Article

The International Journal of Bilingualism

International Journal of Bilingualism
2015, Vol. 19(4) 423–443

DOI: 10.1177/1367006913516035
ijb.sagepub.com
SAGE

Spanish-English bilingual voice onset time in spontaneous code-switching

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Abstract

In this study, we test the hypothesis that code-switching leads to phonological convergence by examining voice onset time (VOT) realization in the spontaneous code-switched speech of New Mexican Spanish-English bilinguals. We find that average VOT duration values in New Mexican Spanish fall within the range typical of non-contact varieties of the language, while New Mexican English displays VOT values in the low range of typical non-contact English. When we examine the VOT values of Spanish- and English-language words at varying degrees of proximity to code-switch points, we find a similar asymmetry. In Spanish, no effect of recent code-switching is evident. In English, conversely, close proximity to code-switch points results in a significant reduction in VOT values, i.e. in the direction of Spanish. We argue that while the data studied here do not directly demonstrate a causal connection between code-switching and long-term phonological convergence, they would not be inconsistent with such a view. We discuss a number of possible causes for the observed asymmetry between Spanish and English.

Keywords

Code-switching, phonology, convergence, Voice Onset Time, bilingualism, Spanish, English

Introduction: code-switching and phonetic convergence

Code-switching in spontaneous conversation can be understood as "discourse in which words originating in two different language systems are used side-by-side" by bilingual speakers (Backus, 2005, p. 307). The concept of "words originating in two different language systems" is best understood in the synchronic sense, as Backus (2005) means it, to indicate that bilingual speakers understand the words they use as indexed to or associated with each of their languages.

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In this way, the process of code-switching between two languages involves the simultaneous access of both language systems, including the phonological and phonetic representations (Fowler, Sramko, Ostry, Rowland, & Hallé, 2008).

The hypothesis that bilingual code-switching leads to convergence in language contact situations is widespread (Backus, 2004, p. 179; Clyne, 2003; Gumperz & Wilson, 1971; Muysken, 2000; Myers-Scotton, 2002), despite limited empirical evidence supporting the claim (see Torres Cacoullos & Travis, 2011 for discussion). Convergence, whereby two languages become gradually more similar (Aikhenvald, 2002, p. 1)—either as a general outcome of long-term contact or as a specific consequence of code-switching in the long- or short-term—is presumed to occur at all levels of the bilingual language system. Least explored among these are changes occurring at the phonetic level (see Bullock & Toribio, 2009; Bullock, 2009 for discussion). The lack of investigation of the phonetic outcomes of code-switching is particularly true for naturalistic, spontaneous data.

That bilinguals' linguistic systems may influence each other regardless of code-switching is well established (Kroll, Dussias, Bogulski, & Valdes Kroff, 2012). The observation that bilingual sound systems have the potential to interact to varying degrees at the phonetic level is supported by a variety of studies across diverse bilingual populations and experimental paradigms (e.g. Amengual, 2012; de Leeuw, Mennen, & Scobbie, 2012; Flege, Schirru, & MacKay, 2003; Fowler et al., 2008; Guion, Flege, & Loftin, 2000; Nagy & Kochetov, 2013; Olson, 2013). However, the notion that code-switching *per se* might act as a mechanism for interaction and convergence has found only mixed support in the literature, in particular as regards phonetics and phonology (Antoniou, Best, Tyler, & Kroos, 2011; Bullock & Toribio, 2004; Grosjean & Miller, 1994; Piccinini, 2011; Toribio, Bullock, Botero, & Davis, 2005). If it can be shown that convergence effects occur specifically near code-switch points in spontaneous speech, the case for code-switching as a driving force of phonetic convergence would be strengthened.

Studies examining code-switching effects range from reports of no convergence (Grosjean & Miller, 1994) to claims of bi-directional and gradient convergence (e.g. Toribio et al., 2005) and even hyper-articulation effects, whereby bilinguals exaggerate the distance between their phonetic categories (Bullock & Toribio, 2009). Importantly, the majority of this evidence relies on elicited or otherwise controlled productions, which may impact bilingual participants' behavior in a way that would not be evident in natural, spontaneous code-switching. While the laboratory setting has allowed researchers to control for diverse variables in their stimuli, the relevance of such studies for spontaneous speech production remains unclear.

The goals of our study are as follows. Our first aim is a descriptive one, to document the degree to which New Mexican Spanish and English demonstrate the effects of language contact as manifested in the realization of voice onset time (VOT) in word-initial voiceless stop consonants. Our second aim is to test the hypothesis that convergence effects may arise specifically in the context of code-switching, so as to determine whether code-switching itself can be understood as a mechanism of convergence. To do this, we look at the VOT of Spanish- and English-language words at varying degrees of proximity to code-switch points.

Background

The variable under analysis: voice onset time

The variable under investigation, VOT, is defined as the temporal lag of vocal fold vibration following a stop consonant release. The exact manner in which VOT is used in Spanish and English overlaps and diverges in important ways, but for the present study, it is sufficient to observe that in monolingual Spanish, the VOT of voiceless stop consonants is characterized by a short lag of approximately 0–30 milliseconds (Abramson & Lisker, 1973; Borzone de Manrique & Gurlekian, 1980), while in monolingual English, the VOT of the counterpart consonant class is characterized by a long lag, with durations minimally greater than 30 milliseconds, up to approximately 90 milliseconds (Lisker & Abramson, 1964). This robust difference in both languages in VOT durations in each language provides a potential measure of phonetic convergence via code-switching if these differences are found to be less robust in switching contexts. Convergence in the context of VOT can be understood as a reduction in the phonetic differences between the two languages, such that English VOT would demonstrate a reduced duration (towards Spanish-like values) and Spanish VOT an increased duration (towards English-like values).

Previous research on convergence and code-switching

Proffered evidence supporting or contradicting phonetic convergence via code-switching is based primarily on the analysis of elicited speech in laboratory contexts (Antoniou et al., 2011; Bullock & Toribio, 2009; Grosjean & Miller, 1994; MacSwan & Colina, 2005; Olson, 2012, 2013; Pedraza & Suárez, 2012; Toribio et al., 2005), while other accounts use isolated illustrative examples assumed to represent widespread, completed convergence (Clyne, 2003: 104; Hlavac, 2003). Recently, researchers have begun to use spontaneous speech data to test the convergence-via-code-switching hypothesis (Piccinini, 2011), but such studies remain relatively scarce.

A survey of the relevant experimental literature on the subject reveals mixed results. Most studies show some effect of code-switching on the phonetic implementation of VOT (one exception is Grosjean & Miller, 1994), but the direction and the size of the effect varies from study to study according to the experimental set-up. Scholars typically appeal to notions such as the relative language dominance or history of language acquisition of the bilingual participants (Bullock, Toribio, González, & Dalola, 2006) though operationalization of these characteristics varies.

