolingual tokens [ $\beta = -0.03$ ,  $SE = 0.010$ ,  $r = 0.10$ ,  $p < 0.001$ ]. For the rest of the models (English Target word 2, Spanish Target word 1, Spanish Target word 2) there was no effect of context. In summary, a context effect is present, however only for English words in pre-switch position.

To be sure that the effect of context was really due to intermediate productions and not simply a bimodal distribution of English-like and Spanish-like productions, the

three way interaction was plotted as density plots in Figure 3.9. As one can see, the distributions are normal and not bimodal, suggesting that code-switching productions are indeed produced intermediate to both languages, and do not simply map on to one language or the other half of the time.



**Figure 3.9:** Results for word-initial voiceless VOT productions by language, context, and word number as a density plot. Productions of word-initial voiceless VOT separated by language, context, and target word number.

### 3.4 Discussion

The present study tested for whether code-switching could induce a context such that speakers had both languages more heavily activated. This increase in cross-language activation would manifest itself in intermediate phonetic productions. Intermediate

phonetic productions here refers to productions that are intermediate to both languages, and show evidence of increased cross-language activation. Three phonetic features were examined: 1) /l/-clarity in different positions, 2) lenition of word-initial voiced stops to fricatives, and 3) voice onset time of word-initial voiceless stops. Results found that there is evidence for increased cross-language in code-switching, however where effects are found can vary by each language and phonetic feature under investigation.

In the /l/-clarity analysis, a general effect of context was found for both English and Spanish. In English, the difference between F3 and F2 decreased, showing that the /l/ was becoming more Spanish-like (lighter, or less velarized). Conversely, in Spanish, the difference between F3 and F2 increased, the /l/ became more English-like (darker, or more velarized). However, an interaction of context and target word number in Spanish showed that the context effect was specific to Target word 2, or post-switch position. These results match the initial predictions based on the time it would take to reactivate both languages. Since English is the dominant language, it takes longer to reactivate, thus there is not an effect of English on Spanish in pre-switch position, but there is in post-switch position. Since Spanish is the non-dominant language though, it is reactivated more quickly, thus resulting in a global effect of code-switching in both pre- and post-switch positions in English.

One surprising result was the lack of an effect of position in English. There was a trending three-way interaction of context, target word number, and position, but since the effect was not robust, follow-up analyses were not conducted. This may be due to a more general effect from Spanish that goes beyond just code-switching contexts. Indeed, Barlow et al. (2012) found that Spanish-English bilingual children, while maintaining separate categories of /l/ for each language, did have less velarized instances of /l/ in their English than their monolingual English counterparts, producing something closer to a Spanish /l/. Thus the general influence from Spanish may reduce the allophonic variation

in English, resulting in no effect of position even for monolingual productions.

For VOT of word-initial voiceless stops, an effect of context was found; however, it was limited to a specific environment. In English pre-switch position, VOT was shorter (more Spanish-like) in code-switching contexts than monolingual contexts. This result matches past work which found an effect of code-switching on English VOT (Bullock et al., 2006; Antoniou et al., 2011; D. J. Olson, 2013; Balukas & Koops, 2015; Piccinini & Arvaniti, 2015; Fricke et al., 2015; D. J. Olson, 2016). The fact that it was limited to pre-switch position matches both past results and the predictions made earlier regarding language activation. Bullock et al. (2006) found effects for English VOT, but only at pre-switch and switch position, but not at post-switch position. The present study in effect only had pre-switch and post-switch targets, as there were no target words directly at the switch point. This result also adds further support for the claim that the non-dominant language (Spanish) is activated quickly, thus having an effect as early as pre-switch target words.

One potential issue is that for English VOT the context effect went away by post-switch position, but in the /l/-clarity analysis there was a consistent, global effect of code-switching both in pre- and post-switch position. This may be due to the specific variables under investigation. Perhaps /l/ is more prone to effects of cross-language activation than stops. In English, if a long-lag production (e.g. [p<sup>h</sup>] as in “pat”) gets too short due to effects from Spanish, it risks becoming another phonological category in English (e.g. [p] as in “bat”). To avoid category merger, speakers may then make an extra effort to avoid effects of cross-language activation in their VOT productions, resulting in more limited effects of code-switching. Conversely, this does not occur with /l/ productions, as a particularly light version of English /l/ cannot be confused with any other phoneme.

