**Effect of withholding acoustic cues to English-Spanish codeswitching in Wh-questions**

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**Abstract**

The state of activation of each language of a bilingual person will change depending on the other part of the communication, and this change of behavior can affect both language production and language perception (Grosjean, 2013; Baetens Beardsmore, 1986). The amount and type of mixed language used in one bilingual context can affect the language mode as the activation of each language will be altered, thus code-switching can serve as a scope to investigate language mode. Code-switching is the linguistic phenomenon when more than one language is used in one utterance. A line of studies showed that there can be an additional cognitive cost for bilinguals in a code-switching context (Grainger & Beauvillain, 1987; Soares & Grosjean, 1984; Olson ,2017). Shen et al. (2020) showed that in English-Chinese code-switching tonal cues can help mitigate switch cost. The present study will align with Shen et al. (2020) study, examining the role of acoustic cues in auditory recognition of English-Spanish CS utterances, as the language pair under study in Shen et al. (2020) study is an intonational-tonal pair, the present study aims to fill the gap of an intonational-intonational pair (English-Spanish). The present study seeks to expand the conclusions made in Shen et al. (2020) by gathering evidence from a different type of language pair. Furthermore, the two experiments setting will provide with us more evidence of if acoustic cues help mitigate the higher cognitive cost in code-switching context by providing anticipatory information. Finally, the 4-version design of the stimuli can also provide us with preliminary understanding in how segmental and suprasegmental levels of acoustics work in such kind of bilingual context.

**Introduction**

Bilingual communication is a common practice in almost all the countries around the world and constitutes an important area in linguistic studies (Schmidt, 2014). Bilingual communications differ from monolingual ones in that bilinguals can alter their ways of communication according to the counterpart: when bilinguals are with monolinguals, they may avoid using their other language(s) while when they communicate with other bilinguals who share their language(s), they may change completely to the other language or bring elements of the other language(s) into the one already in use (Grosjean, 2013). This difference in using language(s) has been discussed by Grosjean (2013) as bilingual and monolingual language modes. Especially, for bilinguals, language mode is the state of activation of their languages (say language A and language B) and language processing mechanism at a given point of time, or a specific occasion of communication: the level of activation for language A and B along the language-mode continuum, as illustrated in his work (Figure 1). As a bilingual speaker moves along the language-mode continuum in different linguistic contexts, the amount of use of the other language (guest language), the amount and type of mixed language use, the ease of processing the two language and the frequency of the base-language change will undergo changes accordingly. One common practice when bilingual communicates in bilingual mode is switching from one language to another, and often in one utterance.

**Figure 1**

*A visual representation of the language-mode continuum*

Diagram, schematic

Description automatically generated

Note. Two positions on the continuum are illustrated for a person with two languages (A and B): toward the monolingual end (on the left) and toward the bilingual end (on the right). The level of activation of a language (square) is depicted by the degree of darkness (black represents an active language and white an inactive or deactivated one). From “Bilingual and Monolingual Languages Modes,” by François Grosjean, 2013, *The Encyclopedia of Applied Linguistics,* Copyright 2015 by Blackwell Publishing Ltd, 489-493.

Code-switching communications

Code-switching (CS) is the linguistic phenomenon during which more than one language is used in one utterance. As a result of language contact, in US Latino communities the alternating use of Spanish and English in the same conversational event is quite common (Toribio, 2002). Toribio’s case studies (2002), combining linguistic form and function in specific social contexts, has shown that despite some low prestige associated with code alternation, the practice of code-switching is commonly used and even some use the alternation of English and Spanish in their speech to signal social identities. Below are some of the naturally produced code-switching sentences reported in Toribio’s study (2002):

1. *La madre de caperucita le da* a jar of honey.

Little Red Riding Hood’s mom gave her a jar of honey.

1. They both finish talking *y el lobo camina en otra dirección opuesta a la de caperucita.*

They both finish talking and the wolf walks in the opposite direction of Little Red Riding Hood.

