2024-05-01

Bilingual Comprehension of Accented Speech and Spoken Code Switches

Liam John Gleason
University of Texas at El Paso

BILINGUAL COMPREHENSION OF ACCENTED SPEECH AND SPOKEN CODE SWITCHES

LIAM JOHN GLEASON

Doctoral Program in Psychology

APPROVED:

Christine Potter, Ph.D., Co-Chair

Wendy Francis, Ph.D., Chair

Carla Contemori, Ph.D.

Iva Ivanova, Ph.D.

Ana Schwartz, Ph.D.

Stephen L. Crites, Jr., Ph.D.
Dean of the Graduate School

BILINGUAL COMPREHENSION OF ACCENTED SPEECH AND SPOKEN CODE SWITCHES

by

LIAM JOHN GLEASON, M.A.

DISSERTATION

Presented to the Faculty of the Graduate School of

The University of Texas at El Paso

in Partial Fulfillment

of the Requirements

for the Degree of

DOCTOR OF PHILOSOPHY

Department of Psychology

THE UNIVERSITY OF TEXAS AT EL PASO

May 2024

Abstract

Across three experiments, the current study explored how accented speech and coarticulation impact how bilingual listeners comprehend code-switches in speech. Eye-tracking methodology was used to compare responses to single-language and code-switched sentences. Experiment 1 observed how accented speech influenced the costs involved in comprehending code-switches by comparing responses to speakers that had North American English accents to speakers with Juarez/El Paso Spanish accents when speaking English. Experiment 2 compared responses to English speech produced by speakers with North American English, Flemish, and Bulgarian accented speakers. To examine coarticulation as a cue to an upcoming code-switch, Experiment 3 compared naturally produced speech to speech that manipulated coarticulation prior to a code-switch. Results demonstrated that switch costs are involved in the comprehension of code-switches, non-English accents impact a listeners' comprehension of English speech, and the relative impacts of accent on switch costs vary across accent types. Additionally, the subtle cue of coarticulation assists listeners when comprehending code-switches. These findings suggest that bilinguals may use accent as a cue to anticipate upcoming speech. However, when a cue is deemed unreliable based on a bilingual's previous experiences, the listener then uses sub-lexical cues such as coarticulation to facilitate the comprehension of code-switches.

Table of Contents

List of Tables

List of Figures

Introduction

Word Recognition in Speech

The ease that listeners recognize words in speech is remarkable due to the degree of variability of the input of speech. The same phoneme differs dramatically when produced in different words, this is often referred to as the lack of invariance problem. This variation is considerably greater for bilingual speakers.

The time course in which a word is recognized is based on an interplay of bottom-up and top-down activation dynamics. Bottom-up activation refers to a set processes that fire immediately upon input, with activation spreading from smaller to larger units. For example, when hearing the word "*bear*" constituent phonemes (/beə(r)/) are activated, these in turn send activation to words that contain them (e.g., bear, pear). Top-down activation dynamics occur in parallel to bottom-up dynamics. Top-down activation refers to the activation of larger units leading to smaller constituent units. For example, if a listener hears "*In the forest we saw a grizzly bear*." the meaningful context preceding "*bear*" will cause it to become activated even before the word is heard. This type of top-down influence speeds word recognition.

Unique to bilingual listeners is that when hearing words there is bottom-up activation of words across both of their languages (Chambers & Cooke, 2009; Ju & Luce, 2004; Marian & Spivey, 2003). In one classic study Russian-English bilinguals completed a visual world task. In such task participants' eye-movements were recorded as they listened to words and looked at the related picture on a screen. Visual stimuli contained four pictures, one target and three distractors. The critical manipulations researchers included were cross-language competitors presented in the three distractors pictures. For example, if the target word were *speaker* [spikəɹ], one English distractor: *spear* [spiɹ], one Russian distractor: *спички* [spiqki]), and one unrelated control distractor: *plate* [plέjt] were included. Participants looked longer at pictures of the cross-language competitors, suggesting that phonological units are activated in a language non-selective way. These results demonstrated there is cross-language bottom-up activation of phonemes, in that listeners face both within- and between-language competition in speech comprehension (Marian & Spivey, 2003).

The observation of cross-language phonological activation is consistent with the Bilingual Interactive Activation Plus (BIA+) (Dijkstra & Van Heuven, 2002), a model of the bilingual mental lexicon. One critical assumption within the BIA+ is that word representations across languages are housed in one integrated lexicon. As a consequence, when words are presented to the system, words across languages are accessible. How quickly a word is lexically accessed is dependent upon two factors; 1) the word's resting level of activation, and 2) the word's match with the input. Importantly, the language membership of a word does not influence the time it takes to be retrieved. The architecture of the BIA+ does allow for top-down activation from semantic cues such as words in highly predictive contexts. A final critical assumption of the BIA+ is that the bottom-up cross-language activation is unaffected by nonlinguistic factors such as strategies or expectations.

Bilingual Speech Comprehension

A critical characteristic of bilingual speech comprehension is that for many bilinguals they regularly hear language that is mixed, this is referred to as code-switching. This is yet another source of variation in speech because the same speaker can say words in more than one language. Even though bilinguals can understand code-switched language with apparent ease, research conclusively shows that there is a cost in processing time when there is a switch in language. This 'switch cost' is present in both written and oral comprehension (Li, 1996;

Litcofsky & Van Hell, 2017; Macnamara & Kushnir, 1971; von Studnitz & Green, 1997). Switch costs are often attributed to difficulty accessing the correct representation due to competition between languages (for reviews see Declerck & Philipp, 2015; Kroll et al., 2008).

There is evidence that subtle cues in the input can reduce switch costs. For example, in one study English-Greek bilinguals completed a lexical decision task, on critical trials words contained language-specific letters (e.g., '*Γ*' and '*Λ*' are unique to Greek, '*C*' and '*F*' are unique to English. switch costs were reduced when stimuli contained language-specific orthography (e.g., '*ΚΑΘΕΤΗ*' or '*ALREADY*'). However, the speech signal has many more language specific cues than written language. Thus, bilingual listeners are likely to exploit these cues to improve comprehension.

One such cue is coarticulation, which is when a speaker begins articulating the phonemes of the upcoming word as they are finishing the prior word (e.g., when producing '*the bear*', a speaker articulates /b/ in *bear* as *the* is completed, such that if isolated, it would sound similar to '*theb*'). It has been demonstrated listeners are sensitive to phonetic cues provided by coarticulation even from a young age (Mahr et al., 2015; Salverda et al., 2015). When coarticulation is manipulated to provide misleading phonetic information, listeners' processing is delayed suggesting the subtle phonetic information in coarticulation provides listeners with useful cues when processing speech (Tobin et al., 2010).

