11-2013

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Recommended Citation
Olson, D. J. (2013). Bilingual language switching and selection at the phonetic level: Asymmetrical transfer in VOT production. *Journal of Phonetics, 41*(6), 407-420. https://doi.org/10.1016/j.wocn.2013.07.005

Bilingual Language Switching and Selection at the Phonetic Level: Asymmetrical transfer in VOT production

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Abstract

The present study examines the effect of language switching on phonetic production, contributing to an understanding of the underlying interaction between a bilingual's two phonetic systems. While phonetic interaction has been studied in non-switched and code-switched paradigms, effects of connected speech (e.g. speech planning, pragmatics, etc.) may obscure underlying phonetic interaction. To investigate the impact of language switching, a cued picture-naming task was employed, with Spanish-English bilinguals of differing dominance profiles naming pictures in English and Spanish. Stimuli were produced both as switched and non-switched tokens. Addressing the impact of context, stimuli were presented in three contexts varying in quantity of language. Results indicate an asymmetrical effect of language switching on voice onset time. Specifically, both Spanish-dominant and English-dominant bilinguals demonstrated unidirectional transfer, with the dominant language significantly impacted by language switching. Drawing parallels with findings of asymmetrical temporal costs found at the lexical level, and resulting theoretical models, implications are discussed with reference to possible inhibitory mechanisms at play in bilingual phonetic selection and switching.

Keywords: Language Switching, Language Mode, Code Switching, Bilingualism, Spanish, English, Voice Onset Time

1. Introduction

Bilinguals are consistently faced with the challenge of storing, separating, and selecting the competing languages within a single mind. Particularly in the case of highly proficient bilinguals, given the relatively equal strengths and overlapping neural networks of the two languages (e.g. Illes et al., 1999), one might expect confusion and persistent, uncontrolled language switching. However, this is not the case; the exact opposite is true. Bilinguals, excepting cases of trauma (e.g. Perecman, 1984), are very capable of segregating and limiting interference between their two languages. This feat becomes even more impressive when we consider natural, everyday bilingual practices, such as code switching. Not only are bilinguals able to maintain the division between their two languages when necessary, but when contextually appropriate, they are able to switch back and forth between them in a systematic, predictable manner (Zentella, 1997). The question then arises as to how bilinguals manage to separate their two languages, while still allowing for language switching when appropriate. This issue is further complicated when we consider the complexities and different levels of language. As such, bilinguals must separate their languages across a number of levels: syntactic, lexical, phonological, phonetic, etc.

While a fairly substantial body of research has begun to make significant inroads into understanding the cognitive mechanisms for language separation at the lexical level (e.g. Green, 1998), interaction and separation at the phonetic level has received much less attention (Fabiano-Smith & Barlow, 2010). In addition, the extant research addressing the potential interaction of the two phonetic systems has focused predominantly on code switching, switches between two languages occurring within connected speech. While code switching may offer some insights, effects of context and connected speech (e.g. pragmatics, speech planning, etc.) may obscure underlying phonetic interaction. Language switching, switches between languages not occurring in connected speech such as those prompted in experimental research, on the other hand, may allow for an investigation of the interactions between the two systems without the influence of discursive constraints.

To address the broader goal of furthering the understanding of the language switching mechanism at the phonetic level, the present study examines the interaction of a bilingual's two phonetic systems in an experimental, cued language switching paradigm, absent the effects of connected speech. The results will be discussed with reference to proposals for the cognitive mechanisms responsible for language separation at the lexical level, most notably the Inhibitory Control Model (ICM) (Green, 1998).

1.1 Two Phonetic Systems

Early research on phonetic production in bilinguals sought to establish that bilinguals maintain and produce separate phonetic categories in their two languages (Caramazza, Yeni-Komshian, Zurif, & Carbone, 1973; Hazan & Boulakia, 1993, MacLeod & Stoel-Gammon, 2010). While such categories may be distinct from monolingual norms (see Flege & Eefting, 1987; Flege & Port, 1981), bilinguals distinguish between the phonetic norms in the production of their two languages (although for very similar phonetic contrasts between two languages, see Flege, 1995). This finding holds for highly proficient bilingual speech perception as well (e.g. Bosch & Sebastian-Galles, 2003; but for possible perceptual limitations see Pallier, Bosch & Sebastian-Galles, 1997).

Further support for this distinction between the two phonetic systems comes from research on early bilingual acquisition as well as sequential second language acquisition.

For bilingual language acquisition, while there is an ongoing debate as to whether the dual systems emerge as a result of one single system that then divides into two autonomous systems (e.g. Unitary System Model: Volterra & Taeschner, 1978; Vihman, 1985;) or as dually developing systems (e.g. Dual Systems Model: Keshevarz & Ingram, 2002; see also Genesee, 1989; Koppe & Meisel, 1995; Lanza, 1992), there is consensus that even from a young age, bilinguals separate their two phonetic systems. Similarly, for acquisition of a second language (L2) (cf. first language- L1), several distinct proposals have been made as to how learners acquire new phonetic categorizations (e.g. Perceptual Assimilation Model-L2: Best & Tyler, 2007; Native Language Magnet Model: Kuhl, 1992; Speech Learning Model: Flege, 1995), but again, there is general agreement that, with some exceptions, L2 learners are capable of establishing separate phonetic systems for their two languages. Thus, switching languages requires not only a switch at the lexical level, it also requires a switch at the phonetic level.

However, the two systems are not entirely autonomous. In non-switched interaction, there are several different types of interactional outcomes that have been reported including influence of the L1 on L2 (e.g. Caramazza et al., 1973), influence of L2 on L1 (e.g. Flege, MacKay, & Piske, 2002), and bidirectional influence of L1 on L2 and L2 on L1 (e.g. Fowler, Sramko, Ostry, Rowland, & Hallé, 2008). Furthermore, during bilingual acquisition, children may evidence differing patterns of interaction between the two systems depending on language specific and proficiency factors (Kehoe, Lleó, & Rakow, 2004, Paradis & Genesee, 1996). As noted by Fabiano-Smith and Barlow (2010), while it is generally accepted that bilinguals differentiate their systems from an early age, and that these two systems interact, "the extent to which they interact is as of yet unclear" (p. 2). A similar sentiment was previously conveyed by Flege (1995), who notes that phonetic elements of the L1 and L2 will undoubtedly have an influence on one another, as the phonetic elements of the L1 and L2 reside in a "common phonological space" (see also Yeni-Komshian, Flege, & Liu, 2000). While the authors referred specifically to non-switched production in either of a bilingual's two languages, this statement holds particularly true for cases in which bilinguals switch from one language to another.

1.2 Interaction in Code switching

While there is a substantial body of work on the phonetic interaction of a bilingual's two languages in non-switched contexts, there have been surprisingly few studies that have addressed the phonetics of code switches. *Code switching* has been defined as "the selection by bilinguals or multilinguals of forms of an embedded variety in utterances of a matrix variety during the same conversation" (Myers-Scotton, 1993, p. 3). Code switching offers a unique opportunity to investigate phonetic interaction between a bilingual's two languages given the "interlanguage interaction" that occurs in code switching (Antoniou, Best, Tyler, & Kroos, 2011, p. 4). The few extant studies, described in detail below, have differed methodologically in several significant ways and have reported varied findings. Overall, findings have included no phonetic interaction (Grosjean & Miller, 1994), unidirectional transfer and bidirectional transfer (Bullock & Toribio, 2009; Bullock, Toribio, González, & Dalola, 2006), and L1 to L2 transfer (Antoniou, et al., 2011).