There two examples were collected from the language user in a code-switching narrative writing task. A code-switching narrative retelling task was also conducted in their study. It was shown that the language user had a strong sensitivity to code-switching well-formedness; in other words, as noted by Shana Poplack, among others, a prerequisite for successful code-switching is competence in the component languages. The code-switchers have access to linguistic knowledge in both languages at the same time, hence the cognitive process should be different from monolingual or unilingual communication.

In comparison to a monolingual (unilingual) discourse, it is reported in a line of studies that more complex processes are involved in recognition, production, and comprehension in a code-mixing or code-switching context.

In Grainger and Beauvillain’s study (1987) compared the effects of mixed- and pure-language lists on lexical decision times with English-French bilinguals through two experiments, and it is reported in one experiment that pure-language (unilingual) presentation received faster reaction time than mixed-language presentation; together with the second experiment they found that the effect of language alternation depends language-specific orthographic information: if the word is not language specific, it takes longer for participants to recognize.

Soares & Grosjean (1984) conducted a study comparing Portuguese-English bilingual speakers’ monolingual language mode versus bilingual mode through an on-line task with also English monolinguals as controlled group: the phoneme-triggered lexical decision task (Blank, 1980). The results showed that despite the bilingual participants’ response times in lexical decision task in monolingual modes were identical to the monolingual group, bilinguals’ response times to code-switched word targets in the bilingual mode were significantly slower. In addition, in detecting pseudowords the bilinguals’ respond times were longer than monolingual group in both monolingual (unilingual) speech and bilingual speech. They therefore hypothesized that bilinguals search both lexicons when confronted with nonwords, even when in a totally monolingual mode.

Studies have found consistently a small reaction time delay as proofs of switch cost in production and such cost can be modulated by both individual difference and contextual factors (Meuter & Allport, 1999; Costa & Santesteban, 2004; Olson, 2016). Amengual’s study (2018) on the acoustic realization of voiced lateral approximants in the Spanish and English of heritage Spanish speakers and L2 Spanish learners. One of indications of the results of their study is that different immigrant generations and late L2 Spanish learners produce a less target-like lateral when in bilingual mode, in that the non-dominant language shifts towards the dominant language. Olson’s study (2017) by using eye-tracking paradigm extended the line of production-oriented switch costs research to auditory comprehension.

Cues to switch

As discussed so far, since there is a performance cost for language users when involved in code-switching communications, we can naturally ask next question: whether there is information in the discourse/context to help bilinguals to activate the bilingual mode and to cope with the higher performance cost and the higher cognitive cost? Grainger and Beauvillain (1987) reported language-specific orthographic cues in language mixing context that could help bilinguals to recognize the alternation in languages. Thomas and Allport (2000) looked further into the orthographic cues by using non-words in their experiment; they found that orthographic cues alone are not sufficient to mitigate switching cost and they argue that visual word recognition is not language selective.

Beyond written language, Fricke, Kroll and Dussias (2016) report subtle shifts in voice onset time (VOT) before English-to-Spanish code-switches, while other studies reported opposite results suggesting that there’s no difference between phonetic productions in monolingual versus code-switching utterances (Grosjean & Miller, 1994). Furthermore, Piccinini & Garellek’s study (2014) found that listeners may be able to rely on the anticipatory phonetic cues to mitigate the increased processing cost. It is reported in their study that, in either Spanish-English or English Spanish direction, there were subtle shift prior to code-switches, and bilingual listeners have access to these acoustic cues to help themselves anticipating and comprehending CS utterances. Phonetic cues can mitigate switch cost by playing as an anticipatory role in CS utterances. On the other hand, Shen et al. (2020) pointed out that code-switching pronunciation (phonetic cues to upcoming code-switches) could potentially be another barrier for the listeners when recognizing and comprehending CS utterances due to preservative coarticulation of matrix language phonetics into the code-switch, and vice versa from the switched item into the matrix language, which could be detrimental to recognition.

By looking into how do pronunciation of matrix language and of switch items interact could provide us with a possible explanation to the former addressed conflict between the possible role of code-switching pronunciation in CS production and comprehension. Shen et al. (2020) summed up three possible mechanisms:

…*blending mechanism* by which code-switching pronunciation might represent a blend of the phonetic features of both languages (Grosjean, 2012; Olson, 2013) … *preparation mechanism* by which code-switching pronunciation might reflect articulatory gestures that are preparatory to the production of a specific code-switched target… A third possibility is that code-switching pronunciation might reflect *global cognitive costs* of code-switching.