Differences in subtle aspects of the phonetic realization of words has been shown to affect bilingual word recognition. In one eye-tracking study, Spanish-English bilinguals listened to Spanish words that were pronounced with either typical Spanish phonology or they were manipulated so they sounded appropriate for English. Participants fixated on interlingual distractors more often on trials that included the English-appropriate phonology (Ju & Luce, 2004). Critically there is evidence that there are phonetic cues that signal an upcoming switch in language. When bilinguals produce spontaneous code-switches, they alter the phonetic realization of the word prior to the switch (Bullock et al., 2006; Deuchar et al., 2014; Olson, 2016). In one study the timing between the initial consonant and onset of the vowel for English words prior to a code-switch were reduced to be more similar to Spanish (Balukas & Koops, 2015).

Accented Speech

Accents are the variation in speech or differences in phonological features which are perceived as different from the 'standard' in any particular region (Valles, 2015). Individuals that speak more than one language often have different types of accents in their second or non-native language when compared to native speakers. Often, bilingual environments are diverse in the make-up of accents within the environment. Speech produced by bilinguals that learned their second language later in life can decrease accuracy and speed of listeners' comprehension when compared to familiar accents (Munro & Derwing, 1995, 1999).

When non-standard accented speech is paired with other factors that tax listeners, challenges in speech processing are amplified. For example, as speech rate increases, comprehension of non-native accented speech deteriorates more than comprehension of native-accented speech (Anderson-Hsieh & Koehler, 1988). Further, to understand the effect of different types of accents on native and non-native listeners' speech comprehension, one study had participants complete comprehension tasks while listening to different types of accented speech that was paired with additional factors know to be detrimental to speech comprehension, background noise and reverberation time (i.e., the time taken for sound to decay in an enclosed space). Non-native listeners showed greater impacts of background noise and reverberation time, but interestingly when the accent matched the listener's language background the negative impacts of high reverberation were reduced (Peng & Weng, 2016). This suggests that when a listener shares language background or is familiar with the accent of the speaker, the negative impacts of a less standard accent may be reduced.

Hearing multiple speakers with different types of accents introduces more challenges compared to hearing multiple speakers with the same type of accent (Bent & Frush Holt, 2013). While this may suggest that greater accent variability could increase processing demands, other evidence suggests a less straightforward influence of accent on comprehension. Listeners are able to rapidly adapt to non-native accented speech when listening to single talkers or multiple talkers with the same types of accents (Bradlow & Bent, 2008; Sidaras et al., 2009). Further, when participants were trained in speech conditions that contained multiple types of accents, they could demonstrate similar comprehension to participants trained on a single target accent (Baese-Berk et al., 2013). Taken together, these studies suggest that when given appropriate time and exposure to non-standard accented speech, listeners are able to show robust comprehension of different types of accents.

Research has also explored how easily listeners adapt to non-native accented speech by examining how listeners process the grammatical and semantic aspects of non-native accented speech (Grey & van Hell, 2017). ERP data was collected as participants were exposed to sentences that contained either semantic or grammatical errors spoken in native or non-native accents. Participants showed more neural sensitivity to both types of errors when they were able to correctly identify where the non-native accent was from. However, when participants were unable to identify a non-native accent, they only showed responses to semantic errors (Grey &

van Hell, 2017). These results suggest that when listeners are even slightly familiar with an accent, they are more responsive to speech errors.

Overall, while non-standard accents do initially produce disruptions in speech comprehension, variability in exposure and time for generalization allow listeners to adapt to different accent conditions (Cristia et al., 2012). Moreover, the accent of the speaker may impact the predictions of a listener. In one study, researchers used ERP measures to test participants' responses to unexpected phonological events. Participants showed greater sensitivity when hearing a target word in a non-native accent following a sentence produced in a native accent, compared to hearing a target word in a native accent following a sentence produced in a non-native accent (Brunellière & Soto-Faraco, 2013). These results imply that listeners may make predictions about upcoming speech that depend on the speaker's accent. That is, a listener may use accent as a cue to adjust their sensitivities and expectations.

One factor that should be mentioned within this literature is the negative bias towards individuals with non-native accented speech. Factors such as age of acquisition (AoA) and context of use greatly impact a non-native speaker's accent in their L2 (Flege et al., 1995). Additionally, it has been demonstrated that non-native accented speech impacts how listeners perceive a speaker in social variables such as credibility and intelligence (Dewaele & McCloskey, 2015; Foucart et al., 2020). Living location has also been shown to modulate how listeners perceive accented speech (Kutlu et al., 2022). Researchers measured listeners' accent judgements and transcription accuracy of accented speech in Gainesville, Florida and Montreal, Quebec. Results demonstrated judgements in accentedness of speech increased to 'heavier accent' and intelligibility accuracy decrease for Gainesville participants when speech was paired with South Asian faces. However, this effect wasn't seen in Montreal listeners. The researchers suggest the visual cue of race paired with accented speech is more impactful on speech perception in locations with greater ecological diversity (Kutlu et al., 2022). While the social aspects involved in the perception of a speaker's accent may not be the most influential variable in speech comprehension, they are important factors that should not be overlooked when examining accent related effects.

Previous research has demonstrated listeners face processing difficulties when comprehending non-standard accented speech (Munro & Derwing, 1995, 1999). However, when listeners are allowed time and exposure to non-native accents, they are able to adapt to different types of accents (Baese-Berk et al., 2013; Cristia et al., 2012; Grey & van Hell, 2017; Peng & Weng, 2016). Further, listeners have demonstrated the ability to use accent as a cue when adjusting expectations in speech (Brunellière & Soto-Faraco, 2013). Together, this literature may be expanded by exploring the different aspects of speech comprehension that different types of accented speech may influence.

Top-Down Processing in Speech Comprehension

When considering how bilingual listeners resolve within- and between- language competition during speech comprehension it is important to note that these language competition effects are present regardless of 'language mode'. Language mode refers to the relative levels of activation of a bilingual's languages (Blumenfeld & Marian, 2011; Grosjean, 2013; Marian & Spivey, 2003). For example, bilinguals are in 'monolingual mode' when there is no inclusion or indication of the second language during input. Even when bilinguals are communicating in 'monolingual mode,' there is between-language lexical competition. Additionally, this cross-language lexical competition is not exclusive to native bilinguals (i.e., bilinguals that have been exposed to/started to acquire a language from birth). Research has demonstrated between language lexical competition is present in both native and non-native listeners, and often the most apparent competition effects are seen when listening in the non-native listeners (Weber & Culter, 2004). Taken together, this research suggests that regardless of language mode or when a bilingual acquired their languages, between-language lexical competition is present.