In a standard elicitation paradigm, speakers are asked to either read sentences containing target items embedded near code-switch points (Antoniou et al., 2011; Bullock et al., 2006; Toribio et al., 2005) or are instructed to code-switch while performing a story-telling task (Grosjean & Miller, 1994; Pedraza & Suárez, 2012). Grosjean and Miller (1994, p. 205) concluded that the French-English bilinguals of their study switch in and out of languages completely, with no spill-over effects at the phonetic level. In this language pairing, the differences in VOT duration are comparable with the Spanish/English distinction. However, Bullock and Toribio (2009) found that VOT duration values in single-language contexts were significantly different from VOT values in switch contexts, where they shifted in the direction of the non-target language. This finding was similar to a previous study by the same research group (Toribio et al., 2005), with the added observation that certain asymmetric switching effects occurred according to the language dominance of the speaker group. Typically, but not always, the more dominant or earlier-acquired language is argued to be less susceptible to the impact of code-switching (Antoniou et al., 2011, p. 569). Speakers in the Spanish-English studies maintained largely separate VOT categories in single-language contexts, which were argued to more closely—though not perfectly—resemble those of monolingual varieties, in support of the idea that bilinguals can maintain separate phonemic categories in certain contexts (Bullock & Toribio, 2009; Flege & Eefting, 1988, p. 737; Piccinini, 2012).

A few studies on phonetic interaction in code-switching have utilized semi-spontaneous speech. Khattab (2009) examined VOT production in the semi-naturalistic speech of Arabic-English bilingual children growing up in the United Kingdom. The researcher found that VOT durations in each language demonstrated an effect of code-switching such that /ptk/-words in switch contexts had VOT values more similar to those of the previously used language.

Critically, not all bilinguals regularly code-switch, an observation which few elicitation studies have controlled for in participant selection. One exception is ongoing work by Pedraza and Suárez (2012; Suárez & Pedraza, 2013), who have examined the realization of /k/ among Spanish-English bilinguals who self-report to code-switch regularly. Their results revealed no statistically significant effect of code-switching on VOT durations, despite the use of the same elicitation paradigms employed by previous researchers.

Aims of the present study

Any conclusions drawn from experimental studies and the predictions they make must be tested against cases of spontaneous code-switching within communities and speakers that regularly code-switch, and in the patterns evident in the speakers' own speech, and not a hypothesized norm. The present study investigates the impact of code-switching on VOT in English- and Spanish-language tokens in the New Mexico Spanish-English Bilingual (NMSEB) corpus (Torres Cacoullos & Travis, in preparation), which features spontaneous, fluid, and unmonitored code-switching.

We analyzed the VOT durations of word-initial voiceless stops in both Spanish and English preceded by a code-switch from the other language relative to their temporal distance from the code-switch point. We predict that words more recently preceded by a code-switch will demonstrate evidence of cross-language influence and convergence, such that the VOT values of Spanish-language /ptk/-words will increase in the proximity of English-language material, while the VOT values of English-language /ptk/-words will decrease in the proximity of Spanish-language material.

Method of analysis

The community and corpus under analysis

Our study focuses on a situation of language contact between Spanish and English in central-northern New Mexico. The Spanish variety in question, Traditional New Mexican Spanish (henceforth Traditional NM Spanish), is currently used within a bilingual community that, importantly for the purposes of the present study, regularly engages in code-switching. This variety of Spanish also features a number of phonological traits that distinguish it from related varieties of the language (Bills & Vigil, 1999; Lipski, 2008, pp. 204-206). However, fine-grained phonetic comparisons between Traditional NM Spanish and English are rare (Vigil, 2008 is an exception). There also appear to be no studies of Northern New Mexican English that explore the question of Spanish influence.

The NMSEB corpus that we use to test the convergence-via-code-switching hypothesis comprises informal, conversational interviews of primarily older family members and close friends. These provide an ideal context in which to test hypotheses about Spanish-English linguistic convergence at all levels of linguistic structure. The NMSEB corpus is a unique resource in that it specifically targets code-switching among practiced, frequent code-switchers for whom code-switching is an unmarked, common in-group discourse mode (Gonzales Velásquez, 1995, 1999). The speakers featured in the corpus demonstrate high proficiency in both of their languages, based on self-reporting, field-worker observations, and their speech during the course of the interviews themselves (see Wilson & Dumont, 2015). Given this, in combination with their frequent employment of code-switching, the NMSEB corpus allows for the examination of the impact of code-switching on the phonetics of a bilingual population that engages regularly and naturally in the practice.

The present study is based on a subset of interviews from the NMSEB corpus, specifically the first 18 corpus files. These comprise 17.5 hours of speech, approximately 180,000 words, and a total of 20 participants (excluding the interviewers themselves and those participants who appeared only briefly during the recordings). The participants also completed a questionnaire. In answer to questions about which was their "first" and which their "second" language and where they learned English, the majority of the participants indicated that Spanish was their first language, with English being learned in primary school. It is important to stress that the terms "acquisition" and "learning" are not always understood the same way, and that for the NMSEB participants these terms may well be colored by notions of correctness and literacy. It is unlikely that these bilinguals had no exposure to English whatsoever before entering primary school. Their self-reporting nevertheless suggests that this time point marked a significant increase in their exposure to English and, more importantly, their own greater and more sustained use of English.

The interviews were recorded using a Zoom H4n hand recorder at a sampling rate of 44 kHz with 32 bit quantization. The transcription of the interviews was completed using ELAN (Sloetjes & Wittenburg, 2008), a software program that allows for time-aligned transcriptions that are export-compatible with the *Praat* acoustic analysis software program (Boersma & Weenink, 2013). The interviews were transcribed in ELAN in accordance with Du Bois, Schuetze-Coburn, Cumming, and Paolino (1993)'s transcription protocol, according to which conversational features such as pauses, false starts, laughter, and speaker overlaps are noted, and each line of transcript corresponds to an Intonation Unit (IU), defined as "a stretch of speech uttered under a single, coherent intonation contour" (1993, p. 47). For a full description of the composition of the corpus, the characteristics of its speakers and the transcription methods used, see Travis and Torres Cacoullos (2013).

Data selection procedure

The selection of tokens for our acoustic analysis followed a three-step procedure that was largely automated via scripts written in *R* (R Core Development Team, 2012) and *Praat* (Boersma & Weenink, 2013).

Selection of /ptk/-tokens. We first identified all words containing an initial /p/, /t/, or /k/ in both languages produced by the NMSEB participants (henceforth */ptk/-words* or */ptk/-tokens*). We restricted our analysis to words in IU-initial position so as to hold the prosodic context in which the words were produced as constant as possible. In that same process, we also eliminated tokens marked by the NMSEB corpus transcribers as unclear and words that were truncated mid-articulation.