Previous studies have reported segmental properties going through alternation when produced in CS context in both matrix language and switched items (eg, VOT in Fricke, Kroll and Dussias, 2016), and there were reported suprasegmental features involved in similar phenomenon (intonation in Piccinini & Garellek’s study, 2014). Also, Olsen (2012) reported that insertional code-switched tokens are produced with a degree of hyper-articulation, evidenced by an increase in pitch height and duration. Furthermore, Olsen in also suggested that the suprasegmental realizations of code-switched tokens correspond to a degree of contextually driven predictability. Shen et al. (2020) showed that in English-Chinese code switching withholding acoustic cues can cause slower recognition of switched item, reflecting the possible predictability lies in tonal cues in matrix language as the latter language shows lexical tone while the other does not. They concluded that bilingual listeners have access to phonetic cues in the matrix language, furthermore they discussed the implication of tonal aspect of the phonetic cues to code-switching based on their acoustic analysis. In Shen et al.’s study the language pair under study consists of a tonal language and an intonational language and they found evidence in the linguistic property (tone) that plays a much more important role in one language than the other. Then what will we find if we compare a language pair that has less distance: Spanish – English.

Intonational changes in English and Spanish bilinguals

In monolingual speech, the wh-questions in English and Spanish shows rather similar syntactic structure:

1. ¿Dónde compraste estos libros?

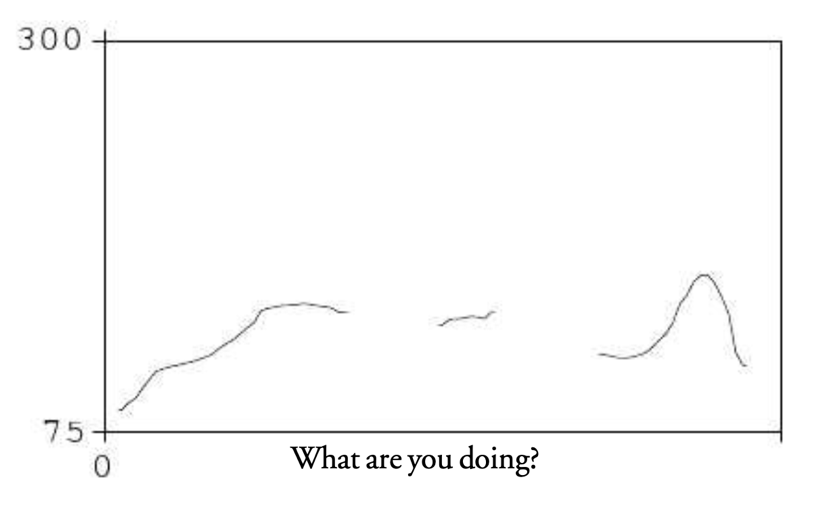
*Where buyPAST-2S these books*

1. Where did you buy the books?

However, when comparing pitch contour of wh-questions in American English (participants from Minnesota) reported in Farías (2013) and Mexican Spanish (participatns from México DF) reported in De la Mota, Butragueño & Prieto (2010), even the general tendency is the similar rising-plateau-rising-falling, in English we can observe a more contrastive comparison between the plateau and the rising-falling pitch change in final position (Figure 2 and Figure 3).

**Figure 2**

*Example of the pitch contour of a wh-question produced by an English speaker reading a sentence in English*



Note. English wh-question produced by an English speaker. From “A Comparative Analysis of Intonation Between Spanish and English Speakers in Tag Questions, Wh-Questions, Inverted Questions, and Repetition Questions,” by Maria Gabriela Valenzuela Farías, 2013, *Revista Brasileira de Linguística Aplicada.*

**Figure 3**

*Example of the pitch contour of a wh-question produced by a Spanish speaker*

Diagram

Description automatically generated

Note. Waveform, spectrogram and F0 trace for the information‐seeking wh‐ question ¿Y tú de qué pueblo vienes*? ‘And you, whereabouts are you from?’* produced with a L+H\* HL% nuclear configuration. From “Mexican Spanish Intonation” by Carme de‐la‐Mota, Pedro Martín Butragueño and Pilar Prieto, 2010, *Transcription of intonation of the Spanish language,* Copyright 2012 byLINCOM publisher.