In one of the first studies specifically designed to investigate the phonetic effects of code switching in production, Grosjean & Miller (1994) investigated the phonetic realizations at the point of switch by exploiting the voice onset time (VOT) difference between French and English. VOT corresponds to the lag between the release of a stop consonant and the onset of vocal fold vibrations (Lisker & Abramson, 1964). French has short-lag voiceless stops (0-30 ms) and English long-lag voiceless stops (30-120 ms) in initial position. Results for a task in which participants re-told stories they had previously read, with single English tokens inserted into French utterances, indicated that there were no significant differences between the non-switched English and the code-switched English productions. That is, English code-switches were produced with VOTs similar to monolingual English tokens. With respect to the VOT production of a code-switched token, Grosjean & Miller (1994) conclude that switching does not induce any interaction between the two phonetic systems. In short, "Switching from one language to another appears to involve a total change, not only at the lexical level but also at the phonetic level" (p. 203).

Standing in contrast, Bullock et al. (2006) and Bullock and Toribio (2009), examined VOT for Spanish-English bilinguals and found significant interactions between the two phonetic systems. Examining the VOT for Spanish-English bilinguals, their studies encompassed both early (Bullock & Toribio, 2009) and late bilinguals (English-dominant and Spanish-dominant: Bullock et al., 2006). Exploring the production of word-initial voiceless consonants at the point of switch, their results indicated that there was a degree of phonetic convergence with respect to VOT values, yet this effect differed based on the direction of switch (English to Spanish vs. Spanish to English), as well as dominance profile of the bilingual. Specifically when switching from Spanish to English, all bilinguals produced code-switched English tokens with significantly shorter, more "Spanish-like" VOTs relative to non-switched English tokens. Conversely, when switching from English to Spanish, only the early bilingual group evidenced convergence, with code-switched Spanish tokens produced with significantly longer, more "English-like" VOTs relative to non-switched Spanish tokens. Importantly, the stimuli for these studies consisted of randomized utterances in which approximately half of the utterance came from each language, representative of alternational code switching (Muysken, 2000).

Similarly, Antoniou, et al. (2011) investigated the VOT of code-switched tokens in Greek-English bilinguals who were L2-dominant (English). Again, the experimental design paired a long-lag (English) and short-lag (Greek) language. Using a procedure in which subjects produced code-switched pseudo-words in both Greek and English, results indicated a significant effect of the L1 on productions of the L2, with code-switched English tokens being produced with significantly shorter VOTs than non-code-switched tokens. Important to note, given that the subjects were L2-dominant, the direction of transfer may be described as both non-dominant to dominant, as well as short-lag VOT language to long-lag VOT language.

Table 1 summarizes the variety of phonetic interaction patterns that have emerged (L1 to L2; L2 to L1), with the most consistent pattern to emerge is an effect of transfer on a language with long-lag VOT. This pattern was found both for speakers dominant in short-lag languages (Spanish-dominant bilinguals: Bullock, et al., 2006) as well as for those dominant in long-lag languages (English-dominant bilinguals: Atoniou, et al., 2011; Bullock, et al., 2006). However, it appears that short-lag languages may not be immune to transfer (see early bilinguals: Bullock & Toribio, 2009). Thus, the results from these studies seem to indicate the potential for interaction between the two separate phonetic systems in cases of code switching.

<Insert Table 1 about here>

1.3 Code switching and Language Switching

A crucial distinction should be made between *code switching* and *language switching*. Mainly, while code switching occurs within the context of a larger discourse or utterance, *language switching* refers to switches occurring without such discursive constraints, often in an experimental paradigm. While code switching paradigms present a unique opportunity to study the interaction of two phonetic systems, they are potentially problematic on several levels for the study of language separation and selection mechanisms.

First and foremost, in both reading paradigms and naturalistic speech, speakers must plan their productions, with "buffering" times of up to 1000 ms required before beginning to name objects (e.g. Griffin & Bock, 2000). Given this planned nature, speakers have the opportunity to modulate ahead of a switch, accessing the language of the code-switched token prior to producing this language, potentially resulting in different phonetic effects in advance of and at the point of switching, due not solely to effects of language switching, but the pre-modulation. The assertion is supported in findings from Bullock et al. (2006) and Bullock and Toribio (2009), who found shifts in VOT *prior to* a code-switched token, indicative of planning of the switch and partial access to the phonetic norms of the language of the switch. Second, code switching in discourse, on a broader level, is generally performed for specific pragmatic reasons, related to communicative factors, clarification, and a lack of linguistic knowledge (Auer, 1998; Chan, 2003; Gumperz, 1982; Zentella, 1997; for children: Reyes, 2004). These various pragmatic intents may affect phonetic production. Third, given that discourse is generally produced for communicative purposes (Linell, 1998), speakers may modulate the phonetic properties of a switch within the constraints of a discourse based on perceived interlocutor needs and issues of predictability and intelligibility (e.g. Bell, Brenier, Gregory, Girand, & Jurafsky, 2002), in addition to the pragmatic function of the switch itself. As such, these discursive properties may partially drive the production of code-switches, masking underlying effects of interaction (i.e. for hyper-articulation of code switching see Olson, 2012). Lastly, in the case of Grosjean and Miller (1994), the stimuli used in the production paradigm have been selected to be bilingual homophones, a point noted in Bullock (2009). The use of bilingual homophones may lead to intentional exaggeration of the relevant contrasts, or *divergence*, leading to patterns being found that are not generalizable to the majority of naturally occurring code switches.

These, as well as other potential factors, may affect the phonetic implementation of code-switches, by definition produced within the context of a larger discourse. As such, while code switching paradigms have served to highlight the potential outcomes of interaction between the two systems and describe in detail the phonetic effects of code switching, they may not be representative of the underlying phonetic interaction resulting from the act of switching languages.

In contrast to code switching, the cued picture-naming paradigm prompts language switches free from discursive constraints and interlocutor effects, eliminates the possibility for advanced planning, and thus provides a clear view of the underlying nature of phonetic transfer. Using this type of language switching paradigm, researchers have begun to study the mechanisms that allow for the separation of two lexical systems (e.g. Costa & Santesteban, 2004; Costa, Santesteban, & Ivanova, 2006; Linck, Schwieter, & Sunderman, 2011; Meuter & Allport, 1999; Philipp, Gade, & Koch, 2007; Philipp & Koch, 2009; Schwieter & Sunderman, 2008 among others). While informative at the lexical level, this same paradigm has yet to be applied at the phonetic level. In addition, while lexical productions represent a relatively categorical distinction, with items either from language A or language B, the continuous nature of some phonetic features (e.g. VOT) provides a unique opportunity to investigate interaction of the two phonetic systems in the language switching paradigm.

Of the previous studies investigating language switching, particularly through the use of a cued picture-naming study, only Meuter & Allport (1999) make a brief mention of possible phonological effects. Specifically, in discussing their discarded data, they claim that while the overall number of errors was limited, "a number of phonological blends between the two languages" were found (p. 35). While they present no metric for determining what constituted a phonological blend, it is clear that, at minimum, the effect of language switching on phonetic production warrants further investigation. Other authors discuss production errors that result in discarded data, including false starts in the opposite language (e.g. Costa & Santesteban, 2004), and these types of errors may be what are included under the term of "phonological blend." However, it is unlikely that Meuter & Allport are referring to the fine-grained degrees of phonetic transfer, the subject of the current investigation.

1.4 Language Mode

Finally, while the actual point of language switching may serve as a catalyst for interaction between the two systems, it is possible that a shift in speaker expectation, akin to *language mode*, may also serve to cause an interaction between the two systems.