Identification of code-switch points. The second step of the data selection procedure required an analysis of the interviews with respect to their code-switch points. A custom script identified all time points at which speakers code-switched between Spanish and English (and vice versa), based on a language coding scheme in which each IU is assigned a language code by transcribers based on lexical content. To explain the process, we briefly review relevant aspects of the NMSEB corpus language coding categories.

In the simplest case, an entire IU has either English-only or Spanish-only lexical content, marked E and S, respectively. IUs containing an internal code-switch, or several internal switches, are marked accordingly as SE, ES, SES, etc. In principle, a code-switch point was operationally defined as a point at which a code S directly follows a code E, or vice versa, regardless of whether the sequence spans two IUs or is contained within one IU. In theory, then, the distance of any given

Table 1. Treatment of discourse markers.

Language-non-specific discourse markers	*okay/mkay, hey*
English-specific discourse markers	*well, yeah, yes, anyway, like, you know, right, so*
Spanish-specific discourse markers	*bueno, pues, sí, entonces, oye, ves, claro, ay*

/ptk/-word from the nearest preceding code-switch point can be identified as the distance to the time of the nearest previous SE or ES switch.

Several factors complicate this simple logic. To begin, some IUs contain non-linguistic material, such as laughter or filler words like *uh* or *um*. These were considered language-neutral and were ignored by the script so that code-switches separated only by such material were included in the analysis (1).

(1) Token preceded by filler word

Susan	*I don't know if that's what it meant.*	*'I don't know if that's what it meant'*
Gabriel	***hm**.*	'**hm**.'
Susan	*… pero se llamaba .. Alazar.*	'but he was called .. Alazar.'

[01 El abuelo, 0:26:02-0:26:06][1]

Another complication arises in the case of discourse markers used by our speakers of interest. The decision as to whether the marker belongs to the previous or the upcoming language is often not straightforward, as some are used in both English and Spanish. We distinguished between discourse markers that we identified as being used in monolingual varieties of *both* languages (e.g. *okay*), discourse markers that we identified as English-specific (e.g. *you know*, *so*), and discourse markers that we identified as Spanish-specific (e.g. *pues* 'well'). We based these assessments on the appearance (or non-appearance) of each discourse marker in the Corpus of Contemporary American English (COCA) (Davies, 2008-) and the Corpus del Español (Davies, 2002-), though note that *so* is more frequent than *entonces* in monolingual Spanish stretches in this community (Aaron, 2004, p. 173). A list of the relevant discourse markers and their treatment is given in Table 1.

A considerable challenge is posed by single, other-language words surrounded by English or Spanish (Aaron, 2015; Sankoff, Poplack, & Vanniarajan, 1990; Torres Cacoullos & Aaron, 2004). Such 'lone' items have not yet been distinguished in the NMSEB coding protocol as being established borrowings (*dad*), spontaneous borrowings (*flowers*), or partially integrated borrowings (*pushó*) within the bilingual NM speech community. This distinction is important, as it has implications for the degree of cross-language activation that is occurring in the use of such words. A similar problem is posed by place names and the names of famous people, which have been hypothesized to occupy a special place in the bilingual lexicon due to their socio-cultural specificity (see, for example, Witteman & van Hell, 2009 on such terms, and Clyne's (2003) triggering hypothesis). As in the case of 'lone' other-language items, it is not clear whether such items are indexed as Spanish or English in the minds of the interlocutors.[2] A final issue involves IUs for which the language cannot be identified, including IUs consisting only of *no*, as well as those containing unintelligible words, i.e. words that could not be accurately transcribed but which are still identifiable as meaningful speech. As such, these IUs are potentially English or Spanish.

The practical implication of these IU types that are potentially of either language (lone other-language words, names, unintelligible words, and IUs containing only the word *no*) is that such IUs essentially leave the following discourse in an indeterminate state as to when the nearest preceding code-switch point occurred. For instance, we cannot say with certainty that a code-switch occurred before or after a 'lone' item, nor can we rule it out. As a result, potential tokens that are preceded by such items cannot be assigned a distance value relative to the nearest preceding code-switch, and fall outside of the scope of the present study. Our script was designed to identify points at which a continuous stretch of English or Spanish was interrupted by one of these IU types was interrupted by one of these IU types.

Two additional exclusion criteria were applied that both follow from the fact that the NMSEB corpus recordings include multiple participants and frequent speaker changes. First, we included only tokens that follow within-speaker code-switches, i.e. code-switches that occur within the speaker's own speech. We excluded tokens that follow across-speaker code-switches, i.e. where one speaker simply continues in the other language. The reason for excluding across-speaker switches is that they are not clear as to what level of language activation the speaker who continues in the other language had been in previously. Across-speaker code-switches are quite common in the NMSEB corpus, so that this step resulted in a further reduction of data points. The second, less frequent, code-switch configuration excluded is one in which the code-switch happens within one speaker's speech, but where there is a subsequent speaker change and the subsequent speaker then produces the target. In other words, we included only tokens in which the person who code-switched and the person who produced the target word were one and the same.

Identification of analyzable /ptk/-tokens. The third step of the data selection procedure was to match up the list of /ptk/-words with the list of code-switch points and stretches of unambiguous Spanish or English. This gave us the list of tokens for further analysis.

Overall, the initial data selection criteria discussed above yielded approximately 300 relevant English /ptk/-tokens and approximately 1100 relevant Spanish /ptk/-tokens. This discrepancy is not due to the fact that the corpus includes more Spanish speech than English speech. Rather, Spanish /ptk/-words include more words that frequently occur in IU-initial position, e.g. *pero* 'but' and *pues* 'well'. There is only one such item in English, the word *cause* (*because*). Given this asymmetry, we decided to acoustically analyze only a subset of 600 of the Spanish tokens. We devised a data-reduction procedure that was designed to provide us with an essentially arbitrary subset and, at the same time, reduce some of the quantitative imbalance of the data. Some lexical items, such as the aforementioned function words and discourse markers *pero* 'but', *que* 'that', *porque* 'because', *pues* 'well', are overrepresented in the data, as are some speakers who talked more than others. A script arbitrarily removed data points from only these overrepresented speakers' lexical items, without letting the token frequency of any lexical item drop below 20 and without letting the number of /ptk/-tokens contributed by any one speaker drop below 40.

Exclusions due to phonetic criteria

We performed a preliminary acoustic analysis of the remaining tokens and came up with a list of additional exclusion criteria based on practical problems with the acoustic measurements. In some cases no definitive acoustic measurement could be taken for one of several reasons having to do with the fact that the corpus is composed of naturalistic field recordings.