According to Spaii and Hermes (1993), pitch variations are essential components not only to distinguish the speaker's intention, but also to identify non-linguistic tasks such as emotions, social status, and personalities. Non-native speakers of English (in our case, focusing specifically on Spanish speakers), show a hard time acquiring the intonational patterns in English. Since Spanish is a language with a narrow variation in intonation, ESL learners may tend to transfer their pitch into English, having as a result a "flat" sound (Celce-Murcia et al., 1996). Bowen (1956) suggested that Spanish speakers reading utterances in English will negatively transfer the intonation patterns of their L1, for example, a Spanish emphatic sentence, such as "he does eat pasta" (él sí come pasta) to an English speaker is perceived as annoying. This annoyance is attributed to negative intonation transfers. The same effect occurs if an English speaker speaks the same sentences, transferring English intonation into Spanish utterances.

Farías in her production study (2013) tested the differences and similarities in intonation when producing tag questions, wh-questions, inverted questions, and repetition questions among native English speakers and ESL Spanish speakers. Her results showed that 100% of the participants who were native English speakers ended the questions with a falling contour, while more than half (66%) of the L1 Spanish speakers can produce such English sentences with the same falling contour. Spanish wh-questions produced by the participants had the tendency to end with rising intonation, as opposed to the falling contour given by the Spanish speakers to English sentences. Another difference in producing wh-question in English and Spanish for the L1Spanish speakers is the mean pitch, as the then mean pitch is 180Hz when they are producing English target items and 143Hz in Spanish.

In Piccinini and Garellek’s work (2015), they specifically investigated listeners’ ability to anticipate code-switches in speech-in-noise and the role of prosodic cues in code-switching speech. They also ran an F0 analysis of the stimuli created by a 22-year-old early Spanish-English bilingual female who speaks both Mexican and Peninsular Spanish. Figure 4 demonstrates that her speech displays an interesting patter, where it seems that the code-switching utterances shows a more similar F0 contour to the embedded language rather than the matrix language, which is in line with the findings from Shen et al. (2020) where matrix language is going through some tonal changes and thus language users can use such information to anticipate code-switch and mitigate the switch cost.

**Figure 4**

*Normalized F0 contour for full sentence by context. Error bars indicate one standard error*

Chart

Description automatically generated

Note. From “Prosodic Cues to Monolingual versus Code-switching Sentences in English and Spanish” by Page Piccininio and Marc Garellek, 2014, *Proceedings of the 7th Speech Prosody Conference.*

**Present Study**

The present study seeks to expand the conclusions made in Shen et al. (2020) by gathering evidence from a different type of language pair: English-Spanish (intonational languages). More specifically, we are looking into late learners of Spanish who are native speakers of American English and their manner in recognizing and comprehending English-Spanish code-switching utterances.

The first objective of this study is to investigate if native speakers of English who are late learners of Spanish can make use of acoustic cues to cope with a higher cost on cognitive ability when a switch of language happens in a sentence that starts in English and ends in Spanish. More specifically, we are taking a further look at both the segmental level of the acoustics and the suprasegmental level using the resynthesized audios: the spliced audios.

Research Question 1: *When perceiving Wh-questions start in English and end with code-switched items in Spanish, are English speaking learners of Spanish able to make use of acoustic cues to cope with switch cost?* Previous studies have reported segmental properties going through alternation when produced in CS context in both matrix language and switched items (eg, VOT in Fricke, Kroll and Dussias, 2016), and there were reported suprasegmental features involved in similar phenomenon (intonation in Piccinini & Garellek’s study, 2014); Shen et al. (2020) showed that in English-Chinese code switching withholding acoustic cues can cause slower recognition of switched item. In line with Shen et al. (2020) study, we hypothesize that English speaking learners of Spanish can make use of acoustic cues to cope with switch cost in English-Spanish code switching Wh-questions.