In natural speech, bilinguals can operate either monolingually, speaking in one of their two languages, or bilingually, alternating between them. Yet, such a division cannot be considered categorical. Addressing the range of options available to bilinguals, Hasselmo (1970) notes that Swedish-English bilinguals alternate between three different norms or "modes" of speaking: English-only, American-Swedish, and Swedish-American. Here, Hasselmo (1970) differentiates between monolingual communication and two different degrees of bilingual communication (for Spanish-English see Poplack, 1980). The idea of various language norms, or *language modes*, has been further explored, most notably by the work of Grosjean (Grosjean, 1985, 1997, 1998, 2001, 2008; Soares & Grosjean, 1984). In summary, bilinguals have the ability to move along a continuum from monolingual to bilingual speech production. Considering both psychological and linguistic factors, a bilingual must decide "which language to use, and how much of the other is needed—from not at all to a lot" (Grosjean, 2001, p. 2). Crucial for the current study, language mode has been discussed in terms of activation levels of a language A and language B.[1] When operating in the monolingual mode of language A, language B is minimally activated (Blumenfeld & Marian, 2007; Marian & Spivey, 2003). The concept of language mode has been used to refer to both written and oral speech (Grosjean, 1997), production and perception (Grosjean, 1998), and discussed in terms of the impact that it could potentially have on bilingual speech behavior.

Relevant for the current project, Soares & Grosjean (1984) note that the place of a bilingual along such a continuum may have an impact on their language production patterns (see also Grosjean, 1997), including phonetic realizations. Supporting this assertion are several studies that have indicated an effect of language mode on the frequency and types of language switching, as well as the phonetic production of code-switches. Treffers-Daller (1998), in an observational case study of a Turkish-German bilingual, showed that a bilingual's position on the language mode continuum affected the quantity and type of code switches (see also Lanza, 1992; Grosjean 2008).

Representing a case of language mode impacting phonetic production, Khattab (2003, 2009) presented a case study in which English-Arabic children were able to modulate their phonetic productions based on the communicative role. That is, they were able to produce English tokens with English-like phonetic patterns or Arabic-like phonetic patterns, depending on the communicative context and interlocutors. Similarly, Olson (2010) presented a study in which phonetically-controlled code switches were produced in a more monolingual-like context and a bilingual context. Results demonstrated a possible effect of language context on production at the segmental level, VOT varying with language mode, as well as the suprasegmental level, with variation in intonation patterns and duration.

While language mode considers both the linguistic and sociolinguistic variables, *language context* focuses exclusively on the linguistic content of a paradigm (Olson, 2012). Language context, for the current study, is defined as the quantity of each language present in a given discourse or experimental paradigm. Language context can be conceptualized as falling within the over-arching umbrella of language mode, but with the understanding that many other factors also serve to induce differing language modes. An effect of language context on production was demonstrated by Olson (2012) in a read-aloud paradigm in which subjects produced code-switches following either unilingual or bilingual discourse. The study was carried out in a laboratory environment, lacking interlocutors, with only the quantity of each language present being manipulated. Results showed a shifting of VOT for the code-switched tokens, depending on the preceding unilingual or bilingual discourse.

Thus, while language switching may serve as a catalyst for interaction between the two systems, such interaction may be subject to effects of the language mode or context of the greater interaction or paradigm.

Research Questions

The previous literature has highlighted two potential sources of phonetic interaction that may be exploited to shed light on the nature of the bilingual phonetic systems. The first, as has been seen through investigations on code switching, is that language switching may lead to interaction, most notably phonetic transfer, between the two sets of phonetic norms. These effects may be considered to be local, resulting from and evidenced at the point of the language switch. The second, more global, is that the language context itself may serve as a source for interaction. That is, a more balanced bilingual context may serve to induce phonetic interaction relative to a more monolingual context. Following from these two potential sources for phonetic interaction, the research questions for this project are two-fold:

RQ1: Does language switching impact phonetic production, as evidenced by differences in voice onset time between switched and non-switched tokens?

Hypothesis: Given the findings in the code switching literature, although acknowledging the potential mitigating effects of switching languages in connected speech, it is hypothesized that language switching will impact phonetic production. If, as is proposed at the lexical level, inhibition plays a role in language selection at the phonetic level, asymmetrical effects (L2 to L1 transfer) may be expected.

RQ2: Does language context impact phonetic production, seen as differences in voice onset time dependent on the language context of the experimental paradigm?

Hypothesis: Considering that language context, as well as language mode, has been shown to impact phonetic production, it is hypothesized that language context may serve as source of phonetic interaction. While asymmetrical transfer may be observed in the more monolingual-like paradigms, a more balanced bilingual task is expected to evidence less asymmetry.

Results obtained in answering these two questions will serve to create a clearer picture of the effect of language switching, specifically outside of connected speech. More broadly, these results will serve to enhance the current understanding of the language switching mechanism. While current theories regarding the cognitive mechanisms governing language switching have focused predominantly on the lexical level, this study begins to address the issue of language switching at the phonetic level.

2. Methods

To investigate the above research questions, two groups of Spanish-English bilinguals were recruited to participate in a cued picture-naming task (described in detail below). The potential effects of language switching and language context on phonetic production were investigated specifically with respect to VOT. As in previous research, this variable was selected to exploit the differences between VOT in English, being a long-lag language, and Spanish, a short-lag language. Tokens were produced as both switched and non-switched tokens, in three language contexts with varying ratios of Spanish to English.

2.1 Participants

A total of 20 Spanish-English bilinguals participated in the cued picture-naming study. Participants were recruited on the campus of the University of Texas at Austin and all received a stipend for their participation in the study. All subjects reported normal speech and hearing, and normal or corrected to normal vision.

Ten participants each were drawn from two distinct language background categories: (1) Spanish-dominant; and (2) English-dominant; Participants were grouped into these categories by means of a modified version of the Language Experience and Acquisition Questionnaire (LEAP-Q) (Marian, Blumenfeld, & Kaushanskaya, 2007), which employs a theoretical framework incorporating both language history and self-assessed language proficiency. Self-ratings have been used as a measure of linguistic ability (Bachman & Palmar, 1985; MacIntyre, Noels, & Clement, 1997; Shameem, 1998; Stefani, 1994), and have been shown to correlate reliably with linguistic performance (e.g. Flege, MacKay, & Piske, 2002). Additionally, results demonstrate that bilinguals are able to self-assess language proficiency in a manner that is highly correlated with behavioral performance (Chincotta & Underwood, 1998; Flege, Yeni-Komshian, & Liu, 1999; Flege, MacKay, & Piske, 2002; Jia, Aaronson, & Wu, 2002). The LEAP-Q was administered prior to beginning the task, and was provided in English or Spanish, depending on participant preference.

With respect to age of acquisition, Spanish-dominant participants (*n* = 10) are defined as those having learned Spanish as an L1, starting acquisition of English after the age of 12 (*M* = 15, *SD* = 3.91). Correspondingly, English-dominant participants (*n* = 10) are defined as those having learned English as an L1, beginning acquisition of Spanish after the age of 12 (*M* = 14.3, *SD* = 1.95). Given this age of acquisition criteria, there was no potential overlap in subject categorization, with subjects not fitting these criteria eliminated in a screening process.

Addressing language abilities, subjects were asked to rate their skills in English and Spanish, for both speaking and comprehension, on a Likert scale of 1 to 9 (1= don't understand; 9= native speaker). Spanish-dominant participants rated their Spanish as stronger than English in both speaking (English: $M = 6.3$, $SD = .67$; Spanish: $M = 8.9$, $SD = .32$) and comprehension (English: $M = 7.6$, $SD = .70$; Spanish: $M = 9$, $SD = 0$). Statistical analysis, employing paired two-tailed t-tests, confirms these differences (speaking: $t(9) = 9.75$, $p < .001$; comprehension: $t(9) = 6.33$, $p < .001$). Correspondingly, English-dominant participants self-rated their English as stronger than Spanish in both speaking (English: $M = 8.9$, $SD = .32$; Spanish: $M = 7.1$, $SD = 1.19$) and comprehension (English: $M = 9$, $SD = 0$; Spanish: $M = 8.1$, $SD = .32$), differences confirmed by statistical analysis (speaking: $t(9) = 9.00$, $p < .001$; comprehension: $t(9) = 9.00$, $p < .001$). Similar trends were also found in reporting of current daily exposure, self-perceived accent, and other-perceived accent, as shown in Table 2 below.