This does not explain why there were at least limited effects in Spanish for /l/,

but none for the VOT analysis. Phoneme confusion cannot be a possible explanation, as a particularly aspirated Spanish /p/ will not result in another Spanish phoneme. However, the lack of an effect could be related to the fact that both English and Spanish have the short-lag category [p]. As such, higher activation of English in Spanish may not affect the production of the short-lag category, as it does exist in both languages. Also, in regards to past work on the phonetics of code-switching, effects being limited to only one language has been documented (Antoniou et al., 2011; D. J. Olson, 2013; Balukas & Koops, 2015; D. J. Olson, 2016). The fact that this result differs from Piccinini and Arvaniti (2015) who tested the same population, may reveal something about scripted versus spontaneous speech. In spontaneous speech, VOT in both English and Spanish was found to be affected. This could be related to speaking rate and its effect on time it takes to suppress a language. The VOT values for English were on average longer in the current study (monolingual 71 ms, code-switching 69 ms) than in Piccinini and Arvaniti (2015) (monolingual 59 ms, code-switching 54 ms), suggesting a slower speaking rate. A slower speaking rate would give a speaker more time to plan the utterance, and thus suppress the language they are about switch out of. This could then result in more limited effects of cross-language activation than in spontaneous speech. Future work can test this hypothesis by focusing on one type of speech (e.g. scripted) and test the role of speaking rate on phonetic realizations in code-switching utterances.

Finally, the analysis of lenition of word-initial voiced stops did not show any effects of context for either language. For English, speakers almost exclusively produced stops, and thus no analyses could be conducted. For Spanish, while there was variability in stop versus fricative production, context did not play a role. One of the goals of this paper was to examine both gradient and categorical differences between languages. Interestingly, for both voiced and voiceless stops there was more strengthening in Target word 2 position (voiced stops – more stop productions; voiceless stops – longer VOT). This

could be because Target word 2 is consistently in a prosodically stronger environment. This also could be due to the fact that Target word 2 items were less often preceded by sounds that could condition lenition, as compared Target word 1 items (Target word 1 17/20 contexts conditioned lenition, Target word 2 13/20 contexts). However, given that the results for VOT of voiceless word-initial stops showed the same effect of strengthening in Target word 2 position, this seems less likely. The fact that effects of context were found in both the gradient variables (/l/-clarity and VOT) but not the categorical variable (lenition) may suggest that these effects of cross-language activation are too small to affect productions on a categorical level (e.g. a complete change from a stop to a fricative). Future work may explore other types of categorical and continuous variables to see where effects are most robust.

Another goal of this paper was to see what had more of an effect on activation, language dominance or order of acquisition. The asymmetrical effects of Spanish consistently affecting English, but English only affecting Spanish in post-switch position, suggests that indeed current dominance is a greater predictor of speed of activation than order of acquisition. As the dominant language, English takes longer to reactivate. This delay in activation results in no effect of context for Spanish in pre-switch position, although effects can arise in post-switch position. Spanish (the non-dominant language) is activated very quickly though, resulting in effects of context in English on both pre- and post-switch position.

Returning to past psycholinguistic work on language switching such as picture naming (e.g. Meuter & Allport, 1999), these results suggest that the asymmetrical delay in switching is not necessarily tied to the L1, but instead the dominant language. Future models of language activation should take care to differentiate effects due to language dominance versus order of acquisition. However, it should be noted that these are still early, high-proficiency bilinguals. Despite the effects found, speakers are still able to

produce native sounding productions at all times, and past work has shown this is highly predicted by age of acquisition (Flege et al., 1999). It is unclear if the effect would be the same for late bilinguals, or what would happen with simultaneous or completely balanced bilinguals. Furthermore, the difference between language dominance and order of acquisition could be task specific, where a task focusing on the phonetic level of language production may show different effects than a task focusing on the lexical level of language production. Future work can continue to tease apart these often conflated variables.

### **3.5 Conclusion**

Three phonetic features known to differ between English and Spanish were compared in monolingual and code-switching utterances. Results showed that in English there were global effects of code-switch, both in pre- and post-switch position, while in Spanish effects were limited to post-switch position. In addition to providing evidence that contexts such as code-switching can induce different degrees of cross-language activation, it also shows that language dominance is a more important predictor than order of acquisition in terms of language activation. The presence of effects varied by phonetic feature. Most prominently, effects did not appear when the feature involved a categorical change. Future work should continue to explore other phonetic variables in code-switching, to see where effects are most consistent. Additional bilingual populations should also be tested to better understand the interplay of language dominance and order of acquisition on language activation.