The second objective of this study is to investigate how are native speakers of English who are learners of Spanish make use of the two formerly mentioned levels of acoustics to mitigate the difficulty in a language mixing context. More specifically, we are testing if the acoustic cues are acting as anticipatory cues to upcoming switching.

Research Question 2: *Are the acoustic cues (segmental and suprasegmental) helping mitigate switch cost by providing anticipatory information?* In line with previous studies, we hypothesize that our participants will make use of both types of acoustic cues (segmental and suprasegmental) to predict upcoming code switching, which will suggest the change of language mode, in other words, anticipatory activation of the other language.

We designed a two-experiment setting that will provide with us more evidence of whether listeners are able to use acoustic cues to mitigate the higher cognitive cost in code-switching context to in an anticipatory manner or not. In addition, we also designed a 4-version stimuli setting using splicing and resynthesizing recordings so that we can have a better control over segmental and suprasegmental properties of the utterances, which will provide us with preliminary understanding in how these two levels of acoustics work together in a code-switching context.

**Methodology**

Participants

A total of 29 participants took part in the study and after reviewing their language background and their experiment completion status, and we ended up having 22 participants (7 males and 15 females) with valid data for our analysis.

Participants were between 18 and 26 years old, mostly righthanded (one lefthanded), educated (they had at least completed high school education). No participant has reported or demonstrated to have hearing or visual impairment that may stop them from completing all the tasks in the experiment. Participants were compensated with course credit or monetary reward.

Participants’ linguistic background information was collected using the Language Background Questionnaire, covering language proficiency, age of acquisition of the second language, language use, language exposure, bilingual profile, and language proficiency in Spanish, etc. The Language Background Questionnaire consists of four parts:

1. an adapted Language History Questionnaire (LHQ) (Li et al., 2020);
2. an adapted Bilingual Language Profile (BLP) (Gertken, Birdsong & Amengual, 2014);
3. an adapted Bilingual Switch Questionnaire (BSWQ) (Rodriguez-Fornells, Krämer, Lorenzo-Seva, Festman & Münte, 2012);
4. a language proficiency test (Lextale-Esp, Izura & Brysbaert, 2014)

All the participants were English native speakers living in the United States who use English as their daily dominant language (percentage of the time using English: mean = 97.95, SD = 3.87), currently are using and/or learning Spanish as their second language. In addition, the learners had an average prociciency score of 8.64 (SD = 13.33) points. The Participants were randomly divided in to two groups and finished one of the two versions of the tasks.

Materials and procedure

Prior to the recruitment of participants, written materials were created first bearing in mind that they would be used in both experiments. Then visual and auditory materials were collected, created and modified in accordance to the written materials.

Visual Stimuli

There are in total 72 different images used in both experiments. Images were downloaded from open-source websites. Then every single image was adjusted to the resolution rate of 72\*72 with a white background. In PsychoPy (Pierce et al., 2019) images appeared in pairs in Size (0.5, 0.5) and Position (-0.5, 0) and (0.5, 0) respectively (Anchor center).

Auditory Stimuli and Splicing

All the stimuli used in this study are all Wh-question, written for created by us. The target sentences are designed to be intrasentential code-switching Wh-questions that have English as matrix language and only the last lexical item in the sentence is switched to Spanish (e.g., Where is my *perro*?). To avoid conflict, all switched items are preceded by a possessive adjective in English. All the switched items in target sentences are designed to be easy to visualize in an illustration and are not culturally embedded in either Hispanic or English language. Additional sentences including Spanish unilingual, English unilingual, Spanish-Englsih code-switching are also created for splicing and filler use. A 30-year-old female speaker of Mexican (Mexico City) Spanish recorded all the stimuli through Zoom (2016), recoded using the built-in function of Zoom (2016) and Voice Memos App on iPhone. The sentences that the speaker was supposed to record were presented one by one on her screen and she could repeat many times as needed to create a most naturalistic sound. All the recordings then are manipulated using Praat (Boersma & Weenink, 2022).

Splicing and F0 manipulations are applied to the creation of auditory stimuli. Two conditions of the target sentences require such manipulation: spliced English-Spanish CS F0 not controlled, spliced English-Spanish CS F0 controlled.