Lastly, given that not all bilingual communities and speakers engage in language switching, participants were asked to evaluate how often they switch languages, and how comfortable they are when others switch languages. Results showed that speakers switch languages with similar frequency and are equally comfortable when others switch languages ($t(19) = .592$, $p=.558$).

<Insert Table 2 about here>

In short, all speakers are considered to be highly proficient Spanish-English bilinguals and equally receptive to code switching. The participant groups (Spanish-dominant, English-dominant) differed in age of acquisition, self-rated dominance in speaking and comprehension, current daily usage, and perceived accentedness. Spanish-dominant speakers learned Spanish as an L1, are more dominant in Spanish, are exposed to more Spanish on a daily basis, and have less accented Spanish productions. English-dominant speakers showed a complementary trend, as they learned English as an L1, are more dominant in English, are exposed to more English on a daily basis, and have less accented English productions.

2.2 Stimuli

Target stimuli for the cued picture-naming study consisted of 12 target pictures, all black and white line drawings of non-ambiguous objects, taken from Snodgrass and Vanderwart (1980). To investigate the effects of language switching on phonetic production, target stimuli all contained voiceless, word-initial stops. Specifically, there were three English stimuli and three Spanish stimuli with word-initial /k/ (English: *corn*, *candle*, and *cat*; Spanish: *casco* 'helmet', *cama* 'bed', and *casa* 'house').

As Bullock (2009) notes, previous research has shown more of a tendency for shifts in the long-lag language (i.e. English, Greek) relative to the short-lag language, potentially owing to the "relatively compressed range of the short-lag stops" (p. 175). Thus, in order to provide a more sensitive measure in the short-lag language, an additional set of 6 tokens was included with word-initial /p/ in Spanish (Spanish: *pez* 'fish', *pie* 'foot', *pelo* 'hair', *pato* 'duck', *pan* 'bread', and *perro* 'dog'). While analysis from the word-initial /k/ stimuli will form the base of argumentation, word-initial /p/ data is included in a supporting role where relevant.

The target picture names have a similar number of phonemes in both English (*M* = 4.0, *SD* = 1.0) and Spanish (M = 3.88, *SD* = .60), and statistical analysis showed that there is no significant difference in number of phonemes of the picture names between the two languages (*t* = .869). In addition, all tokens are considered to be of high frequency (frequency <5,000 in frequency ranking list) (for Spanish frequency Davies, 2005; for English frequency Davies & Gardner, 2010), and again statistical analysis revealed no significant difference in frequency between the items in English (*M* = 2758.6, *SD* = 1097.16) and Spanish (*M* = 1702.1, *SD*= 1475.0) (*t* = .250). Lastly, all target tokens were non-cognate to minimize any cross-linguistic activation (Amengual, 2012). Table 3 below shows sample target pictures, with names in English and Spanish, as well as frequency and number of phonemes. An additional 113 pictures (Snodgrass & Vanderwart, 1980), also representing non-cognate tokens, were used as fillers.

<Insert Table 3 about here>

Target pictures were named in three different conditions. The *Monolingual English Context* consisted of 95% of tokens to be named in English and 5% to be named in Spanish. The *Monolingual Spanish Context* consisted of 95% of tokens to be named in Spanish and 5% to be named in English. The *Bilingual Context* condition consisted of exactly 50% of tokens named in English and 50% named in Spanish. It is important to note that the stimuli presented in each of the contexts were randomized, such that the language of the following stimulus to be named was never predictable by the subject. Each condition was presented in a separate experimental session, administered on different days. The order of the sessions was counterbalanced across all participants.

Within each condition, stimuli were presented in series consisting of a short list of pictures, varying from 6-14 pictures in length (*M* = 10), presented visually using SuperLab Pro 4.1.2 (Cedrus Corporation, 2010) experimental software. Targets were named in English and Spanish, both as switch and stay tokens. *Switch* tokens are defined as those in which the language of response was different from that used in the immediately preceding token. *Stay* tokens are those in which the language of response was the same as that used in the immediately preceding token. Unlike previous studies, (Costa & Santesteban, 2004; Costa, Santesteban, & Ivanova, 2006) the first picture in a series was always a filler, and thus never analyzed as a switch or stay trial. As illustrated in Table 4, in the Monolingual English Context, pictures were named in English as stay tokens and Spanish as switch tokens. In the Monolingual Spanish Context, pictures were named in Spanish as stay tokens and English as switch tokens. In the Bilingual Context condition, pictures were named in both English and Spanish as stay and switch tokens. In total, there were 144 tokens per speaker and a total of 2,880 target tokens (12 stimuli x 2 stimuli types (stay/switch) x 2 contexts (monolingual/bilingual) x 3 repetitions = 144 tokens per speaker).

<Insert Table 4 about here>

2.3 Procedure

The cued picture-naming study was conducted at the University of Texas at Austin, with participants comfortably seated approximately 24” from a computer display. Through a series of instructional slides, participants were instructed to name pictures as “quickly and accurately” as possible, and that the language of the token would be based on the color of the background, red or blue. The color-language pairings were counterbalanced across all participants, with half instructed that red indicated English and blue indicated Spanish. The remaining half of the participants received the inverse color-language pairing. Participants underwent a brief training, and completed 3 practice lists discarded from the analysis, to become acquainted with the procedure and the color-language pairing. The switch-to-stay ratio used in the practice lists was identical to that in the following naming task.

Each session began with presentation of instructions, with the language of the instructions corresponding to the language of the session (English, Spanish, or mixed-with half of the instructional slides in each language). Following the instructions, participants were presented with a set of red and blue circles with the words *ENGLISH* and *ESPAÑOL* 'Spanish', listed in the corresponding circles. Each series began with a fixation cross, presented in the center of the screen for 500 ms, followed by the first picture of the list. Each stimulus picture was presented in the center of a red or blue circle (800 x 800 pixels) and remained on the screen until the onset and offset of the voice key as triggered by participant production of the target word or 2000 ms passed. A blank interval of 700 ms was then presented, followed by the next stimulus in the trial list. The end of a series was indicated by a series of asterisks ('*****'). Participants started the following series by pressing the <spacebar>. The opportunity for short rest (approximately 1-3 minutes, as determined by the participant) was given after every 25 lists to limit fatigue. The procedure implemented here was designed, in part, drawing on previous research on language switching at the lexical level (Costa & Santesteban, 2004; Costa, Santesteban, & Ivanova, 2006; Meuter & Allport, 1999). Figure 1 presents a schema for stimulus presentation in a given list.

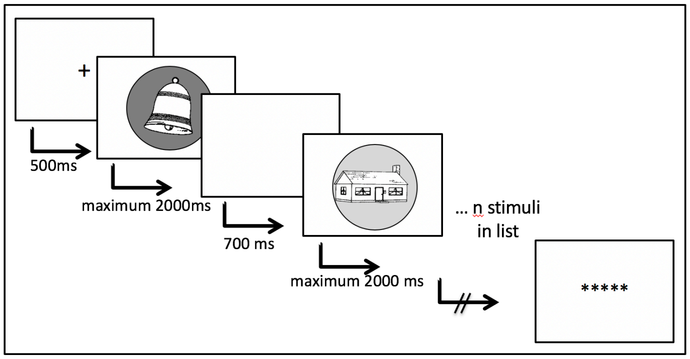


Figure 1: Schema of the time course of presentation of stimuli

Audio recordings of productions made during the picture naming task were made using a Shure Beta 54 head-mounted, wired, unidirectional microphone with a pop-filter, and Audacity 1.2.5 software with a sampling rate of 44.1kHz. Gain levels for the voice key were set for each subject and used in all 3 experimental sessions.