## Chapter 4

### General Discussion

The present dissertation examined the phonetics of code-switching in speech production and perception to test for effects of increased cross-language activation. Results in production confirmed that speakers do indeed produce intermediate phonetic productions in code-switching utterances relative to monolingual utterances. Furthermore, listeners can anticipate upcoming switches, arguably due to these intermediate phonetic productions, however they are limited in which direction they can predict switches. These results both bear on how researchers should model bilingual language activation and control, and the role of factors such as language dominance.

#### 4.1 Summary of Results

##### 4.1.1 Results from Chapter 2

In Chapter 2, production of spontaneous code-switching was examined, specifically production of the discourse marker *like*, to test for intermediate phonetic productions in code-switching contexts. Follow-up perception experiments were run to see if bilinguals can anticipate language switches, potentially due to these intermediate phonetic

productions. Results demonstrate that: 1) bilinguals do have intermediate phonetic productions in code-switching contexts, and 2) bilinguals can anticipate upcoming language switches, however only from their dominant language into their non-dominant language (L2 to L1).

The phonetic analysis of the discourse marker *like* included a variety of variables, /laɪ/ duration, /k/ closure and burst realization, and formant structure of the /laɪ/. There was a significant effect of /laɪ/ duration such that monolingual Spanish tokens were longer than monolingual English tokens; code-switching tokens, of both directions, had durations intermediate to both monolingual categories. Effects were also found for the formant structure analysis when looking at productions over time. Spanish tokens ended higher and more fronted than English tokens, with code-switching tokens being somewhere in between. No effects were found for the realization of the /k/ or formants of the /laɪ/ at static points in time.

These results demonstrate that tokens of *like* are phonetically different in English and Spanish, with each token type matching the expected phonetic characteristics of their given language, assuming the Spanish diphthong ends higher and more fronted than the English diphthong. Additionally the duration difference suggests the Spanish diphthong may actually be closer to two monophthongs (/a/ + /i/). Given that tokens of *like* in Spanish are produced with Spanish phonetic characteristics, this would suggest that the discourse marker *like* has been lexicalized in Spanish, and is not simply an English word being inserted into a Spanish utterance. This makes the code-switching contexts all the more interesting. There are two possible hypotheses for the code-switching tokens of *like*: 1) they are tagged to a specific language (either the language pre- or post-switch), but show evidence of intermediate phonetic productions because they are at code-switching boundaries, 2) because they are at code-switching boundaries, they are not tagged to either language and exist as a third category, being produced truly phonetically intermediate to

both languages. The results found here support the second hypothesis. The fact that the two types of code-switching tokens of *like* did not differ from each other would suggest that they are not tagged to specific (different) languages, but instead represent some kind of third, other category.

In addition to testing for the presence of intermediate phonetic productions, this chapter also tested if listeners could anticipate upcoming language switches, the hypothesis being that they would use the intermediate phonetic productions to accomplish this. Two experiments were carried out where listeners had to predict the language of the next word: one where the number of code-switches to predict was open, another where they had to evenly sort utterances into monolingual and code-switches. Both studies found that listeners could predict code-switches from their dominant language (English) to their non-dominant one (Spanish), although they were unable to predict switches in the other direction. This difficulty with predicting Spanish to English switches could be somewhat mitigated by language mode, as listeners who received instructions in Spanish were, at least initially, able to predict switches in both directions equally well.

Taken together, these experiments demonstrate that intermediate phonetic productions do exist in spontaneous code-switching, and that listeners can potentially use these productions to anticipate upcoming language switches. These results match previous studies on VOT in code-switching which found effects of intermediate phonetic productions (Bullock et al., 2006; Antoniou et al., 2011; D. J. Olson, 2013; Balukas & Koops, 2015; Piccinini & Arvaniti, 2015; Fricke et al., 2015; D. J. Olson, 2016). While these previous studies all focused on VOT, this study goes beyond just this measure. Regarding speech perception, there is limited available literature to compare to. Both Li (1996) and Fricke et al. (2015) found that speakers could benefit from phonetic information that could cue a language switch. The same result was found here, though limited to one direction. This supports the literature that listeners can use phonetic information to

anticipate a language switch, not just in regards to full phonological switches, but also more gradient switches.