For instance, some tokens showed no clearly defined stop release (N=99). This is common in field recordings in which the microphone is not very close to the speaker's mouth. In other cases, overlapping speech or background noise prevented measurement of the VOT (N=46). Finally, some tokens had a completely devoiced vowel following the /ptk/-onset (N=10), while others appeared to have undergone voicing (N=9) or a complete deletion of the stop consonant (N=16).

In addition, we made language-specific exclusions having to do with apparent allophonic variation due to affrication processes. First, /t/ preceding /ɹ/ was so frequently affricated in English that we excluded all cases (N=8). We also excluded analogous cases of affrication in Spanish /tr/

sequences (*N*=16). In the Spanish /k/ tokens, we also observed affrication in the form of a palatal fricative in place of aspiration, and excluded accordingly (*N*=32).

Following these exclusion criteria, we arrived at the final token numbers of 245 English /ptk/-tokens and 397 Spanish /ptk/-tokens. Note also that one of the 20 speakers of interest, Anita, was excluded in this way, as none of her tokens met our criteria.

Dependent variable: voice onset time

Our phonetic analysis was based on a standard acoustic definition of VOT as the time difference between two acoustic events in the course of a word-initial voiceless stop (Lisker & Abramson, 1964, p. 385): the onset of the release burst and the onset of periodicity. We identified the former as the time point when the acoustic waveform shows a rapid pressure rise followed by a transient (burst noise). We identified the latter as the point where the waveform begins to show a periodic oscillating pattern, regardless of whether that pattern already displays the same shape as it does during later parts of the vowel.

Independent variables

We coded each token for several additional variables, some of which required further acoustic measurements. To begin, we coded the tokens for the type of voiceless stop (/p/, /t/, or /k/); the speaker who produced the word; and the lexical item containing the stop, treating different inflectional forms as separate lexical items, given the differences in phonological shape.

Our major independent variable is more complex: the time since the nearest preceding code-switch. We defined the time of a code-switch as the onset of the first word produced in the switched-into language. To determine this point we used the timestamp of the start of the IU that contained the code-switch, as identified by our script (see above), making manual adjustments in the case of IU-initial pauses and for IU-internal code-switches. Having determined this exact time point, the time from the code-switch point was established by subtracting the time of the release burst from the time of the code-switch point.

One known covariate of VOT is speech rate (Kessinger & Blumstein, 1998; Miller, Green, & Reeves, 1986). A faster speaking rate leads to smaller VOT values. We used an indirect measure of speaking rate: the duration of the following vowel. Having vowel duration as a covariate was also a way for us to capture a possible effect of syllable stress on VOT, as stressed syllables in English are longer, increasing VOT (Gimson, 1962). Thus, our covariate of vowel duration was used to control the effects of both speaking rate and stress. Additionally, as many of our /ptk/-words are polysyllabic, we predicted the effect of vowel duration on VOT to be mediated by the number of syllables contained in the word due to polysyllabic shortening. We therefore included the number of syllables in the word as an independent variable and tested a possible interaction of this variable with vowel duration.

We coded each /ptk/-token as to the height of the vowel in the syllable containing the initial voiceless stop (Berry & Moyle, 2011) (distinguishing three degrees of height: high, mid, and low), and whether an approximant was present, and where there was one, the type of approximant. The presence of an approximant following the voiceless stop, as in *clear* or *crew*, is an additional potential covariate of VOT duration. We are aware that the inclusion of stops followed by an approximant is not consistent with most previous work on VOT, which is typically restricted to stops immediately followed by a vowel. Our decision to include the pre-approximant context was due to the constraints of working with a finite set of naturalistic data in which tokens of the desired phonological type cannot be multiplied, as is the case in experimental studies.

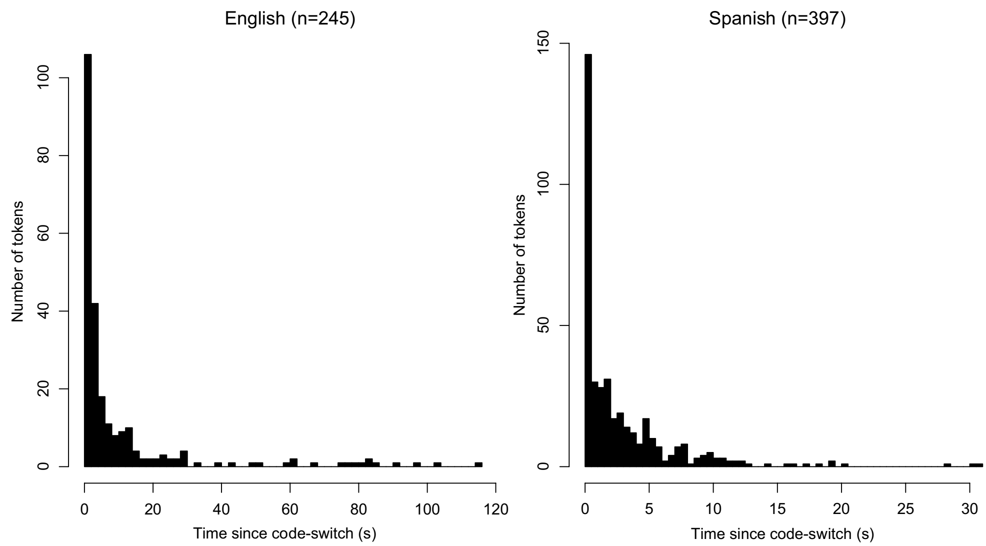

Figure 1. Amount of data points of /ptk/-tokens at different distances from a code-switch point.

Finally, we coded the data for the lexical frequency of the item containing the voiceless stop. We obtained frequencies from the NMSEB corpus itself on the basis of the transcripts of 30 interviews in the corpus. We also obtained Spanish and English frequency values from the oral sections of the Corpus del Español (Davies, 2002-) and the COCA (Davies, 2008-), respectively.

Results

We begin with a descriptive summary of the distribution of the raw VOT durations. The histograms in Figure 1 show that almost all measurements come from /ptk/-words produced shortly after a code-switch. In fact, in both the English and Spanish datasets, a large share of the /ptk/-word tokens have a distance value of zero, i.e. they are the first word produced in the switched-into language (English: 22%; Spanish: 35%); two-thirds or more fall within a 5-second window following the code-switch (English: 66%; Spanish: 81%); and the vast majority fall within a 15-second window (English: 84%; Spanish: 97%). This skewed distribution results from the fact that code-switching is copious in these materials and that stretches of continuous, unambiguous Spanish or English are usually short.

The boxplots in Figure 2 illustrate the central tendencies and the variability of the English and Spanish VOT durations separately for each stop type. The plot whiskers extend to 1.5 times the interquartile range from the box. Means are marked with a '+'. The numerical VOT means and standard deviations for each stop type in each language are also summarized in Table 2.