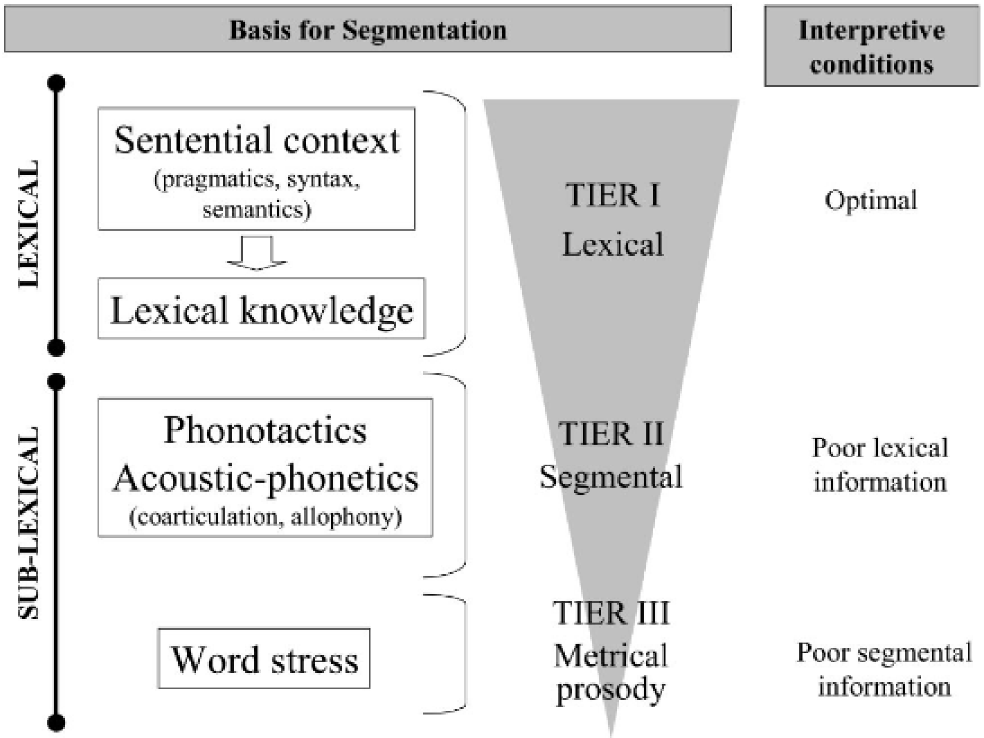
It has been suggested that top-down cues impact the different language modes in which bilingual listeners operate during speech comprehension (Grosjean & Li, 2013). One proposal is that when top-down factors indicate that input will be exclusively from one language, bilinguals may enter monolingual mode. However, this concept becomes convoluted when taking into account bottom-up factors, such as phonetics, that are still at play when bilingual listeners are in monolingual mode (Marian & Spivey, 2003). One model that may lend itself to explaining the complexities and interactions of bottom-up and top-down processing is the Adaptive Control Hypothesis (ACH) (Green & Abutalebi, 2013). The ACH suggests bilingual language control is a flexible process that can adapt to changing environments. When determining which language to activate, a monitoring language activation cognitive mechanism takes into account both linguistic and non-linguistic cues. As contexts differ in degree and types of code-switching, bilinguals can flexibly adapt to facilitate comprehension.

To examine the processing of different patterns in code-switches, participants' eye movements were monitored as they listened to sentences and looked at the related pictures on a screen (Olson, 2017). Sentences either included a single switch, "*Cuando era pequeña, mi hermana <u>loved spiders and other bugs</u>*.", or multiple switches "*<u>She closed her eyes</u> proque no quería ver <u>spiders</u> y otros bichos.*". Switch costs were larger in single-switch sentences than in multiple-switched sentences (Olson, 2017). These results suggest non-semantic cues can assist the listener in generating predictions about upcoming input. Additional linguistic factors such as gender determiner cues are also useful for bilingual listeners when processing upcoming input (Valdés Kroff et al., 2017). This suggests that bilinguals take advantage of multiple types of cues when processing code-switches. These cues and reductions in switch costs imply that bilinguals are able to incorporate a wide variety of information when comprehending speech.

The Dual Operation of Bottom-up and Top-Down Cues

To expand on which cues listeners find useful in speech comprehension, researchers examined how listeners segment speech, or how listeners isolate words from a connected speech stream. Researchers compared lexical and sub-lexical cues (e.g., coarticulation) in speech by manipulating the degree of coarticulation at word boundaries. Results demonstrated that while sub-lexical cues such as coarticulation impact speech processing, lexical cues are more impactful (Mattys et al., 2005). These results suggest that while listeners are using both lexical and sub-lexical cues, the cues are given different weights. The researchers proposed a hierarchical approach to speech segmentation (Figure 1).

Figure 1:



Hierarchical approach to speech segmentation.

Note. The possible weights of cues involved in speech segmentation, the greater the width of the triangle the more weight is given to the cue (Mattys et al., 2005).

This hierarchical approach to speech segmentation allows for different weighting of cues, suggesting more weight may be placed on easily accessible lexical cues such as sentence context and lexical knowledge, and less weight on sub-lexical cues such as coarticulation and the stress put on words. However, the Adaptive Predictability hypothesis (Valdés Kroff & Dussias, 2023) suggests bilinguals shift the weight of different cues when determining when and if to predict upcoming information. This adaptability is not an intrinsic trait of all bilinguals. Instead, exposure to code-switching and bilingual experiences facilitate this shift in the weights of cues bilinguals use in speech comprehension (Valdés Kroff & Dussias, 2023).

Current Study

In bilingual speech many bottom-up (e.g., phonetic input and coarticulation) and top-down (e.g., sentence and speaker context) cues influence how listeners approach speech comprehension (Blumenfeld & Marian, 2013; Chambers & Cooke, 2009; Li & Yip, 1998; Marian & Spivey, 2003). Research has demonstrated that code-switching involves costs to listening comprehension, and switch costs are impacted by a variety factors and cues in speech that may help prepare bilinguals for a code-switch, thus reducing switch costs (Foucart et al., 2015; Grey & van Hell, 2017; Ju & Luce, 2004; Olson, 2017). Another factor that introduces difficulties in speech comprehension is non-native accented speech (Munro & Derwing, 1995, 1999). Bilinguals are capable of adapting to accents and have been shown to use accent as a cue when adjusting expectation in speech (Baese-Berk et al., 2013; Brunellière & Soto-Faraco, 2013; Grey & van Hell, 2017; Peng & Weng, 2016). Additionally, bilinguals are sensitive to very subtle phonetic cues in speech, such as coarticulation (Ju & Luce, 2004; Tobin et al., 2010). The current study explored how non-native accented speech and coarticulation may influence a listener's ability to comprehend speech by comparing responses to single-language and code-switched speech. Across experiments, listeners heard single-language English sentences and code-switched sentences where the target noun was in Spanish. Experiment 1 tested how listeners experienced switch costs in speech produced in English and Spanish accents. We predicted that when speakers had a Spanish accent, it would cue the listener that a code-switch to Spanish was possible in upcoming speech. Further, Experiment 2 compared responses to bilingual speech produced by English vs. Flemish and Bulgarian accented speakers. We predicted that switch costs might be impacted by the unfamiliar Flemish and Bulgarian accents. To examine the possibility of coarticulation acting as a cue of an upcoming code-switch, Experiment 3 compared naturally produced English speech that included coarticulation to speech that manipulated coarticulation prior to a code-switch. Across all three experiments, the current study aimed to better understand specific cues involved in the comprehension of spoken code-switches.