2.4 Data Analysis

Analysis centered on the production of VOT, defined as the temporal lag in milliseconds between the release of the closure of the stop consonant and the onset of voicing, as indicated by the presence of periodic vocal fold vibrations seen in the wave form and the voicing bar of the spectrogram.

Analysis of VOT included 2,880 tokens beginning with /k/ or /p/. VOT was marked by hand, using PRAAT 5.1.04 (Boersma & Weenink, 2009), and to eliminate inter-coder variation, all coding was performed by the experimenter. While boundaries were marked by hand, duration measurements were performed using an automated script. To confirm the reliability of the measurements, a randomly selected subset of 10% of tokens were blindly re-coded, demonstrating a high degree of intra-rater reliability ($r(286) = .985$, $p < .001$).

Tokens were initially examined and coded for two different classes of errors: production errors and naming non-agreement.[2] Production errors included responses in the opposite language, false starts in the opposite language, false starts in the target language, fillers and non-naming. A total of 11.8% of tokens were eliminated for production errors (English-dominant group: 11.4%; Spanish-dominant group: 12.2%). The total number of tokens eliminated from each subject was similar for both the English-dominant and Spanish-dominant groups, as demonstrated by a one-way ANOVA ($F(1, 18) = 0.059$, $p = 0.898$). Statistical analysis was conducted using R statistical software, version 2.6.1 (The R Foundation for Statistical Computing, 2008).

The main factors were considered in the statistical analysis of VOT were: (1) *Language Context* (Monolingual Context vs. Bilingual Context), (2) *Response Type* (Switch vs. Non-switch token). Given the inherent differences in VOT for English and Spanish (Lisker & Abramson, 1964), analysis was conducted separately on tokens in each language.

3. Results

3.1 Results- Spanish-dominant Group

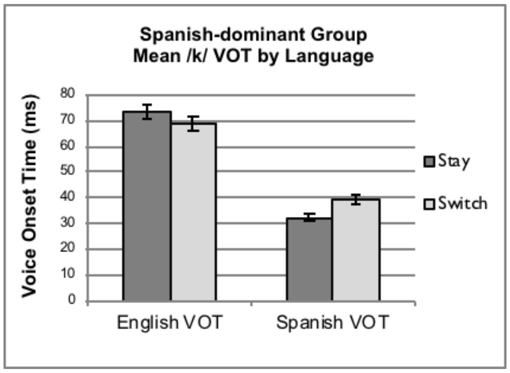
Initial analysis revealed that the Spanish-dominant group produced significantly different VOTs for English ($M = 69.5$ ms, $SD = 22.3$) and Spanish ($M = 35.1$ ms, $SD = 15.5$) word initial /k/ tokens ($t(502) = 22.71$, $p < .001$), and as such, each language is discussed separately. While these VOT values differ slightly from those published in Lisker & Abramson's (1964) seminal work, the categorical difference between English and Spanish is clear (for discussion of bilingual norms see Caramazza et al., 1973; Flege, & Eefting, 1987).

In considering the English word-initial /k/ tokens, a linear mixed model analysis was conducted, with main factors of *Response Type* (Switch vs. Stay) and *Language Context* (Monolingual vs. Bilingual), with *Subject* as a random effect. Results revealed no significant effect of either *Response Type* ($F(1, 298) = 2.22$, $p > .1$) or *Language Context* ($F(1, 298) = .3559$, $p > .1$), nor an interaction between the two main effects ($F(1, 298) = .960$, $p > .1$). As such, these results indicate that the VOTs produced for word-initial /k/ tokens were similar for Switch and Stay trials in both Monolingual (Switch $M = 68.69$ ms, SD = 24.3; Stay $M = 73.47$ ms, SD = 21.6) and Bilingual Contexts (Switch $M = 67.25$ ms, $SD = 21.8$; Stay $M = 67.88$ ms, $SD = 20.8$). Thus, when producing tokens in English, Spanish-dominant speakers have fairly consistent VOTs regardless of switching languages or not.

The results for the Spanish word-initial /k/ tokens stand out in contrast. Statistical analysis revealed a significant effect of *Response Type* ($F(1, 290) = 10.41$, $p < .001$), with Switch ($M = 37.12$ ms, $SD = 15.0$) trials produced with significantly greater VOTs than Stay trials ($M = 33.01$ ms, $SD = 15.9$). Crucially, there was a significant interaction between *Response Type* and *Language Context* ($F(1, 290) = 9.06$, $p = .003$), indicating that the difference between Switch and Stay trials was modulated by language context.

Post-hoc analysis (Tukey HSD) revealed that in the Monolingual Context, there was a significant difference in the VOTs produced in Switch trials and Stay trials (*diff.* = 7.83, *p* = .001). Specifically, Switch trials (*M* = 39.05 ms, *SD* = 16.3) were produced with significantly greater VOTs than Stay trials (*M* = 31.22 ms, *SD* = 18.1). In contrast, there was no significant difference in the VOTs produced in Switch and Stay trials in the Bilingual Context (*diff* = .40, *p* > .1).

Results for the Spanish word-initial /p/ tokens patterned after Spanish word-initial /k/ tokens, with a significant interaction between the two main factors of *Response Type* and *Language Context* (*F*(1, 448) = 7.79, *p* = .010). Post-hoc analysis showed that in the Monolingual Context, although not reaching statistical significance, the trend was towards a difference between the Switch (*M* = 21.27 ms, *SD* = 16.6) and Stay (*M* = 17.70 ms, *SD* = 16.3) tokens (*diff.* = 3.57, *p* = .102). There was no significant difference in the Bilingual Context between Switch and Stay trials (*diff.* = 0.30, *p* > .1). It should be noted that the direction of the difference for the VOTs of the Spanish Switch tokens represents a shift towards the higher English-like VOTs.



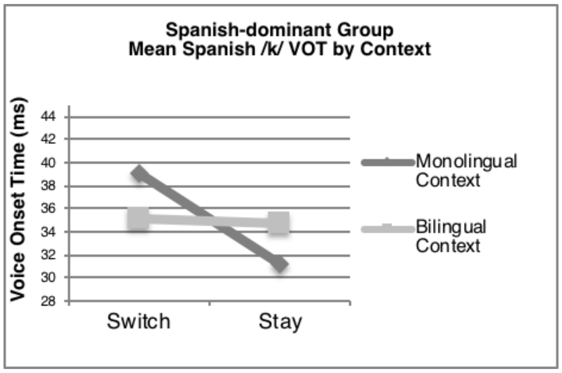


Figure 2a (left): Mean VOTs produced by Spanish-dominant speakers for word-initial /k/ tokens by language.
Figure 2b (right): Mean VOT produced by Spanish-dominant speakers for Spanish word-initial /k/ tokens by language context.

Illustrating the difference in the English and Spanish tokens produced by the Spanish-dominant group, Figure 2a shows the mean VOT produced in the Monolingual Context for Switch and Stay trials. Spanish switched tokens were found to be significantly longer than non-switched tokens. English switched tokens, in contrast, were not shown to differ significantly from their non-switched counterparts. Demonstrating the interaction between *Response Type* and *Language Context,* Figure 2b illustrates the VOTs produced by Spanish-dominant speakers for Spanish word-initial /k/ tokens. In the Monolingual Context, VOTs of Switch tokens were significantly longer than VOTs of Stay tokens. Again, it should be noted that when switching languages, the Spanish /k/ VOTs shift in the direction of English-like VOTs. In the Bilingual Context, in contrast, there is no significant difference between the Switch and Stay tokens.