The values in Figure 2 and Table 2 show the well-known, general VOT differences between Spanish and English, whereby Spanish voiceless stops have consistently shorter VOT durations than their English counterparts. What is striking, however, is how short the English VOTs are overall, with a grand mean of only 36.6 milliseconds. This value is considerably lower than VOT means typical of monolingual English populations (e.g. Lisker & Abramson, 1964, p.394). The Spanish VOT mean (21.9 ms), meanwhile, is within the range reported for monolingual Spanish populations (e.g. Abramson & Lisker, 1973, p. 392).

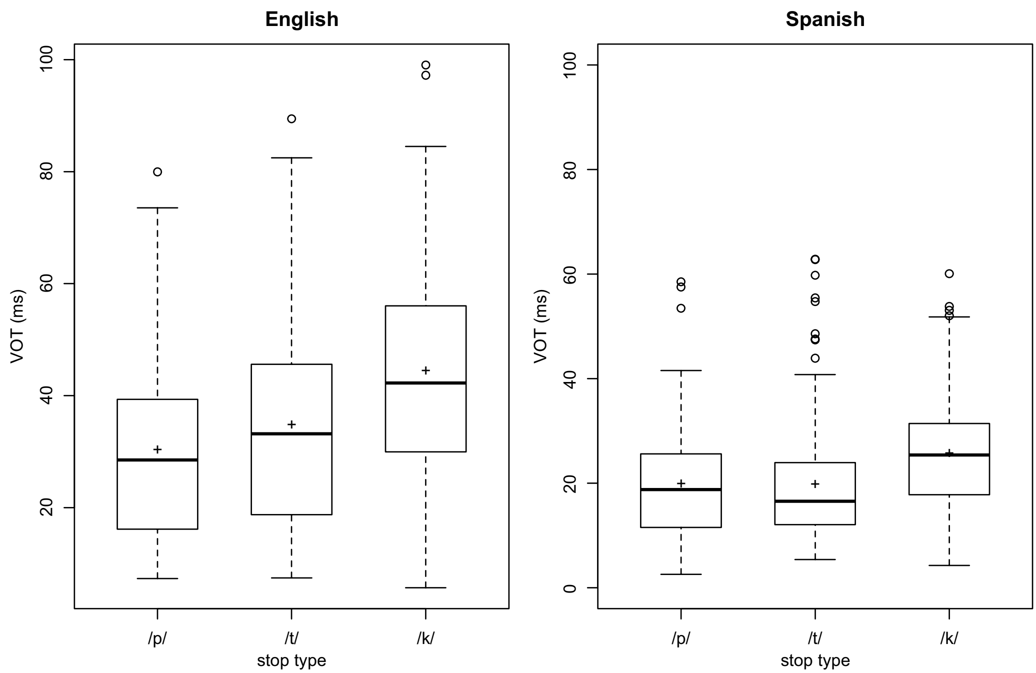

Figure 2. English and Spanish VOT distributions.

Table 2. VOT means, standard deviations (in milliseconds); token numbers.

	English			Spanish		
	mean	standard deviation		mean	standard deviation	
/p/	30.4	17.6	n = 59	19.9	10.6	n = 114
/t/	34.9	18.9	n = 103	19.9	11.6	n = 145
/k/	44.5	20.2	n = 83	25.9	11.3	n = 138
grand mean	36.6	18.9	n = 245	21.9	11.2	n = 397

We now turn to the relationship between VOT and the variable "time since the nearest preceding code-switch point". The scatterplots in Figure 3 and Figure 4 show the distribution of VOT values in the time window from 0–15 seconds following a code-switch. Note that the English data in Figure 3 show a marked trend in the predicted direction that characterizes the first few seconds after a code-switch point, and which is observable across all three stop types. To bring out this trend in the scatterplots, we have superimposed on the VOT values from 0–5 seconds solid gray lines produced by a scatterplot smoother. The slopes of the lines indicate a rapid increase in VOT from the tokens produced at the switch-point to those produced within a few seconds thereafter.

The Spanish data in Figure 4 show no similar trend. If there were a carry-over effect from English, we would expect VOT to be initially high and then to decrease immediately after the code-switch. But visual inspection of Figure 4 does not suggest that VOT values near the code-switch point are systematically different than those produced later. Only one of the three stop types, /p/, shows a tendency in this direction.

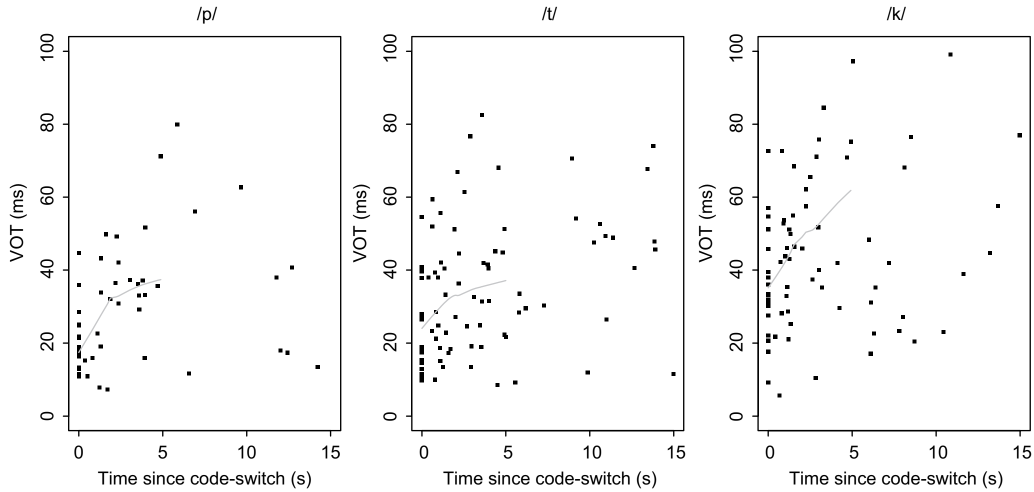

Figure 3. English VOT values by time from the code-switch point.