### 4.1.2 Results from Chapter 3

While Chapter 2 tested code-switching in spontaneous speech, Chapter 3 tested scripted speech. Scripted speech was chosen to gain greater control over the stimuli, as well as allow for the investigation of more phonetic variables. Three variables were examined: 1) /l/-clarity in different syllabic positions, 2) lenition of word-initial voiced stops to fricatives, and 3) VOT of word-initial voiceless stops. In addition to testing for general effects of code-switching, direction of the switch was also specifically examined, to see if results varied accordingly. Direction of the switch was predicted to interact with language dominance. An interaction would manifest itself as global effects of code-switching in English (influence from Spanish), but effects on Spanish (influence from English) would be limited to post-switch position. If the dominant language (here, English) takes longer to activate, having taken more energy to suppress, then there should be limited-to-no effect of code-switching in pre-switch position. However, carry-over effects would still result in an influence on tokens in post-switch position.

Of the three phonetic features examined, they all displayed different patterns. For /l/-clarity, there was a global effect of code-switching for English, but for Spanish the effect was limited to post-switch position. For VOT, there was an effect in pre-switch position for English, but no effect at either position for Spanish. For lenition of voiced stops to fricatives, there were no effects of context in either language. These diverse results show that it is important to expand the number of phonetic variables that are being investigated in code-switching beyond just VOT. The VOT analysis was meant to serve as another data point for comparison with past studies. The results most closely matched those of Bullock et al. (2006), who also found effects in pre-switch position

but not post-switch position. The lack of an effect of Spanish is also interesting in light of the results found by Piccinini and Arvaniti (2015) with spontaneous speech with the same population. Piccinini and Arvaniti (2015) found a general shortening of VOT for both English and Spanish in code-switching contexts, while here the effect was limited to English. As previously discussed, this could be due to speech rate, where post-switch effects are lost when speech rate is slower, and a speaker has more time to plan the second half of the utterance; planning here includes the need to suppress the pre-switch language. This demonstrates the need to continue work on spontaneous speech as well, to get a full picture of effects in more natural code-switching. The lack of any effects for lenition suggests that full categorical changes (e.g. stop to fricative) are not to be predicted in code-switching contexts. Instead, effects of cross-language activation are focused on more gradient changes, such as /l/-clarity and VOT. This prediction could be verified by testing more phonetic features that differ between English and Spanish gradiently (e.g. vowels) versus categorically (e.g. /r/ productions).

The /l/-clarity results are important for the literature for two reasons. One, they highlight the importance of studying multiple different phonetic variables in the phonetics of code-switching; the results for /l/-clarity showed effects for both languages, whereas the VOT results showed effects only for English. Two, the results match the hypotheses regarding the interaction with language dominance. The global (i.e. not pre- or post-switch specific) effect of code-switching in English is due to Spanish being the non-dominant language; Spanish can be activated quickly and thus have effects in both pre- and post-switch position. Conversely, since English is the dominant language, it takes more time to activate, and thus results are limited to post-switch position. Future work should look at more variables like /l/-clarity to see where else an effect like this occurs. As previously mentioned, the difference between the /l/-clarity and VOT results for English could be due to category merger, namely for /l/ there is no risk that intermediate

phonetic productions will result in category merger, while for VOT in English there is. To test this theory, future studies could examine other variables that may result in category merger. For example, English /ɪ/ may become more /i/-like in code-switching due to influences from Spanish, but both /ɪ/ and /i/ are categories in English, so effects may not be extensive. Conversely, English /a/ fronting to /æ/ due to Spanish does not pose the same problem, and thus there may be more wide-spread effects.

## **4.2 Implications for Theories of Bilingualism**

### **4.2.1 Effects of Context on Degree of Cross-language Activation**

The primary goal of this dissertation was to demonstrate that cross-language activation in bilingual speech production and perception is dynamic, and can vary according to context. The specific context chosen for this dissertation was code-switching speech. The IC model (Green, 1998) predicts constant low-level activation of both languages, even when one of them is not use. When language switching occurs there is a shift between which language is more heavily activated (or, conversely, which language is more heavily suppressed). While this theory can account for many effects of cross-language activation previously found in the bilingualism literature, it is still in many ways a static level of activation – either one language is activated while the other is suppressed or visa versa. What is not taken into account is how context, here defined by different language situations, can change the degree to which the not in use language is being suppressed, thus allowing for greater activation of both languages simultaneously.