3.2 Results- English-dominant Group

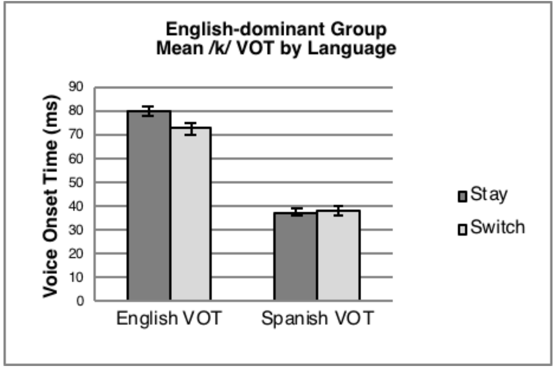
Again, analysis revealed that English-dominant speakers do produce different VOTs in English (*M* = 74.3 ms, *SD* = 18.7) and Spanish (*M* = 38.1 ms, *SD* = 15.3) (*t*(589) = 27.

028, $p < .001$) for word initial /k/, and as such, the results for each language is presented in turn.

Statistical analysis on the English word-initial /k/ tokens was conducted using a linear mixed model analysis with main factors of *Response Type* and *Language Context* and *Subject* as a random effect. Results indicated a marginally significant effect of *Response Type* ($F(1, 299) = 3.749$, $p = .054$) and *Language Context* ($F(1, 299) = 3.356$, $p = .068$). The main effect of *Response Type* demonstrates that VOTs are shorter in Switch trials ($M = 72.67$ ms, $SD = 18.2$) than Stay trials ($M = 76.13$ ms, $SD = 18.9$). When switching from Spanish to English, English-dominant speakers produced overall shorter English VOTs than when producing non-switched English tokens. Similarly, the main effect of *Language Context* demonstrates that English dominant subjects produce overall shorter VOTs in Bilingual Context ($M = 72.75$ ms, $SD = 16.2$) than Monolingual Context ($M = 75.99$ ms, $SD = 20.7$).

There was also a marginally significant interaction between the two main effects (*Response Type* X *Language Context*: $F(1, 299) = 2.978$, $p = .085$)[3]. While there was a significant difference in the VOT between Switch and Stay tokens, that difference was modulated by the Language Context. Post-hoc comparisons (Tukey HSD) revealed a marginally significant difference in the VOT between Switch and Stay trials in the Monolingual Context (*diff* = -6.87, $p = .080$), with Switch trials produced with a shorter VOT ($M = 72.56$ ms, $SD = 20.1$) than Stay trials ($M = 79.43$ ms, $SD = 20.7$). In the Bilingual Context, however, there was no significant difference between the VOTs produced in Switch trials ($M = 72.67$ ms, $SD = 16.2$) and Stay trials ($M = 72.84$ ms, $SD = 16.3$) (*diff.* = -.17, $p > .1$).

For the Spanish word-initial /k/ tokens produced by the English-dominant group, there were no significant effects of either *Response Type* ($F(1,303) = 2.786$, $p > .1$) or *Language Context* ($F(1, 303) = .205$, $p > .1$), nor was there any significant interaction ($p = .167$). English-dominant speakers produced similar VOTs in Spanish for Switch trials and Stay trials in both the Monolingual Context (Switch: $M = 37.46$ ms, $SD = 15.5$; Stay $M = 37.88$ ms, $SD = 17.1$) and Bilingual Contexts (Switch: $M = 41.07$ ms, $SD = 15.7$; Stay $M = 35.85$ ms, $SD = 12.4$). Results for Spanish word-initial /p/ patterned closely after those for the Spanish word-initial /k/, with no significant effects found of either *Response Type* ($F(1,522) = 0.148$, $p > .1$) or *Language Context* ($F(1,522) = 0.08$, $p > .1$), nor any interaction between the two main factors (*Type* ($F(1,522) = 0.001$, $p > .1$)). English-dominant speakers produced similar VOTs for Switch and Stay targets in both language contexts. Unlike the VOTs produced for the English tokens, VOTs of the Spanish tokens were not impacted by switching languages or the surrounding context.



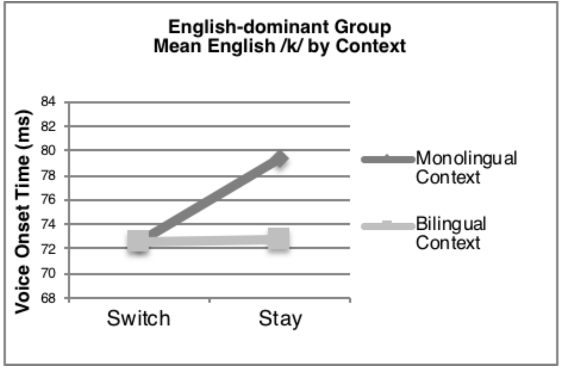


Figure 3a (left): Mean VOTs produced by English-dominant speakers for word-initial /k/ tokens by language.
Figure 3b (right): Mean VOT produced by English-dominant speakers for Spanish word-initial /k/ tokens by language context.

Illustrating the difference in the English and Spanish tokens produced by the English-dominant group, Figure 3a shows the mean word initial /k/ VOT produced in the Monolingual Context for Switch and Stay trials. While switched English tokens were found to be significantly shorter than non-switched English tokens, there was no difference between the switched and non-switched Spanish tokens.

Demonstrating the interaction between *Response Type* and *Language Context,* Figure 3b illustrates the VOT of English target tokens produced by English-dominant speakers in the Monolingual and Bilingual Contexts. In the Monolingual Context, when switching to English, VOTs are shorter than when producing a non-switched English token. Important to note, the significantly shorter English VOTs found in the switch tokens represents a shift towards the lower, Spanish-like VOTs. This difference is not found in the Bilingual Context, where the VOTs are similar in switched and non-switched English tokens.

3.2.3 Comparison of English-dominant and Spanish-dominant Groups

The findings presented above, and a comparison of the patterns found in Figure 2a and 2b, illustrate a clear difference between the Spanish-dominant and English-dominant groups in the Monolingual Context. The Spanish-dominant group showed a significant effect of language switching on the VOT of Spanish tokens, with VOTs of switched tokens shifting in the direction of longer, English-like VOT. In contrast, the English-dominant group showed a marginally significant effect of language switching on VOT production of English word-initial /k/, with VOTs shifting in the direction of the shorter, Spanish-like VOT. In short, these L1-dominant speakers showed significant changes in VOT when switching into their L1. However, neither group showed any effect when switching into the less-dominant L2.

In the Bilingual Context, neither group showed any difference between the VOTs of Switch and Stay tokens in either English or Spanish. That is, in the Bilingual Context, speakers produced consistent VOTs for a given language, and were not impacted by language switching. However, the difference between the performance in the Monolingual and Bilingual contexts are indicative of global effects (i.e. not related to the language switch itself), with language context impacting phonetic production.

4. General Discussion

Taken as a whole, two general trends emerge from the results, relating to the original research questions. Regarding the first research question, does language switching impact phonetic production, the hypothesis is confirmed. For all groups, switched tokens differed from non-switched tokens. This effect, however, was not found to be symmetrical. Specifically, as seen in the Monolingual context, language switching caused a shift in VOT whereby productions in the L1 shift in the direction of the L2 norms. The opposite pattern is not found, and L2 VOT productions were similar for switched and non-switched tokens. This interaction pattern can be described as asymmetrical, L2 to L1, transfer.