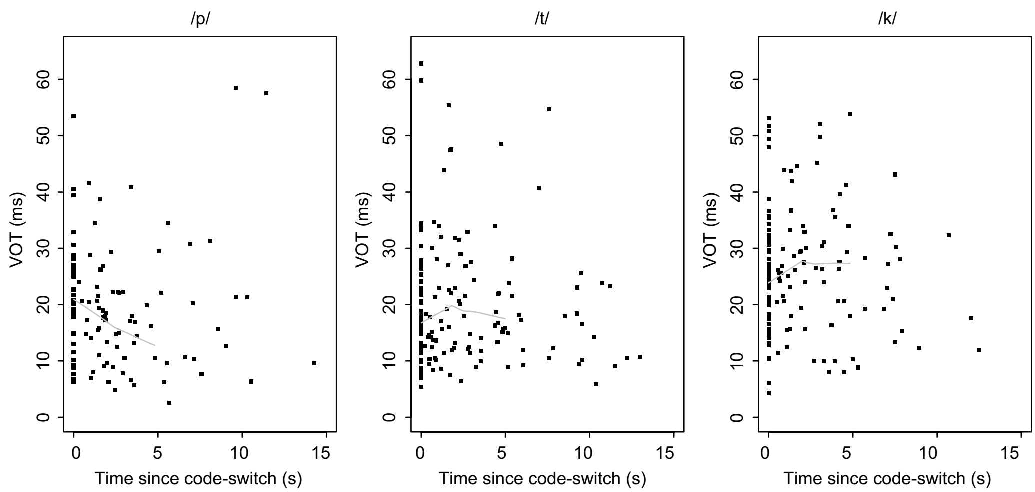

Figure 4. Spanish VOT values by time from the code-switch point.

To test whether the VOT durations are indeed partially a function of the recency of a code-switch from the other language, we fit separate regression models to the English and Spanish data with VOT as the dependent variable. We chose linear mixed-effects regression, specifically the *lmer* function that is part of the *lme4* package (Bates, Maechler, & Bolker, 2012) written for the statistical software *R*. Mixed-effects modeling has become a widely used tool in variationist sociolinguistics within the last few years because it allows for the effects of grouping variables, typically participants (interviewees) as well as lexical items, to be systematically controlled. This is a particular concern in naturalistic datasets where it is practically always the case that more tokens are contributed by some speakers and by some lexical items than by others (Johnson, 2009). As these concerns apply directly to our dataset we opted for a mixed-effects model with random intercepts, following Johnson (2009).

Table 3. Fixed effects for the English VOT data. Time from switch measured in seconds, Vowel duration measured in milliseconds.

	Estimate	*t*-value	*p*-value
Intercept	33.298	4.954	0.0000
log(0.253 + time_from_switch)	1.467	2.313	0.0216
vowel_duration	0.051	3.434	0.0007

Our model for both languages tested the predicted effects of three fixed-effect variables: (i) our main hypothesized predictor, the time elapsed since the most recent code-switch; (ii) vowel duration; and (iii) the number of syllables in the /ptk/-word. We tested the latter in interaction with vowel duration. The following grouping variables were entered as random effects: (i) the speaker who produced the /ptk/-word; (ii) the lexical item containing the voiceless stop; (iii) the stop type; (iv) the height of the vowel following the stop; and (v) the presence of an approximant following the voiceless stop and, where one was present, the type of approximant.

Starting with the fixed effects, the English data show no linear effect of the time since the nearest preceding code-switch on VOT durations. That is, there is no evidence that VOT changes at a constant rate as one moves further away from a code-switch point. This is not surprising, as a linear increase would mean that VOTs keep rising, or falling, without reaching a constant level. It is more plausible that VOT durations are only temporarily variable and then stabilize. This is also what the scatterplots in Figure 3 suggest. One common way of modeling a non-linear relationship between two variables is through a logistic transformation. Log-transforming the time dimension expands time intervals at the low end of the attested range and shrinks time intervals at the high end of the scale. In this way, a temporary effect whereby VOT initially changes quickly but then more and more slowly can be modeled. Indeed, once the variable of time since the nearest preceding code-switch is entered in log-transformed form, it significantly predicts English VOT durations (p = 0.0216; see Table 3).[3] Since log(0) is undefined in a logarithmic transformation, and many of our data points have a time value of 0, we offset all time values slightly from zero by adding a small constant. In our choice of a constant, we attempted to arrive at an optimal model fit. In order to find the optimal constant, we ran a series of models that successively offset the time values in increments of 10 milliseconds between 10 and 500 milliseconds, and chose the offset value that produced the best model fit. Our measure of a good fit was the correlation of the VOT values predicted by the regression model with the attested VOT values. Because mixed-effects models do not provide traditional goodness-of-fit measures, we built a series of traditional (fixed effects-only) models with the same fixed predictors as the relevant mixed model and with all VOT values adjusted by the intercept values of the random-effect structure of the mixed model, and then used the adjusted R-squared values of these traditional models as our measure. We chose the traditional linear model with the highest adjusted R-squared. The offset value of this optimal model was 253 milliseconds from zero. The shape of the logarithmic function, including the slightly shifted zero-crossover point, is illustrated in Figure 5.

Besides a significant effect of the time since the nearest preceding code-switch, we also find a significant effect of vowel duration on the English VOT values. As predicted, VOTs are positively correlated with vowel duration ($p < 0.001$). However, this effect does not interact with the number of syllables per word. We therefore included only two fixed effects in the final model. These effects are summarized in Table 3. The unit of measurement for VOT duration and for vowel duration is milliseconds. The unit of measurement for the time since the nearest preceding code-switch point

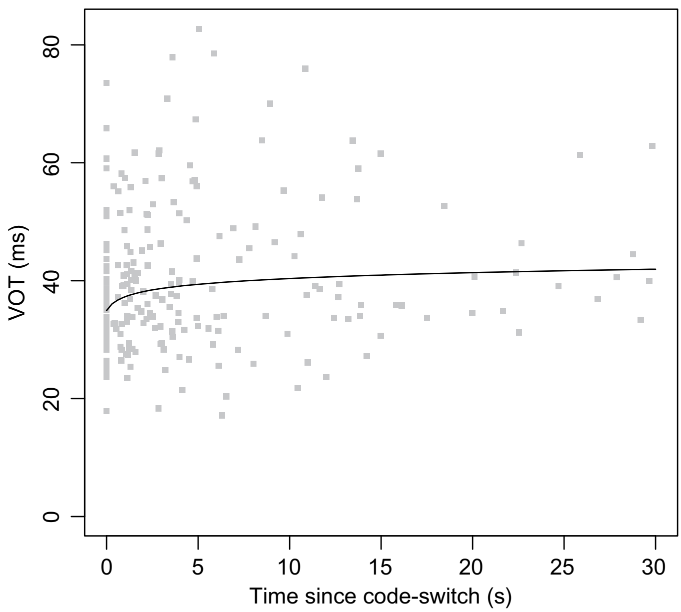

Figure 5. Regression line showing the log-linear increase in the English VOTs.

is seconds. To calculate the p-values we used the *pvals.fnc* function of the *languageR* package for R (Baayen, 2011).

A complete summary of the random-effect structure of the model as well as the individual intercept values for each level of all random variables is given in the Appendix.