The results from this dissertation demonstrate that context (specifically code-switching) can result in intermediate phonetic productions, thus showing that for a given bilingual speaker different contexts can induce different degrees of cross-language activation; this is in contrast to past work which compared bilinguals to monolinguals

to learn more about bilingual language organization. While there has been extensive work comparing bilinguals' phonetic productions to monolinguals' (e.g., Flege & Eefting, 1987; Sundara et al., 2006; Khattab, 2002; Lee & Iverson, 2012; Kehoe et al., 2004; Barlow et al., 2012; Grijalva et al., 2013), less research has focused on differences comparing individual bilingual speakers to themselves in different contexts, specifically in terms of their phonetic productions. Exceptions to this include work where context is manipulated through the amount of the presence of one or both languages (D. J. Olson, 2013; Simonet, 2014), comparing production of cognates to non-cognates (Amengual, 2012; Goldrick et al., 2014), and code-switching (Grosjean & Miller, 1994; Bullock et al., 2006; Antoniou et al., 2011; López, 2012; D. J. Olson, 2013; Balukas & Koops, 2015; Piccinini & Arvaniti, 2015; Fricke et al., 2015; D. J. Olson, 2016). Code-switching is a particularly interesting case as it comes closest to replicating a context that naturally occurs in bilingual speech production and perception, instead of being a context specific to a laboratory manipulation (e.g. picture naming switching studies). The results presented here add to this growing body of work by showing effects of context in speech production as well as speech perception.

Future models of bilingual language organization and access must take into account environmental context, whether it be as broad as the language background of the interlocutor, or as narrow as the lexical status of a specific word. By incorporating the role of context in bilingual language access, we can better model the dynamic, gradient nature of cross-language activation. This should be extended to all levels of language, from lemma selection to phonetic productions. By studying degrees of activation at different levels of language, we can see if effects are uniform across levels of speech production, or if gradient activation affects certain levels of language differently. Given that effects are found as low as phonetic activation, it is likely that context can affect degree of cross-language activation as high as lemma selection. If effects are not found

at higher levels, that would suggest that speech production is not truly hierarchical, or at the very least could be bidirectional, thus resulting in effects at lower levels but not higher levels.

Additionally, if bilinguals are expected to have some measure of control over the degree of activation, they could (and perhaps already do) use this to their advantage in speech production and perception. If a bilingual is in a context where they know both languages will be used, it is more cognitively efficient to have both languages heavily activated, compared to a context where they know only one language will be used. This runs contrary to a lot of past work on cross-language activation in bilingualism, which has often shown the activation of the other language to be a detriment, not a benefit (Meuter & Allport, 1999; Kolers, 1966; Macnamara & Kushnir, 1971). More work should explore situations where increased cross-language activation is beneficial to a bilingual. This can have implications on topics such as language learning for children, as well as inform on how to treat bilinguals with language disorders.

#### **4.2.2 Language Dominance versus Order of Acquisition**

The second goal of this dissertation was to disentangle the often conflated variables of language dominance and order (and age) of acquisition. Many past studies have discussed the role of language dominance in bilingual language activation and suppression. However, the dominant language and the L1 were often the same, making it unclear whether effects were due to language dominance or order of acquisition. This can be important, as even highly-proficient, early bilinguals can show differences depending on which language is their L1 (Sebastián-Gallés et al., 2005). The population of the present dissertation is thus interesting, as there was a mismatch between dominant language and L1, participants were generally L1 Spanish but English dominant.