Addressing the second research question, does language context impact phonetic production, it is clear that language context serves to mitigate the effect of language switching. Specifically, the difference in performance in the Monolingual and Bilingual Contexts reveals a global effect of language context on phonetic productions.

Language Switching and Phonetic Transfer

Considering the previous results found in the code switching paradigm, the current results from the language switching paradigm stand out in contrast. Previous results from the code switching paradigm have found several different patterns of interaction, including: (a) no phonetic interaction (Grosjean & Miller, 1994); (b) bidirectional convergence (Bullock & Toribio, 2009); and (c) unidirectional transfer of a long-lag VOT to short-lag VOT (Bullock et al., 2006; Antoniou et al., 2011). While the unidirectional transfer patterns could be considered in terms of L2 to L1 or L1 to L2 transfer, it is important to note that the asymmetcial pattern of L2 to L1 transfer found in the current study is unique. That is, this is the first paradigm to show exclusively an effect on the L1 productions for distinct groups of speakers that are dominant in long-lag VOT and short-lag VOT languages.

The differing results found in the code switching paradigm and the language switching paradigm serve to highlight the influence of connected discourse on phonetic interaction. Specifically, the production of code-switches is subject to the effects of pragmatic functions (Auer, 1998; Chan, 2003; Gumperz, 1982; Reyes, 2004; Zentella, 1997), discursive properties (i.e. for predictability, see Olson, 2012), and utterance planning (Bullock et al., 2006). The potential impact of these factors is two-fold. Both pragmatic functions and discursive properties may serve to create varying degrees of hyper- and hypo-articulation (Lindblom, 1990), based on the communicative (e.g. loud environment) and cognitive factors (e.g. diminished local predictability, low frequency). This proposal finds support in the code switching literature, specifically at the suprasegmental level, in which local predictability has been shown to negatively correlate with a degree of suprasegmental prominence in both f0 height and duration (Olson, 2012). The impact of utterance planning can be seen in the modulation of the phonetic production prior to the point of switch (Bullock et al., 2006). Such findings imply an interaction of the two phonetic systems *prior to* the point of code-switch. As such, while research on the phonetics of code switching has highlighted some of the possible outcomes of interaction between phonetic systems, as well as clearly described some of the phonetic effects of code switching, it is not clear that these findings are representative of the underlying effects of language switching on phonetic interaction.

In contrast, the language switching paradigm, free from the mitigating effects found in connected speech, offers a unique opportunity to examine the underlying nature of phonetic interaction.[4] The experimental design presented here eliminated pragmatic and discursive factors, and there was no possibility for planning of the next token. Thus, by isolating the factor of the actual change from one language to the other, the language switching paradigm may serve to more accurately represent the underlying interaction of the two language systems. In addition, while these results have focused on the phonetic level, there are possible implications for the study of other aspects of code switching. In short, while the study of code switching is invaluable for understanding actual bilingual language practices, incorporating the language switching paradigm may serve to provide a more complete picture of bilingual cognitive behaviors.

Phonetic Switching and the Language Switching Mechanism

One might expect transfer from the stronger to the weaker language, as opposed to transfer from the weaker to the stronger. Similar to the asymmetrical switch cost findings in the language switching literature, the consistent L2 to L1 transfer found in the current study can be described as somewhat "counterintuitive" (Meuter & Allport, 1999, p. 25). The fundamental question then arises as to why the cued language switching paradigm may result in unidirectional transfer into the L1. While there has been a fairly significant body of research, and resulting theoretical debate, on the nature of the language switching mechanism at the lexical level, there must also exist a mechanism, independent or not, to separate the two phonetic systems of a bilingual. In short, given that bilinguals evidence different phonetic norms in their two languages, these phonetic norms must be separated in some manner. Any proposal for how bilinguals separate their two phonetic systems must account for several aspects of interaction and non-interaction between the two systems.

First, a proposal must account for the bilingual's ability to produce different phonetic norms in their two languages (e.g. Flege & Eefting, 1987; Caramazza et al., 1973; MacLeod & Stoel-Gammon, 2010). Given that bilinguals clearly implement different language-specific phonetic norms, they must be separated. Second, the proposal should account for the different findings of phonetic interaction, including the effects of language dominance and language switching, most specifically in the absence of discursive constraints (e.g. current results). Lastly, any theory on the separation of phonetic systems must account for the effects of language context or language mode on phonetic production (e.g. current results).

One possible hypothesis would be to posit that phonetic activation occurs only after lexical selection[5]. As such, once a lexical item were selected from language A, the phonetic norms of language A would be activated. While this hypothesis would account well for the bilingual's ability to differentiate between phonetic norms, with only the norms associated with a given language activated, it may not account for the differing levels of phonetic transfer evidenced in the current study. The second hypothesis, drawing on the Inhibitory Control Model (Green, 1986, 1998), is that to select a phonetic realization from Language A, Language B must be suppressed or inhibited. Correspondingly, when selecting from Language B, Language A must be inhibited.

At this point it bears noting the clear parallels between switching costs at the lexical level and phonetic production of language switches. Previous research at the lexical level, employing a similar cued picture-naming study but examining the reaction time delay between presentation of the stimulus and naming in the target language, has provided evidence of asymmetrical switch costs. Meuter & Allport (1999) employed a digit-naming task in which the background color of a given numeral corresponded to one particular language; a change in color cued a change in language. Results for the naming task showed that subjects were significantly slower to name a numeral in a switched trial than in a non-switched trial, a reaction time delay referred to as the *switch cost*. Counter-intuitively, results indicated an asymmetry in switch costs, such that switches into the first language (L1) were slower than switches into the second language (L2).

These findings have been replicated and expanded in subsequent research, demonstrating a role of proficiency and dominance, with balanced bilinguals demonstrating symmetrical switch costs (Costa & Santesteban, 2004; Costa, Santesteban, & Ivanova, 2006; Linck, Schwieter, & Sunderman, 2011), a proficiency threshold for a shift from asymmetrical to symmetrical costs (Schwieter & Sunderman, 2008), switch costs across the entire lexical system (Philipp, Gade, & Koch, 2007; Philipp & Koch, 2009), and the possibility for a shift in switch costs driven by language context (Olson, under review). Taken as a whole, this body of research indicates that language switching at the lexical level incurs a switch cost, with switched tokens taking longer to produce than non-switched tokens. In addition, the asymmetrical nature of such switch costs, with bilinguals incurring greater switch costs in their L1 than L2, has been widely replicated (although see Gollan & Ferreira, 2009).

Considering the phonetic level, in the Monolingual Context of the current study L1-dominant bilinguals demonstrated phonetic transfer when switching into an L1, while there was no phonetic interaction when switching into an L2. Given these parallels, it is logical to consider the possibility that similar mechanisms are at work at the lexical and phonetic levels.

According an Inhibitory Control Model (Green 1986, 1998; Kroll & Stewert, 1994), the greater switch costs incurred in the L1 are said to be the result of greater levels of inhibition required on the L1 relative to the L2. This proposal finds support both from the language-switching literature detailed above, as well as Evoked Response Potentials (ERP) (Christoffels, Firk, & Schiller, 2007; Guo, Liu, Misra, & Kroll, 2011; Jackson, Swainson, Cunnington, & Jackson, 2001; Kopp, Mattler, Goertz, & Rist, 1996; Verhoef, Roelofs, & Chwilla, 2009) and Functional Magnetic Resonance Imagine (fMRI) (Abutalebi et al., 2007; Hernandez, 2009; Hernandez, Dapretto, Mazziotta, & Bookheimer, 2001; Prince, Green, & von Studnitz, 1999) demonstrating consistent activation of the executive control function areas of the brain in language switching tasks relative to non-switching tasks. Furthermore, asymmetrical activation of the executive control regions have been found, with greater activation evidenced when switching into L1 relative to the L2 (Wang, Xue, Chen, Xue, & Dong, 2007)[6].