Experiment 1

Experiment 1 aimed to understand the potential impact that accented speech may have on switch costs. We compared listeners' responses to single-language (English) and code-switched (English to Spanish) sentences produced by speakers with English and Spanish accents. We predicted that overall, listeners would respond to code-switched sentences more slowly than single-language sentences. This would demonstrate that when a sudden switch to another language is included in speech, it delays the listener's comprehension. We also predicted that listeners would respond to Spanish accented English speech more slowly than English accented speech. This would replicate findings that show that non-native accented speech delays comprehension (Munro & Derwing, 1995, 1999). Our primary prediction of interest in Experiment 1 was that switch costs would be larger when sentences were spoken in an English accent. This would suggest that when accent implies knowledge of a second language, the listener is cued that a code-switch is possible in upcoming speech. Additionally, it is important to understand the individual differences associated with a listener's comprehension of code-switches. Experiment 1 also measured language proficiency, dominance, experiences with code-switching, and perceptions of accents. We predicted that higher proficiency and dominance in the language of the code-switch would be associated with smaller switch costs. Previous research has shown that when comprehending switches into their weaker language bilinguals' comprehension is delayed more than when comprehending switches into their stronger language (Litcofsky & Van Hell, 2017). We also anticipated that bilinguals with more code-switching experience would have smaller switch costs than bilinguals with less code-switching experience. The goal of Experiment 1 was to expand our understanding of how non-native accented speech may impact switch costs. It was also intended to explore the individual differences in language background and experiences and their associations with the comprehension of code-switches.

Methods

Design

To examine how bilingual listeners process code-switches produced with different accents, Experiment 1 used a visual world eye-tracking paradigm (Cooper, 1974). In this task, participants listened to sentences and look at the picture that related to the sentence. The study followed a 2 (sentence type: Single-language vs. Code-switched) x 2 (accent type: English vs. Spanish) within-subjects design. Single-language sentences with a medial target word in English (*"My little brother likes* ***bears*** *and has many pictures of them."*), and Code-switched sentences with a medial target word in Spanish (*"My father said that he sees* ***osos*** *outside his window*.") were presented auditorily. To evaluate the influence of accent, sentences were produced by speakers with native English or native Spanish accents (Table 1). Auditory stimuli were presented in combination with visual displays that consisted of a target item and three distracter images (Figure 2). Reaction times were measured from the onset of the target word to the first fixation on the target image.

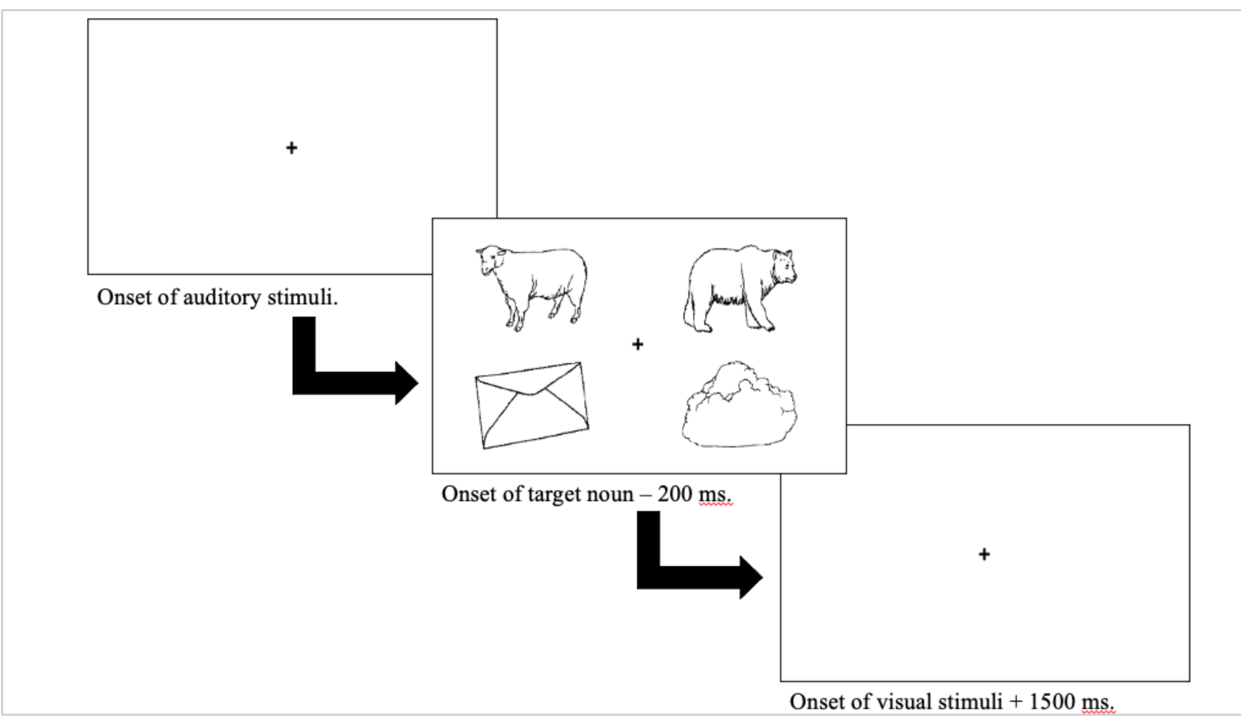
Table 1:

Experiment 1 sample auditory stimuli

Accent Type:	Speaker:	Sentence Type:	Auditory Stimuli:
English	English 1	Code-switched	My father said that he sees **osos** outside his window.
English	English 2	Single-language	When he pays attention, he sees **bears** and other big scary animals.
Spanish	Spanish 1	Single-language	My little brother likes **bears** and has many pictures of them.
Spanish	Spanish 2	Single-language	My father and I always see **bears** and other animals.

Note. Auditory stimuli used for the target item *bear*. Each speaker presented a unique sentence containing the target word. The target was presented in three single-language sentences and one code-switched sentence.

Figure 2:



Example of visual stimuli and timing across one trial.