Results found that language dominance was a better predictor of language acti-

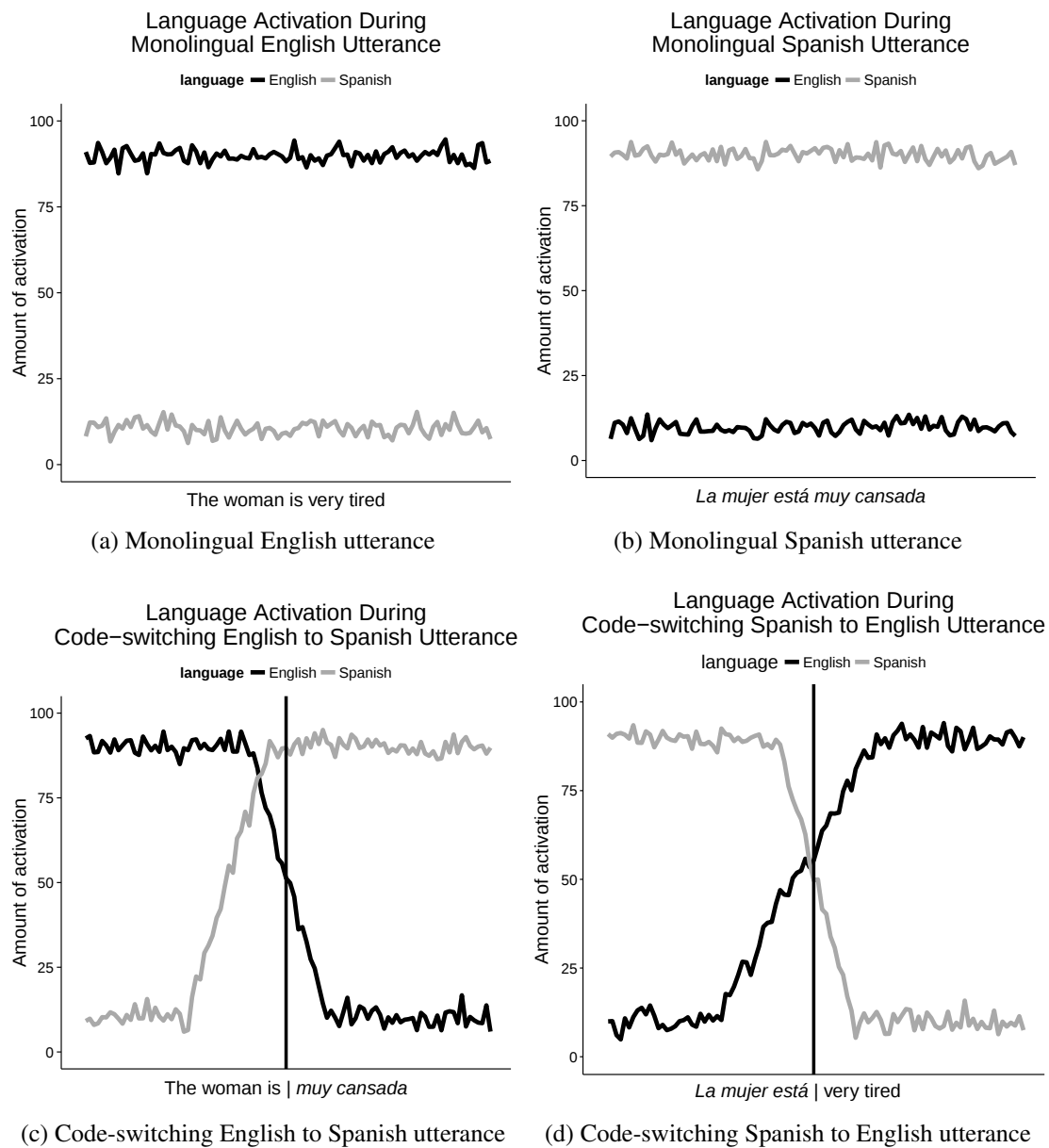
vation than order of acquisition. In the speech perception task in Chapter 2, listeners were able to predict language switches from their dominant language back into their non-dominant language, but not *visa versa*. This could be because the dominant language takes more energy to suppress, and thus more time to switch back into. As a result there is a delay in the ability to detect language switches. See Figure 4.1c and 4.1d for a comparison of the speed of activation for the non-dominant language (Spanish) versus the dominant language (English). One could predict that for low-level sound representations Spanish (being the L1) is more important, while for higher level lexical-semantic representations English (being the L2) is more important. Chapter 3 looked at this in more detail in terms of production, and found that effects were overall more common in English than Spanish, and that when effects were present in Spanish they were limited to post-switch position. This was attributed to the delay in reactivating English, the dominant language. The asymmetry could also be explained by other factors. For example, living in an English dominant environment could affect which direction of switches they are more comfortable with. Additionally, in their own spontaneous code-switching, one direction of code-switching (e.g. English to Spanish) may be more common than the other (e.g. Spanish to English).