To create the spliced English-Spanish CS F0 not controlled condition, we use two recorded sentences, one in English unilingual, and another in English-Spanish code-switch, and replace the lexical item in the same position in English unilingual sentence as the switched item in CS sentence with the word cut from CS sentence. In this way, we obtain one English-Spanish CS F0 not controlled sentence which in the matrix language maintain the acoustics from a unilingual context and the switched item from a CS context (Figure 5).

**Figure 5**

*Splicing procedure visualized 1*

Diagram

Description automatically generated

Note. Splicing auditory stimuli. The double underline and wavy underline respectively represent the F0 contour of each sentence. In this case, the resynthesized sentence’s F0 isn’t manipulated, maintaining the original pattern from the recorded sentence of each part.

To create the spliced English-Spanish CS F0 controlled condition, we repeat the same process as shown in Figure 5, and we add another step of F0 manipulation. More specifically, we will alter the F0 contour using the pitch contour cloning function in Praat and changing the F0 of the whole matrix sentence to the one of English-Spanish CS, naturally produced (Figure 6). In this way we obtain one English-Spanish CS F0 controlled sentence which in the matrix language maintain the segmental properties from a unilingual context and the switched item from a CS context, while maintaining the suprasegmental property entirely from the naturally produced CS sentence.

**Figure 6**

*Splicing procedure visualized 2*

Diagram

Description automatically generated

Note. Splicing auditory stimuli. The double underline and wavy underline respectively represent the F0 contour of each sentence. In this case, the resynthesized sentence’s F0 is manipulated: the double underlined part of the sentence goes through a resynthesized intonational change that clones the F0 contour of the matrix sentence from naturally produced CS, thus maintaining the segmental properties from English unilingual sentence yet having suprasegments from naturally produced CS sentence.

Each list contains 20 target sentences and 35 fillers sentences. Four conditions of target sentences are included: Spanish unilingual, naturally produced English-Spanish CS, spliced English-Spanish CS F0 not controlled, spliced English-Spanish CS F0 controlled.

Procedure

Participants finished 2 experiments individually in one session in following order: consent procedure, Experiment 1(concept monitoring), optional break, Experiment 2(switch prediction), optional break, language background questionnaire. optional feedback. All the participants chose to finish all the steps in their L1.

Experiment 1: Concept monitoring

Experiment 1 is a visual world paradigm task. In this task, participants were asked to sit down in from of a computer screen, paired with a keyboard, a mouse, and a noise cancelation headphone. During the experiment, participants were instructed to make a corresponding choice between two pictures as soon as they hear the audio playing in the headphone mention the one of the two illustrated items using the keyboard. After the instructions, participants completed the practice trials and when they felt confident to start the experiment, they can press a key to start. Each trial starts with a 250-ms blank screen with a cross in the center, visual stimulus appeared 1,250 ms before the onset of the auditory stimuli. Each trial ended when participants made a choice by pressing a key, and if no key was pressed, the program will move on to the next trial after 4,000 ms of the onset of the auditory stimuli. The choice and the reaction time were collected. No break was given until the end of this Experiment. Group A got List 1 and Group B got List 2 in this experiment.

Experiment 2: Switch prediction

Experiment 2 is a prediction task which aims to overtly test participants’ ability to predict language switch. The setting was the same as in Experiment 1. Participants saw two flags on screen, one of the US resenting English and the other of Spain representing Spanish. The choice of flags is made regarding the country of residence of the participants and other philological considerations in order to avoid any possible extra cognitive cost during this online-task based experiment. The participants were instructed to choose a language as soon as they could recognize using the keyboard and once they hear a switch in language, they should switch their choice by pressing the other key. After the instructions, participants completed the practice trials and when they felt confident to start the experiment, they can press a key to start. Each trial starts with a 250-ms blank screen with a cross in the center, visual stimulus appeared 1,250 ms before the onset of the auditory stimuli. Each trial ended after 4,000 ms of the onset of the auditory stimuli. The choice and the reaction time were collected. No break was given until the end of this Experiment. Group A got List 2 and Group B got List 1 in this experiment.

After the two experiments, the participant could take another optional break and continue with the Language Background Questionnaire where the linguistic background and Spanish proficiency was registered.