Participants

We chose our target number of participants (60) as a conservative estimate by doubling the sample size from a previous study that examined similar switch cost effects (Olson, 2017). The final sample included 59 participants who were English-Spanish bilinguals enrolled at the University of Texas at El Paso and participated for course credit. One participant was excluded due to failure to look at the screen for more than 50% of the trials. The median age was 20 years old (*SD* = 3.37, range = 18-35), 71.19% identified as women, and the majority of participants (96.67%) identified as Latino/a ethnicity. All participants self-reported that they had normal hearing and were proficient English-Spanish bilinguals but did not provide detailed information about their subjective proficiency. Proficiency in each language was assessed using the Multilingual Naming Test (MINT) Sprint (Gollan, et al. 2023). Participants demonstrated high proficiency scores on both the English (*M* = 71.08%, *range* = 27.50%-95%, *SD* = 14.31) and Spanish (*M*= 63.43%, *range* = 18.75%-91.25%, *SD* = 17.51) assessments. Based on their MINT scores, participants were classified as dominant in English (*N* = 35) or Spanish (*N* = 24). Additionally, participants' code-switching use and experience was assessed using the Bilingual Code-Switching Profile (BCSP) (Olson, 2022). A higher score on the BCSP (*range*: 0-100) indicates more code-switching use and experience. Participants demonstrated relatively high code-switching use (*M* = 67.35, *range* = 28.54 – 95.00, *SD* = 14.82).

Eye-Tracking Materials

Auditory Stimuli

Auditory stimuli consisted of naturally produced sentences selected from a larger set of stimuli used in a previous study of codeswitching (Olson, 2017). Each sentence contained one of 32 concrete target nouns appearing in the medial position of the sentence. Additionally, sentence frames did not provide cues to the upcoming target noun (for semantic predictability norming see Olson, 2017). Each of the 32 target nouns appeared in four unique sentences creating a set of 128 total sentences. Target nouns were presented in three single-language sentences (*"My father said that he sees **bears** outside his window."*) and one code-switched sentence (*"My father said that he sees **osos** outside his window*."). To avoid participants becoming accustomed to code switches, 75% of sentences were single language and 25% were code-switched sentences.

Sentences were produced by four different female speakers, two with native English accents and two with native Spanish accents. All speakers were fluent English-Spanish bilinguals from the same region as the participants. The two English-accented speakers were native English-Spanish bilinguals that spoke with North American English accents. These speakers acquired English and Spanish simultaneously. The two Spanish-accented speakers were native Mexican Spanish speakers who learned English after Spanish (Spanish-accented speaker 1: English AoA = 6; Spanish-accented speaker 2: English AoA = 12) and had Juarez/El Paso accents when speaking English. Each speaker self-reported their perceived accents when speaking both English and Spanish. English-accented speakers reported little to no Spanish influence when speaking English, while Spanish-accented speakers reported medium to heavy influence of Spanish when speaking English (Table 2). To test how accents were perceived by listeners, participants rated how likely it was that English or Spanish was the speaker's native language (Table 2). Ratings confirmed that English-accented speakers were perceived as sounding more like native English speakers and less like native Spanish speakers, compared to the Spanish-accented speakers (see Accent Rating Task for details).

Table 2:

Experiment 1 average accent ratings

	Self-rating: native English speaker?	Participant rating: native English speaker?	Participant rating: native Spanish speaker?
English Accent 1	5	4.03	2.67
English Accent 2	4	3.67	3.11
Spanish Accent 1	3	2.45	3.91
Spanish Accent 2	2	1.80	4.34

Note. Both speakers and participants were asked how likely it was that each speaker was a native English or Spanish speaker, and responded on a 5-point Likert type scale (*1-Extremely Unlikely; 5-Extremely Likely*). Scores were averaged across participants.

Each speaker recorded one sentence for each target word. In total, each speaker produced 8 code-switched sentences and 24 single-language sentences. All sentences were recorded in a soundproof room with a Blue Snowball microphone using the computer software Praat (Boersma & Weenink, 2023). Sentences were edited to match in intensity (65db), and target noun onset was standardized across sentences by adding silence to the beginning of each audio file, with no other manipulations to ensure natural prosody and coarticulation. After editing, target nouns always occurred 3214 ms after the start of the sentence.

Visual Stimuli

Visual stimuli consisted of standardized black and white images of each of the 32 target words (Snodgrass & Vanderwart, 1980). In efforts to keep visual stimuli consistent and reduce patterns that may cue participants, items were organized into eight sets of four (see Appendix A). Within a set, the phonology of items in English and Spanish did not overlap (e.g., *cloud* was not grouped with *corn* or *caja*). Images were presented in one of four quadrants on the display screen top left, top right, bottom left, bottom right. The center of each image was an equal distance from the fixation cross in the center of the screen. Each set was presented 16 times with each image appearing equally often as the target, and each item appeared equally often in each of the four locations.

Additional Materials

Accent Rating Task

The Accent Rating Task was designed to measure participants' subjective perception of each speaker's accent. Participants were told that they would hear some sentences by the same speakers as the previous task. They were asked how likely it was that English or Spanish was the speaker's native language. Accents were rated on a 5-point Likert type scale ranging from "*Extremely Unlikely*" to "*Extremely Likely*". Participants rated one single-language and one code-switched sentence for each speaker, and ratings were averaged for each speaker (Table 2).

Language Proficiency

To assess proficiency in each language, the MINT Sprint (Gollan et al., 2023) was administered to participants in both English and Spanish. This standardized measure consisted of a picture naming task in which participants were shown a grid of 80 pictures and asked to attempt to name each picture. Responses were scored in real time by researchers. Percentages of correct responses were used to determine proficiency and language dominance.

Code Switching Use and Experiences

The Bilingual Code-Switching Profile (BCSP) (Olson, 2022) was used to assess participants' code switch use and experience by examining their history of code-switch use, proficiency, and attitudes towards and identity with code-switching. Each item response was given a numerical value. Responses for each category (Language History, Language Use, Language Proficiency, and Language Attitudes) were summed then multiplied by weighting factor. The scores were then summed and provided a global score for each participant (Olson, 2022).

Procedure

Participants first read and signed an informed consent form. Upon confirming they met the requirements of the study; participants were asked to sit at a distance of 65cm in front of a monitor with 1920 x 1080-pixel resolution connected to a Tobii Pro eye-tracker that sampled at 1200 Hz. Using the Eye-Tracker Manager software (Tobii Pro, 2014), participants completed a 9-point calibration task, where they were told that a few dots would appear on the screen one at a time and they should look at the dots until they exploded. If calibration failed more than three times, the eye-tracker was reset and participants re-attempted calibration procedures.

After completing calibration procedures, participants received oral instructions for the visual world task from the researcher. Participants were instructed that they would be listening to sentences and as a sentence played, they should look at the picture on the screen that was related to the spoken sentence. To ensure that participants understood the task an example was given, "*If you hear* ***'I bought some flowers at the store'*** *you would look at the picture of flowers.*" Participants were also instructed that each sentence would be preceded by a visual fixation cross in the center of the screen (+) and that they should focus on the cross until the pictures appeared on the screen then move their eyes to the related picture. Each trial began with a white screen and the black fixation cross in the center of the screen. As sentences played, visual stimuli appeared 200 ms before the onset of the target noun and stayed on the screen for 1500 ms. Trials were separated by 500 ms of a blank white screen. To combat participant fatigue, a break was included halfway through the task. Participants were instructed to stay roughly in the same location, but to look away from the screen to rest their eyes.