It should be stressed that this result may be specific to this population (early bilinguals) and/or this level of language (phonetics). As previously discussed, these are all highly proficient speakers of both languages. Even when they showed evidence of intermediate phonetic productions, these productions were still much closer to the intended language than the other; for example, shortened VOT in code-switching for English was still long-lag VOT, and not immediately in between a long-lag and short-lag production. We know that this kind of skill with phonetic productions is heavily influenced by the age of acquisition of a language, where the later a language is learned the less native a speaker sounds (Flege et al., 1999). So, while for this population

language dominance was found to be more important this may be specific to a population where age of acquisition was still very early for both languages. Differences may also be found in other domains of language, e.g. lexical access. The differences found here were very small and cannot necessarily be applied to all levels of language without further investigation. Related to level of language, task differences could affect whether language dominance or order of acquisition comes out as a more important variable. Future work should then attempt to see how effects for factors such as language dominance and order of acquisition vary based on population, level of language, and task.

### 4.2.3 Models of Bilingual Language Activation and Control

Taken with the above comments about degrees of activation, the effect of language dominance shows that not only should context be considered when modeling different *degrees* of activation, but also relative language dominance should be considered as affecting the *speed* of activation and suppression, which in turn affects degree of activation over time. If the dominant language takes more *energy* to suppress (and thus activate later on), then it should also take more *time* to suppress and activate. The “slope of activation”, so to speak, will affect how much a specific language is activated at any given moment. Returning to Figures 4.1c and 4.1d, one can see a much steeper slope in the activation of Spanish when it is the language being switched into than the activation of English. Working on modeling this slope can potentially explain some past results in the bilingualism literature. This includes results beyond just phonetics, such as reaction times and electrophysiological measures. For example, Moreno et al. (2002) found ERP evidence of a cost to processing code-switching in English to Spanish sentences. However, the magnitude of the effect was larger for less balanced bilinguals. By continuing more studies such as this, with groups of varying degrees of proficiency, and examining switches in both directions, we can see how electrophysiological measures



**Figure 4.1:** Language activation in different utterance types. Activation levels of English and Spanish in a different utterance types. In (a) and (b), there is little phonetic influence of the language not in use because activation is low. In (c) and (d), the language to be switched into increases in activation during the switch, thus influencing the language still in use. The speed of the increase in activation is larger in (c) than (d) since Spanish is the non-dominant language and took less energy to initially suppress.

can be gradient in the same way as phonetic measures.

One additional variable the IC and other models do not currently take into account is skill of switching between languages. This can be considered different from being highly proficient in a language. For example, an early English-Spanish bilingual and a late English-Spanish bilingual may have the same proficiency in English, but if the early bilingual has more experience switching languages, they are presumably better at quickly reactivating a language that took a lot of energy to suppress. This enhanced skill at switching could result in different effects of cross-language activation in what is theoretically the same population. One way to test this would be with the same type of experiments presented here, but with two groups of speakers: 1) those who actively code-switch, and 2) those who do not.

Future models on bilingual language activation should thus take into account three variables: 1) context, as it relates to the *degree* to which both languages are activated, 2) language dominance, as it relates to the *slope of activation* of a given language, and 3) skill in language switching, as it relates to how well speakers can modulate the degree of activation and increase their slope of activation. A summary schematic of these and other factors that could affect degree of cross-language activation is presented in Figure 4.2. These three variables will be able to inform future results on bilingual language activation, both in specific contexts and for specific populations.

### 4.3 Other Future Directions

Future work will test the predictions resulting from this dissertation by examining varying degrees of cross-language activation in other populations and contexts. As previously mentioned, it is unclear how well these results would extend to bilinguals who may be less proficient in one language. This is true even within the population used for



**Figure 4.2:** Factors affecting cross-language activation. A schematic of various factors that could affect degree of cross-language activation.

this dissertation. In Chapter 3, 13 of 37 (roughly 35%) of speakers had to be excluded due to disfluencies. This may be because they are less proficient in Spanish, particularly reading in Spanish. It could also be because they have less skill at switching, resulting in pauses at code-switching boundaries. One part of future work could be to look at the productions from these speakers and see how effects may change relative to the speakers analyzed in the data set discussed here. This can include looking at effects both in fluent and disfluent utterances, and seeing how effects across all speakers may correlate with language proficiency in one or both languages. Proficiency here includes both speaking and reading proficiency in both languages. This type of analyses could be extended to

look at how individual differences may affect results across participants.