One might be interested in determining the root cause of the lexical differences in VOT. One possibility is that they result from frequency differences, such that high-frequency items display lower VOT values. To test this possibility, we ran alternative models in which we entered the various lexical frequency measures discussed in the previous section as a fixed linear effect predictor and omitted "word" as a random variable. We applied the lexical frequencies both in raw and log-transformed form. None of the predictors show a significant effect of word frequency on VOT durations.

To conclude the discussion of our statistical model of the English results, Figure 5 shows the log-linear function that we arrived at. As can be seen, the effect is strongest in the first few seconds following the switch-point, with the effect leveling off very quickly. The individual data points plotted in gray have been adjusted to include the five different types of random effects.

Returning to the Spanish data, we have already seen that there was no obvious analogous effect visible in the raw data. To test whether there is indeed no statistically significant relationship between Spanish VOT durations and the time since the nearest preceding code-switch from English, we built the same type of model as for the English data, with the same fixed effects and the same random effects. We find no significant effect of time from the nearest preceding code-switch point, and no significant effect of vowel duration in Spanish. There is only a weak trend towards a decrease in VOT that does not, however, approach significance ($p = 0.115$ for a linear decrease in time; $p = 0.166$ for a decrease in log-transformed time). Figure 6 shows the overall distribution of the Spanish dataset in a form analogous to that in Figure 5 for English. We have not added a regression line to Figure 6 so as to not create the semblance of a significant correlation. In all other relevant respects Figure 6 is analogous to Figure 5.

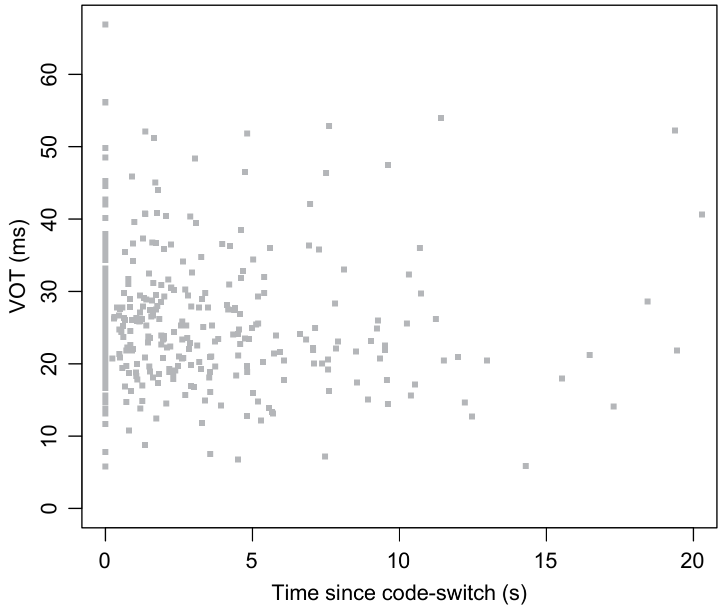

Figure 6. Distribution of the Spanish VOT values.

Discussion

The results of this study show that the Spanish spoken by the speakers in NMSEB included in this study displays overall VOT duration values that fall within the typical range of monolingual Spanish, while their English displays VOT values in the low range of typical monolingual English. It would appear then, on this particular measure, that their English phonetic realizations demonstrate the effects of language contact, as they more closely approach the VOT values typical of the Spanish, short-lag system. The phonetic implementation of their Spanish VOT appears, on the other hand, to be unaffected by the long lag typical of English.

The effect of code-switching on the Spanish and English tokens reveals the same asymmetric pattern. English tokens that occur close to preceding code-switch points have a reduced VOT (in the direction of Spanish), while Spanish tokens show no such effect. We did not predict this asymmetry, given the results of previous experimental and naturalistic studies (Bullock & Toribio, 2009; Piccinini, 2011). Recall that the experimental studies that did report an asymmetric influence in bilinguals typically explained their results as a product of language dominance asymmetry (e.g. Antoniou et al., 2011, p.568).

One possible explanation of our results is that for the NMSEB speakers, the order of acquisition of their two languages creates an asymmetry in the likelihood of cross-language influence. The majority of the speakers analyzed here self-report acquiring Spanish before English. Although they were likely exposed to both languages during early childhood (before primary-school age) and today rate their proficiency in both of their two languages as either a four or a five on a five-point scale, it would not necessarily be expected that their phonetic systems would be entirely monolingual-like in both languages. Seminal work on age of acquisition effects and foreign accentedness by Flege, Munro, and MacKay (1995), for instance, indicates that bilingual adults who acquire their second language even just a few years after birth are judged to be slightly more accented than their monolingual peers (see also Flege, Yeni-Komshian, & Liu, 1999). Though determinations of “accentedness” are based on more than a single phonetic feature, it is possible that order of acquisition, or, in more operational terms, asymmetric use of the two languages in early years, is important in explaining this asymmetry in contact effects.

Another possible interpretation is the greater range of VOT variability that is possible in monolingual English voiceless stops (where VOT durations range from 30 to 90 milliseconds) relative to that of monolingual Spanish voiceless stops (where the range is only from 0 to 30 milliseconds). One could argue, following Bullock et al. (2006, p. 14), that convergence effects have a different baseline likelihood of emerging in English simply because there is more 'room to move' within the English VOT range. However, we note that this explanation rests on the assumption that contact-induced VOT changes are constrained by monolingual norms in such a way that speakers of contact varieties produce average values that remain within the VOT range of monolingual varieties. It is not clear whether or not this would be the case, especially as the only contact features demonstrated for Traditional NM Spanish, the contact variety in question, which clearly set it apart from monolingual varieties are lexical differences (Bills & Vigil, 1999, p. 54-55; Aaron, 2015; Wilson & Dumont, 2015; Wilson, 2013, on *hacer* + verb constructions).

A similar, but different, line of reasoning would argue that the attested asymmetry reflects some type of universal perceptual constraint on short-VOT realizations, with an upper bound at approximately the 30-millisecond mark (Lisker & Abramson, 1964). Under this view, it is not monolingual English and Spanish VOT norms *per se* which constrain variability in contact situations, but the fact that Spanish and English each are sensitive to a universal category distinction between low-VOT and high-VOT stops. The English of the NMSEB corpus speakers displays a voiceless stop category that appears shifted as far downward to this 30-millisecond cut-off point as possible, which sets them apart from typical monolingual English speakers. However, the Spanish of the NMSEB corpus speakers is already fairly close to the 30-millisecond point, which represents the upper bound of perceptible differences between the two VOT types.