Sentences were presented in a randomized order for each participant. Orders were constrained such that code-switched sentences were never preceded or followed by a single-language sentence that contained the same target noun, no more than two code-switched trials were presented back-to-back, and no more than four trials involving the same speaker were presented in a row.

After completing the eye-tracking task participants completed the Accent Rating task. Following the accent perception ratings, a 9-point validation procedure was completed. Validation followed the same procedures as calibration. No participant failed eye-tracker validation. After validation, participants completed MINT Sprint. Then participants completed demographic and language background surveys, including the BCSP. Participants were compensated, debriefed, and thanked for their participation.

Data Analysis

Data were recorded using the experimental program Psychopy (Peirce et al., 2019). The primary dependent variable was participant reaction times (RT) in milliseconds (ms). Reaction time was defined as the time from the onset of the target noun to the first fixation on the image that corresponded to the target noun. Location of fixations were coded based on the five predetermined areas of interest that contained the target image, three distractors, and the fixation cross. Trials were excluded if the participants did not look to the correct target, fixated on the target for less than 200ms, or had RTs less than 200 ms (Huettig & McQueen, 2007; Olson, 2017), 1429 trials (18.92%) were excluded from Experiment 1 analyses. As previously mentioned, data from one participant was excluded for response accuracy being less than 25%, level of chance. The R statistical software v3.1.2 (R Core Team, 2021) and lme4 (Bates et al., 2015) was used for the statistical analyses. The significance criterion was set at t = 2.00.

Results

After excluding trials based on predetermined requirements, a total of 6123 observations were included in Experiment 1 analyses. To test for the effect of sentence type and accent type on speech comprehension and account for variability within the data, linear mixed effects analyses were used. Fixed factors were sentence type (single-language vs code-switch) and accent type (English accent vs Spanish accent). Participant and item (i.e., target word) were included as random factors (Appendix B for full model). Within the dataset, categorical variables were coded as -0.5 and 0.5, single-language sentences were used as the reference level for the sentence variable, and the English accented condition was used as the reference level for the accent variable. Random slopes and random intercepts were included for each of the factors. Participants' responses were slower for sentences that contained a code-switch, indicating that switch costs were present, ($\beta = 74.40$, $t = 3.34$, $p = .002$). Additionally, RTs were slower for sentences presented in Spanish-accented than English-accented speech ($\beta = 59.56$, $t = 2.53$, $p = .02$). There was no interaction between sentence type and accent type ($\beta = -16.11$, $t = -0.39$, $p = .70$), indicating accent type did not influence the costs involved in comprehending spoken code-switches.

Table 3:

Experiment 1 fixed effects of LME

	Estimate	Std. Error	t-value	p-value
Intercept	624.21	23.65	26.39	<0.001*
Sentence Type	74.40	22.29	3.34	0.002*
Accent Type	59.56	23.57	2.53	0.02*
Sentence Type: Accent Type	-16.11	41.38	-0.39	0.70

Note. Fixed effects were sentence type (single-language, code-switch) and accent type (English, Spanish).

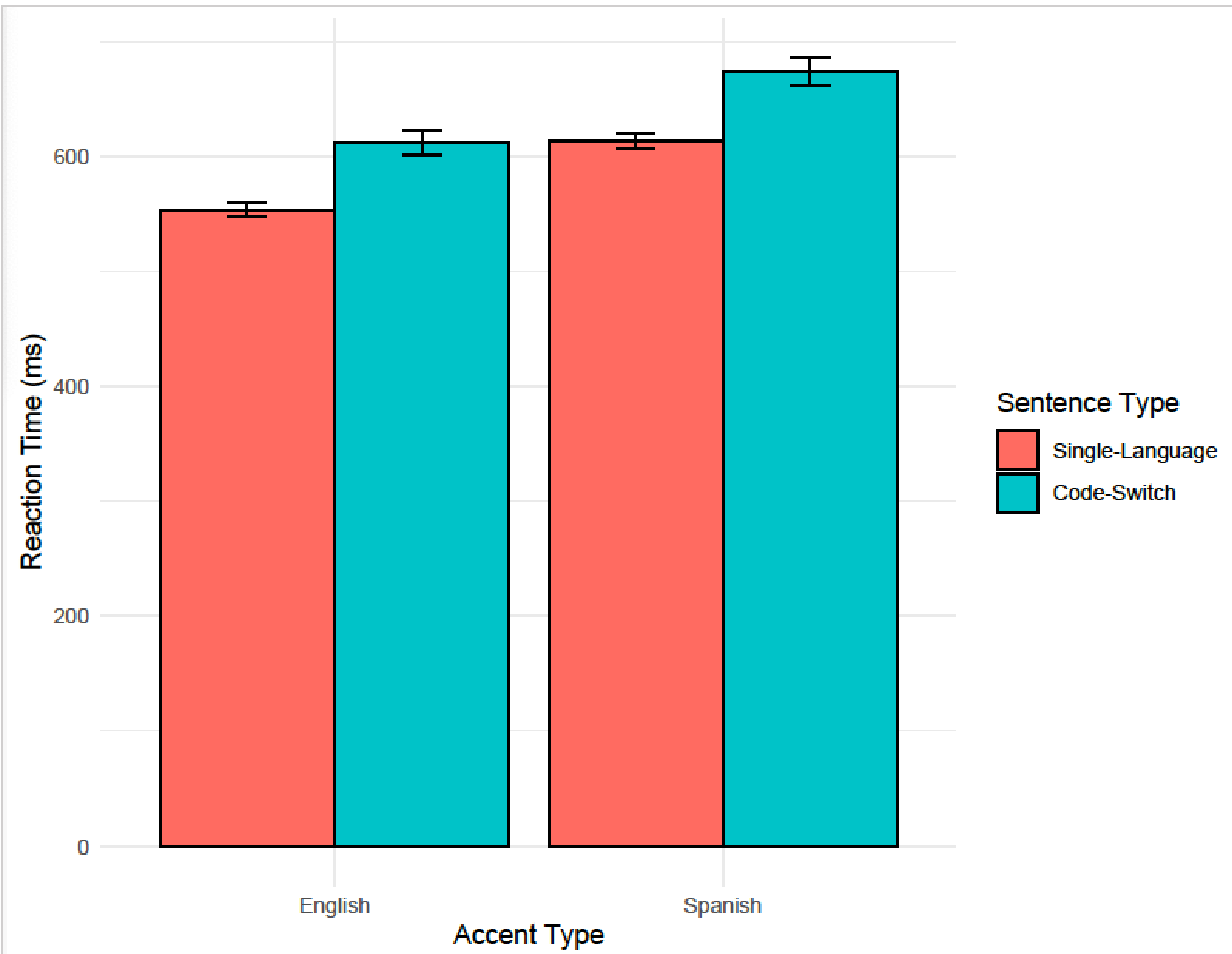
Table 4:

Experiment 1 mean reaction times (ms) by condition

	English Accent *M (SE)*	Spanish Accent *M (SE)*
Single-Language	553 (23.7)	621 (23.6)
Code-Switch	636 (35.3)	687 (36.8)

Note. Means (*M*) and standard errors (*SE*) were calculated using the emmeans package in R (Lenth, 2024).