Code-switching is a useful context to test for gradient effects of cross-language activation, but other contexts need to be tested as well to be sure this is not simply an effect specific to one context. Past research on this has often viewed increased activation of the inactive language as a negative, and as something out of the speaker's control. Instead, I want to focus on contexts where having both languages more heavily activated would be a positive effect. In learning a third language that includes sounds from both a speaker's L1 and L2, it would be useful to have the sounds from both languages available. For example, across English and Spanish there are three VOT categories: negative VOT, short-lag VOT, and long-lag VOT. When learning a language with all three categories phonemically, it would be beneficial to have both languages activated. Another context is when listening to speech in a speaker's L1, but with an accent from their L2, having both languages activated would make it easier to process the speech they are exposed to. For example, if a bilingual is listening to someone speak English with a Spanish accent, and they hear the beginning of a word as /si/, if they have both languages activated they can more easily expect the word to be "sister", and anticipate the /ɪ/ → [i] change due to the accent. Also, if we can find contexts where it is beneficial for bilinguals to have both languages activated (such as the two described above), and thus potentially are activating both languages more on purpose, we can learn more about the mechanism of control bilinguals have in modulating degree of activation. This line of work should also attempt to study how the slope of activation can vary either between contexts or individual. For example, bilinguals could be categorized as "switchers" or "non-switchers" based on language use practices. It could be predicted that "switchers" will show effects such as intermediate phonetic productions in code-switching earlier on in an utterance than "non-switchers", due to their steeper slope of activation.

A third goal of future work is to study more varied bilingual populations to see

which effects fluctuate according to factors such as language dominance and age and order of acquisition. The population for the present study (early bilinguals who are L1 Spanish, English dominant) was a useful population to disentangle the variables of language dominance and order of acquisition. Future work can look at other early bilingual populations to test for skill at switching between languages. For example, is the slope of activation larger for bilinguals who code-switch on a daily basis versus those who do not? Can you train speakers to be better at switching languages, and is it limited to one language? By continuing this research with different bilingual populations, I hope to answer these and other questions.

A final goal for future work is to look at how phonetics interacts with other levels of language in predicting degree of cross-language activation. The present dissertation focused on a very specific, low level of language, phonetics. In perception, I tested whether listeners could use this low-level information to anticipate language switches. However, other, non-phonetic, features of language could also be used by listeners as a means to predict language switches. For example, the presence of discourse markers (“um”, “uh”, “hmm”) as a delaying tactic could be a sign that a code-switch is about to occur. I want to look at the interaction between the use of these discourse markers and their phonetic realization. This would be extending the *like* analysis to other discourse markers, but also seeing what has the greatest effect on the prediction of code-switches: 1) phonetic cues, 2) the presence of discourse markers, or 3) phonetic cues on discourse markers. Other levels of language, such as syntactic constructions, can also be of interest for studying the ability to predict code-switches.

## Chapter 5

### Conclusion

The present dissertation tested for effects of cross-language activation in the production and perception of code-switching speech. The presence of intermediate phonetic productions were tested for, in spontaneous speech with the discourse marker *like*, and in scripted speech. In speech production results showed that intermediate phonetic productions do exist, however there is a greater effect of the non-dominant language (Spanish) on the dominant language (English) than visa versa. Differences were also found between spontaneous and scripted speech, and different phonetic variables. Differences between spontaneous and scripted speech are difficult to compare, as in the spontaneous speech analysis tokens directly at the switch were examined, whereas in the scripted speech analysis target words were not exactly at the switch. Regardless, this shows that distance from the switch can affect degree of cross-language activation. Regarding specific phonetic feature, gradient features (e.g. /l/-clarity, VOT) were found to have more consistent effects than categorial features (e.g. lenition of stops to fricatives). In speech perception, listeners were able to predict code-switches from their dominant language (English) to their non-dominant language (Spanish), but not visa versa, matching the production results. These results have implications for how we model language

activation and control in bilinguals. I propose that future work and theoretical models of cross-language activation should take into account both context and language dominance when modeling the degree to which a language is activated in any given language interaction.

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