**Results**

Experiment 1

The data collected during Experiment 1 were trimmed in following steps: we left out participants who failed to report in Language Background Questionnaire as our target population, then we excluded incomplete data sets, we also calculated the rate of making the correct choice during this experiment and only included participants who scored above 75% in correction rate. We then calculated reaction time(rt) subtracting the duration of matrix sentence from the recorded reaction when participants pressed the key. submitted the data to an analysis to determine whether the participants reacted at different rate when listening to recordings of different conditions and if so, how are the differences. During plotting we trimmed down the data points per participant where rt is 2 standard deviations longer than their mean rt or more. A linear mixed-effects model was run using R (R Core Team, 2022). We included partcipants’ language proficiency (standardized Lextale score) and conditions as two predictors, a by-participant random intercept, and estimated logged reaction time(log\_rt) as the dependent variable. The factors were dummy coded with naturally produced English-Spanish Code-switching condition set(na.es) as the reference group.

The results suggested that the reaction time might tend to be shorter for participants with a higher proficiency, however no main effect was found (t value = -0.712, p = 0.483). No main effect was found either for the interaction between proficiency and conditions.

The by condition analysis showed that, participants reacted at faster speed when hearing naturally produced unilingual English utterance, as main effect was found in this condition (t value = -4.837, p < 0.001). Small effect was found in intonation-controlled condition(f0c.es): participants reacted slower in this condition compared to na-es condition (t value = 3.012, 0.001<p<0.01), For the simple spliced condition (f0u.es), the mean of rt might suggest that partcipants reacted slower than na.es condition, yet no main effect was found (t value = 0.218, 0.1 <p <1) in the analysis.

Experiment 2

The data collected during Experiment 2 were trimmed in following steps: we left out participants whose data were not included in Experiment 1 analysis, then we excluded incomplete data sets, and per data set we filtered out any incorrect data entry including cases when no key was pressed, when wrong key was pressed or when more key(s) than necessary was pressed. In Experiment 2 we collected two reaction times in the target items, reaction time 1 (rt1) when the participants pressed the first key choosing the first language they recognized in the utterance, and reaction time 2 (rt2) when they pressed the second key when they hear a language switch in the utterance. We also calculated the duration of each matrix sentence (durmat) We calculated switching reaction time (rtcs = rt2 – rt1) and matrix reaction time (rtmat = rt2 - durmat). The submitted the data to 2+N analysis to test if participants were anticipating a language switch using the acoustic cues.

**Discussion**

The reported data and analysis for experiment 1 led us to a result that’s partially different from what we predicted. The proficiency score has a negative t value, in other words, as estimated, participants’ rt lowers as they show more advancement in Spanish language; however, this tendency revealed with statistical analysis was too small to have the power. Similar unexpected situation happened with f0u.es condition that, just as expected, participants reacted at a slower pace than in f0u.es condition, yet the analysis suggested that the difference was too small. When compared to the size of effect of group na.en, the results can indicate that, compared to the difference of reaction time originated from introducing a second language (switch cost), the effect of increasing L2 proficiency or the effect of acoustic cues are relatively smaller. In addition, due to the design of the materials, we are analyzing between subject factor, which results in a demand for an even larger pool of participants.

The data and analysis for f0c.es condition revealed unexpected result as well, in addition to the same possible cause, it brings up new challenges. In this condition we resynthesized recordings to adjust their intonation resulting in a more similar F0 contour in matrix sentence to naturally produced CS sentences. However, we found a positive small effect for this condition: participants were reacting slower in this condition. No participants have reported that any of the recordings sounded unnatural or weird, which indicates that the participants weren’t explicitly aware of the manipulation that the recordings received, however, during this fast-paced online experiment, acoustic information could still be perceived and affect participants behavior. In our case, even carefully handled, the resynthesis can introduce features and traits that can sound unnatural to listeners, and without being able to explicitly perceive these traits, L2 learners can still be affected: they did not hear it, but they sensed it. This possibility is particularly interesting in the time we live now, as generative models are producing artificial speeches, the myth of “sounding natural” needs to be unveiled.

**~~Conclusion~~**

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