Figure 3:



Experiment 1 RT by sentence and accent type

Note. Error bars represent the standard errors of the mean by participants.

Individual Differences

To understand the associations of language proficiency, dominance, code-switching use, and perceptions of accented speech on speech comprehension response times, these factors were added to the model (Appendix B for full model). The predictors of participant proficiency scores on the English and Spanish MINT, code-switching scores on the BCSP, and participant accent ratings were added to the model used in the previous analysis. Random slopes and random intercepts were included for each of the main factors, and the categorical variable of language dominance was coded as -0.5 and 0.5, English-dominant was used as the reference level. To better understand how individual factors might be associated with comprehension of speech that includes code-switches, interactions of each of the factors with sentence type were included in the model.

The analysis showed no significant effects of English (β = -2.61, t = -1.40, p = .16) or Spanish (β = -1.99, t = -1.51, p = .13) proficiency. Additionally, there was no significant effect of language dominance (β = -60.61, t = -0.94, p = .35) or BCSP scores (β = -1.14, t = -0.93, p = -0.93). Accent ratings were significantly associated with response times (β = -16.16, t = -3.14, p = .002) indicating as a listener rates a speaker's accent closer to "*Native English Speaker*" the RT decreases.

To better understand the associations of language experiences with comprehension of code-switches, interactions of individual differences measures and sentence type were included in the model. There was a significant interaction of sentence type and English proficiency (β = 3.46, t = 4.04, p < 0.001), showing that as English proficiency increased, the costs involved in code-switching also increased. There was also an interaction of sentence type and Spanish proficiency (β = -3.01, t = -4.88, p < 0.001) showing the opposite effect, in that as Spanish proficiency increased, the switch costs decreased. There was a significant interaction of language dominance and sentence type (β = 67.96, t = 2.29, p = .03) indicating that English-dominant listeners had larger switch costs than Spanish-dominant listeners (Figure 4). However, there were no interactions of sentence type with BCSP (β = 0.34, t = 0.59, p = .55) or accent ratings (β = -12.91, t = -1.41, p = .16). Thus, neither code-switching experience nor perception of accented speech was associated with a listener's ability to contend with code switches.

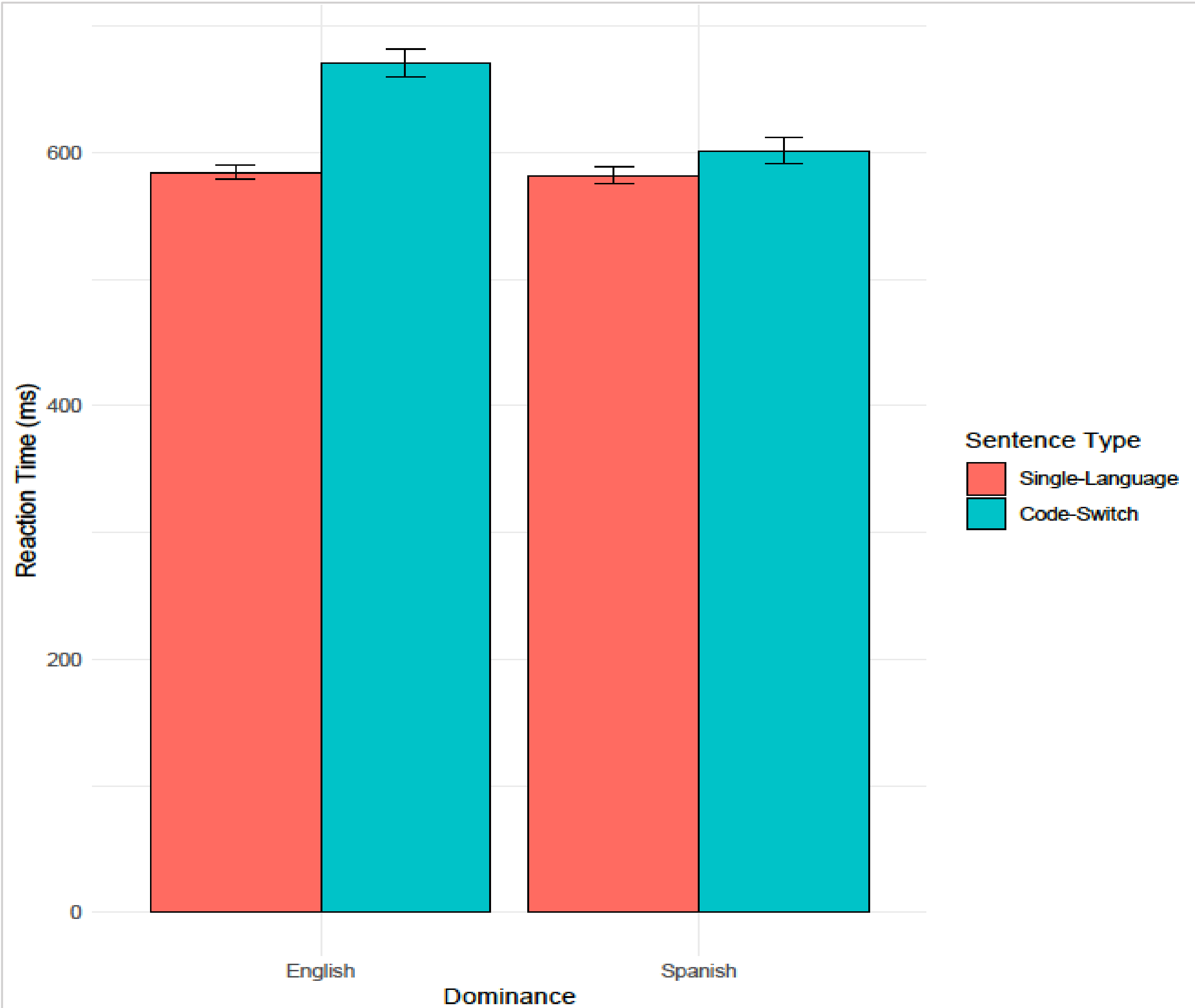
Table 5:

Experiment 1 fixed effects of LME, individual differences

	Estimate	Std. Error	t-value	p-value
Intercept	1054.85	147.88	7.13	<.001*
Sentence Type	40.95	75.90	0.54	0.59
Accent Type	33.46	24.82	1.35	0.18
English MINT	-2.61	1.86	-1.40	0.16
Spanish MINT	-1.99	1.32	-1.51	0.13
Dominance	-60.61	64.36	-0.94	0.35
BCSP	-1.14	1.22	-0.93	0.36
Accent Rating	-16.16	5.15	-3.14	0.002*
Sentence Type: Accent Type	-35.25	43.56	-0.81	0.42
Sentence Type: English MINT	3.46	0.86	4.04	<0.001*
Sentence Type: Spanish MINT	-3.01	0.62	-4.88	<0.001*
Sentence Type: Dominance	67.96	29.64	2.29	0.03*
Sentence Type: BCSP	0.34	0.57	0.59	0.55
Sentence Type: Accent Rating	-12.91	9.14	-1.41	0.16

Note. Fixed effects were sentence type (single language, code switch) accent type (English, Spanish), proficiency (English and Spanish MINT), language dominance, code switching use (BCSP), and accent perception ratings.