Yet, there is a crucial difference between the lexical and phonetic productions.[7] Specifically, at the lexical level, language selection is categorical. A given lexical item, cognates excluded, pertains either to language A or language B. At the phonetic level, productions may be considered to be continuous. Features such as VOT are not inherently categorical (i.e. English or Spanish), but occur along a continuum (0-120 ms). This distinction between the two levels may result in differential effects of inhibition. At the lexical level, greater temporal switch costs are incurred when overcoming the greater level of inhibition on the dominant language (L1). The similar asymmetrical effect on phonetic production, with only effects of L2 to L1 transfer, can potentially be accounted for by the differential degrees of inhibition placed on the weaker and stronger languages. When switching into the L1, residual inhibition on the previously inhibited L1 phonetic system leads to L2 to L1 transfer. However, when switching into the L2, there was previously little inhibition required on the L2 system, and as such switching into the L2 leads to ‘seamless’ access of the L2 phonetic norms and no L1 to L2 transfer. Thus, while inhibition may be used to separate two systems (i.e. lexical and phonetic), the nature of these systems leads to different impacts of inhibition. The inhibition at the lexical level results in asymmetrical temporal delays, while inhibition at the phonetic level results in asymmetrical transfer.

Further supporting the potential use of inhibition to separate the two phonetic systems is the widely reported claim that Inhibitory Control is not language or lexicon specific (e.g. Paradis, 1980; Meuter & Allport, 1999). Meuter and Allport (1999) take this as a working assumption, claiming that the processes for bilingual language selection are “similar in kind to those responsible for the control of task set in other monolingual and/or non-language task domains" (25). This assumption is well supported by comparisons between the language switching and task switching literature (for reviews see Kiesel et al., 2010; Monsell, 1996, 2003). In brief, similar asymmetrical costs have been found for task switching, with greater switch costs, or *shift costs*, observed for more dominant tasks (i.e. easier) relative to weaker tasks (i.e. more difficult) (e.g. Allport, Styles, & Hsieh, 1994). Similar parallels can be made with the neurolinguistic studies, in which activation of the executive control functions in language switching tasks (i.e. Abutalebi et al., 2007) is not found in language-specific brain areas. Inherent within the claim that Inhibitory Control is not language specific is the fact that it is not necessarily lexicon-specific. That is, if inhibition plays a role separating two lexicons and two task types, it is reasonable to posit that it may be employed at the phonetic level.

A Gradient Interpretation

While this interpretation (Inhibitory Control Model) seems to account for the paradoxical L2 to L1 phonetic transfer found, it must also adequately account for the effects of language context. Results in the current study indicate that there was a significant difference in the effect of switching on phonetic transfer in the Monolingual and Bilingual Contexts. With a categorical view of inhibition, similar phonetic interactions should result from language switching regardless of language context. Thus, considering the previously identified pattern of phonetic transfer, a switch from L2 to L1 should always be produced with similar degree L2 to L1 transfer. A comparison of the results for language switches in the Monolingual and Bilingual contexts does not support this prediction.

This difference in performance in the two contexts can be accounted for, however, with a gradient view of inhibition. Roughly equal levels of inhibition applied to both languages could eliminate the asymmetrical phonetic transfer found in the Monolingual Context. Specifically, driven by a globally reactive nature of inhibition, in the Bilingual Context both languages would remain partially inhibited. Thus, in a switch from L1 to L2, the L1 would remain partially inhibited, thus limiting the amount of transfer relative to the non-switched token in the same context. Similarly, in a switch from L2 to L1, the L2 phonetic system would be partially inhibited, again limiting transfer.

Again, this proposal finds support in language switching at the lexical level. Recently, the results presented by Olson (under review), demonstrated that bilinguals may shift their switch costs depending on the language context. Specifically, switching in a monolingual context resulted in asymmetrical switch costs, while switching in a balanced bilingual context resulted in symmetrical switch costs. Paralleling the proposal here, Olson (under review) supports a gradient interpretation of the inhibitory mechanism to account for these differences.

5. Conclusion

The present study has examined the interaction between a bilingual's two sets of phonetic norms, specifically by exploiting divergent voice onset times in English and Spanish, in an attempt to better understand the cognitive mechanism used for selection and separation of the two phonetic systems. In examining the phonetic data from the cued language switching paradigm, parallels emerged between previous findings at the lexical level (e.g. Meuter & Allport, 1999) and the phonetic level. Specifically, asymmetrical phonetic transfer was observed, with subjects evidencing L2 to L1 transfer in the Monolingual Context, similar to the well-documented asymmetrical switch costs found at the lexical level. These results may be accounted for by extending the Inhibitory Control Model (Green, 1986), originally proposed for language switches at the lexical level, with the asymmetrical results stemming from asymmetrical levels of inhibition required on the phonetic systems. The symmetrical results found in the Bilingual Context, with no differences observed between the switched and non-switched tokens, were explained as resulting from similar levels of inhibition on the two systems driven by contextually modulated levels of inhibition.

While the results of the current study are intriguing, there are several limitations, including the number of tokens and distinct stimuli, the focus on a single phonetic feature, and the use of a single language pairing (Spanish-English). Future research should address these limitations, and extend the current results into different bilingual populations. It should also be readily acknowledged that, while an ICM model for bilingual lexical selection has garnered support over decades of research, the current proposal for a phonetic-level ICM is tentative at best. Future research will be needed to confirm these findings and consider other accounts or interpretations of phonetic selection.

Acknowledgements

This project is based upon work supported by the National Science Foundation under Grant No. 1024320. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation. Additionally, I am indebted to the efforts of A. J. Toribio, M. Ortega-Llebaria**,** and all the bilingual participants for this study. A portion of this study was presented at the 6th *Laboratory Approaches to Romance Phonology,* and I am grateful for the feedback of those in attendance. Any errors, of course, remain my own.

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[1] Also worth noting is the association between activation/deactivation and inhibition, a parallel made by Grosjean (2008) with reference to the Inhibitory Control Model (Green, 1986).

[2] The word-initial /p/ stimuli *pez* ‘fish’ and *pelo* ‘hair’ incurred a high rate of naming disagreement, (i.e. *cabello* and *pelo* for the stimulus ‘hair’) resulting in an additional 255 tokens eliminated from the /p/ analysis.

[3] It should be acknowledged that these results were marginally significant, in contrast to the findings for the Spanish-dominant group. This difference may be resulting from the greater acceptable range of VOT production in English than Spanish (see Bullock, 2009), which may be seen through comparatively greater standard deviations in the English data (*SD* = 20.6) relative to the Spanish data (*SD* =16.2).

[4] As noted by a reviewer, the experimental paradigm here may not represent the daily experience of a bilingual speaker. However, the experimental paradigm employed here allowed for an examination of the interaction of these two systems outside the demands of natural speech, and as such may provide insight into the speech processing of bilinguals.

[5] This proposal may be akin to the Direct Access Hypothesis (e.g. Costa & Santesteban, 2004), although it is not clear how this lexically-based hypothesis would be adapted to the phonetic level.

[6] There is still some considerable debate about the language separation mechanism at the lexical level, and some authors propose a non-suppression based system (Costa, 2005; Finkbeiner, Almeida, Janssen, & Caramazza, 2006; Finkbeiner, Gollan & Caramazza, 2006, among others).

[7] Worth noting is that in the original proposal for the ICM, Green (1986) cites an example from Grosjean (1982), in which a French-English bilingual may produce the word *camion* ‘truck’ as though it were an English word, as demonstration of the “joint activation of both systems” (p. 214). Thus, while there is some tacit discussion of phonological transfer, there is no further discussion of the example.