That said, it is nevertheless the case that Spanish and similar short-VOT languages sometimes show evidence of language contact effects in spontaneous speech (though not code-switching effects per se) such that VOT durations in the low-VOT language exceed the 30-millisecond upper boundary (e.g. Michnowicz & Carpenter, 2013, p. 420; Nagy & Kochetov, 2013, p. 30). For instance, Maya-Spanish bilinguals in the Yucatan Peninsula are reported to produce VOT durations in the 70-millisecond range in Spanish. It is notable that the language that shows signs of contact is the one the speakers had learned later in life or showed less proficiency in. Perhaps, then, a weaker version of the universal upper-bound hypothesis would argue that such constraints on VOT boundaries only apply in situations of so-called balanced, simultaneous bilingualism, but can be violated in contact situations in which one language is acquired later than the other, even if speakers report later using both languages equally in adulthood.

As a final step in this line of thought, one might argue that the order of acquisition is not only a crucial mitigating factor, but in fact the only necessary factor to explain the results of the present study. As noted above, the speakers examined in our study, by and large, stated that they had Spanish as their primary home language and came to use English increasingly after entering a formal school setting. This may explain the fact that their English phonology appears to be subject to greater contact-induced change than their Spanish phonology, at least insofar as their VOT durations indicate. An in-depth comparison of individual speakers based on demographics, language history, language use, and language attitudes will be essential in corroborating our suggested explanations for this.

Conclusion

In sum, our results show an interesting consistency. The language in the NMSEB corpus that has a non-typical average VOT duration, English, is also the one that shows code-switching effects on this same measure. Meanwhile, Spanish VOT values appear to be both unaffected by long-term contact, and also resistant to the effects of code-switching. This alignment of the two types of convergence is suggestive. While the data studied here do not directly demonstrate a causal connection between code-switching and long-term contact effects, in which the former directly feeds into the latter, they would not be inconsistent with such a view. Pending supporting evidence, we might posit that *micro*-convergence (at the level of code-switching) and *macro*-convergence (at the level of the community grammar) can go hand in hand, hypothesizing that the direction of the effect is dependent on the acquisition history of speakers.

Further, the fact that we find code-switching effects on the VOT duration of English-language tokens suggests that such effects do indeed occur in spontaneous code-switching, and not only in laboratory-induced code-switching. It thereby lends further support to the small but growing number of naturalistic studies of code-switching that also confirm some of the findings of experimental studies. An obvious extension of this work would be to examine VOT values at points immediately *followed* by a code-switch, so as to test the anticipatory effects that have been observed in some elicitation-based studies. We would additionally explore alternate methods of gauging code-switches (e.g. exploring the role of 'lone' items) and switch distance (e.g. measuring the number of intervening words or clauses).

With a view towards future research, we suggest that long-term convergence need not be cross-generational. Rather, if usage patterns change in a bilingual community because of a changing sociolinguistic landscape, with increased contact with English, then this hypothesized pattern of convergence would quickly reverse. If this prediction is borne out, bilingual speakers of the most recent generation in the Northern NM community who have been raised in English, are dominant in English, and have learned Spanish later and to a different degree of proficiency, should show the opposite pattern of convergence in code-switching, with English phonetic norms into Spanish. Continued phonological studies of the New Mexican Spanish-English bilingual community will allow for the further investigation of such questions.

Acknowledgements

Both authors are equal contributors to this work. We thank our two anonymous reviewers for suggestions for improving this paper, and especially Rena Torres Cacoullos and Catherine E. Travis for granting access to the NMSEB corpus. We are also grateful to the audiences at NWAV 41 (New Ways of Analyzing Variation) and SIUS 24 (Spanish in the United States), and to Ineke Mennen for helpful comments on earlier versions of this work. Any errors are inadvertent and remain entirely our own.

Funding

This work was partially supported by an National Science Foundation (NSF) Partnerships for International Research and Education (PIRE) grant #0968369, awarded by the Center for Language Science (CLS) at Penn State to the first author, as well as by NSF grant #1019112/1019122 to Rena Torres Cacoullos and Catherine E. Travis to support the development of the NMSEB corpus.

Notes

1. This example is from the New Mexico Spanish-English Bilingual corpus (NMSEB, Torres Cacoullos & Travis, in preparation) and is reproduced verbatim from the transcript (see transcription conventions in Appendix 2 Torres Cacoullos and Travis, 2015a, in the introduction to this special issue). Within brackets is the recording number, name and time stamp. The original appears on the left, and the translation on the right, with stretches of speech originally produced in English appearing in italics.
2. Personal names belonging to non-famous individuals were not specifically noted in the NMSEB coding protocol (and have been anonymized) and thus did not lead to the exclusion of tokens following their appearance.

3. We also considered using categorical bins of time to model the effect, for example a binary recoding of the time values as below or above a cut-off value of, say, 2 seconds. Although this modeling strategy also brings out the effect, we do not report the results here because of the inherent arbitrariness in binning and because we did not entertain a hypothesis about any particular temporal cut-off point.

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Appendix

Table A1. Random effects summary for the English linear mixed-effects model.

Group	Variance	Standard deviation
stop type	80.729	8.9849
speaker	139.162	11.7967
word	24.024	4.9014
vowel height	1.844	1.3580
approximant type	10.685	3.2688
residual	170.793	13.0688

Table A2. Random intercept values for the variable 'stop type' in English /ptk/-words (a value greater than 0 indicates longer VOT; this applies to all Tables showing intercept values in this Appendix).

/p/	–7.851165
/t/	–1.595542
/k/	9.446708

Table A3. Random intercept values for the variable 'speaker'.

Rocío	16.095772
Manuel	15.862393
Marta	11.916912
Susan	11.070094
Aurora	9.80158
Pedro	6.044246
Samuel	5.810423
Sandra	5.569283
Inmaculada	4.624941
Francisco	4.136643
Bartolomé	–3.765128
Fabiola	–5.34371
Ivette	–8.896327
Victoria	–9.245439
Miguel	–9.354171
Molly	–9.573511
Betty	–10.153616
Javier	–16.756584
Monica	–17.8438

Table A4. Random intercept values for the variable 'word' (top and bottom 10 only).

Word	intercept (top 10)	word	intercept (bottom 10)
panicked	5.54116143	cause (because)	–10.77693472
close	4.41518681	clean	–3.83136382
clear	4.32907201	plow	–3.73537048
partially	3.7400991	pay	–3.41783284
creamed	3.16337268	cattle	–2.87413505
coffee	2.52963825	can	–2.66753203
put	2.50397131	properly	–2.59065779
carwash	2.4329206	teams	–2.44854041
time	2.37173222	turned	–1.98656309
top	2.29936254	pretty	–1.89509499

Table A5. Random intercept values for the variable 'vowel height'.

vowel height	intercept
high	–1.595542
low	0.2908884
mid	–0.8390514

Table A6. Random intercept values for the variable 'approximant type'.

approximant type	intercept
/l/	2.68615049
no approximant	–2.15577447
/ɹ/	–0.06122546
/w/	–0.46915055