Figure 4



Experiment 1 RT by sentence type and language dominance

Note. Error bars represent the standard errors of the mean by participants.

Discussion

Experiment 1 examined how bilingual listeners comprehend code-switches produced by speakers with different accents. Specifically, we compared how listeners responded to single-language and code-switched sentences when produced by speakers with a typical North American English accent or a Juarez/El Paso Spanish accent. Results revealed that bilingual speech comprehension was delayed when it included code-switches. Individual differences such as language proficiency and dominance were associated with the extent of these switch costs. This relationship between switch costs and language background indicates that when listeners have higher proficiency and dominance in the code-switch language, it may lead to a reduction in switch costs. However, other language background factors such as experience with code-switching, and perception of accents did not seem to influence the costs involved in comprehending code-switches. Experiment 1 also showed that listeners responded more slowly when speech was presented by speakers with non-native accents. Despite listeners being familiar with both accent types, Spanish-accented speech delayed comprehension. Additionally, bilingual listeners did not respond to code-switches differently when presented in different accents. However, it is important to consider that the participants were very familiar with the accent types used in the current experiment.

Impacts of code-switches

As we predicted, the first experiment demonstrated there were costs involved in the comprehension of spoken code-switches. This finding of switch costs is consistent with prior research (Bultena et al., 2015; Li, 1996; Litcofsky & Van Hell, 2017; Macnamara & Kushnir, 1971; von Studnitz & Green, 1997), but interestingly, despite our bilingual population showing high frequency in experiences with code-switching, switch costs were still present. We anticipated several individual characteristics to be associated with the strength of switch costs. As English proficiency increased there were greater switch costs, and as Spanish proficiency increased switch costs decreased. These interactions of language proficiency and sentence type suggest that that less proficiency in Spanish leads to more time to comprehend a Spanish word.

Additionally, English-dominant participants showed larger switch costs than Spanish-dominant participants. Similar results have been seen when examining the effect of dominance and the direction of code-switches in reading comprehension (Litcofsky & Van Hell, 2017), in that switch costs were higher when switching into the readers' weaker language. The preceding interactions may indicate that higher proficiency and dominance in the language of the code-switch (in this case Spanish) lead to smaller switch costs. Another possibility is some aspect of the Spanish speech included a cue of an upcoming code-switch, and said cue was used more efficiently by higher proficiency in Spanish and Spanish-dominant participants.

We examined how other characteristics of bilingual listeners might be associated with switch costs, including their experiences with code-switching and perceptions of accented speech. We predicted that more experience with code-switching would lead to a reduction in switch costs. However, code-switching experience was not associated with overall task performance or switch costs. These results showed that variability in of how often listeners are exposed to, identify with, or use code-switching themselves did not impact the costs involved in comprehending code-switches. Additionally, in the accent rating task, participants perceived the accents as different, but subjective intensity of an accent was not associated with overall performance or switch costs. This lack of association may have to do with the environment in which the data were collected. Experiences with non-native accents, foreign languages, and bilingual environments with greater ecological diversity have been seen to reduce perceived intensity and negative biases of non-native accents (Eisenchlas, & Tsurutani, 2011; Kutlu et al., 2022). It is also important to note that nearly half (40.7%) of the sample were Spanish-dominant bilinguals, and although we did not measure participants' accents, it is reasonable to assume that some had non-native accents when speaking English. This combination of experiences with code-switching and a bilingual environment seems to have led to familiarity with Spanish accented speech. This familiarity with both the Spanish accent and code-switching may have played a role in the findings that switch costs were not associated with code-switching experiences or perceived intensity of accented speech.

Impacts of non-English accents

As anticipated, Experiment 1 showed that listeners responded more slowly to English speech that was presented by Spanish-accented speakers than English-accented speakers. Previous research has shown similar findings that non-native accented speech delays the speed of listener comprehension (Munro & Derwing, 1995, 1999). However, previous research has also shown that listeners are able to quickly adapt to non-native accented speech when given appropriate time and exposure to said accents (Baese-Berk et al., 2013; Cristia et al., 2012; Grey & van Hell, 2017; Peng & Weng, 2016). The majority of participants in Experiment 1 reported living in the bilingual environment of El Paso for most of their lives and had exposure to this type of Spanish accented speech. Even though Spanish-accented English speech is common in El Paso, it is still processed more slowly. One fundamental aspect of Spanish accented speech that may explain why the listeners still processed Spanish accents more slowly despite their familiarity with the accent, is the variability involved in accented speech. Previous research has demonstrated non-native accented speech differs from native accents by additional variability both within and between speakers (Bradlow & Bent, 2008; Cristia et al., 2012). While listeners can adapt to non-native accents, this variability prevents them from processing non-native speech at the same rate as native accented speech (Gass & Varonis, 1984; Mattys et al., 2012; Munro & Derwing, 1999; Van Engen & Bradlow, 2007). Thus, even though participants living in a bilingual community are regularly exposed to Spanish-accented speech, that variability still appears to influence their processing efficiency.

Impacts of accent on switch costs

The primary interest in Experiment 1 was to determine the potential impact of accent on switch costs. We predicted that switch costs would be smaller for the Spanish accent when compared to the English accent. This prediction was based on previous research that has demonstrated many factors are influential in speech comprehension (Blumenfeld & Marian, 2013; Chambers & Cooke, 2009; Li & Yip, 1998; Marian & Spivey, 2003), and accent has been seen as a useful cue for listeners when predicting upcoming speech (Brunellière & Soto-Faraco, 2013; Grey & van Hell, 2017). Contrary to our prediction, switch costs did not differ as a function of accent type. Listeners showed similar switch costs for English- and Spanish-accented speech. These results align with the BIA+ in that the bottom-up cross language activation is unaffected by nonlinguistic factors such as accent of the speaker.

The results can also be interpreted in the framework of the Adaptive Predictability hypothesis (Valdés Kroff & Dussias, 2023), which suggests bilinguals can use a variety of cues to assist the comprehension of code-switches but, the weight of these cues likely depends on a bilingual's previous experiences with code-switching. As previously mentioned, listeners in El Paso are familiar with both the North American English and Juarez/El Paso Spanish accented speech used in the current experiment. Presumably, listeners have also experienced both of these accent types speaking English, Spanish, and code-switching between the two languages. These previous experiences with code-switching may have led listeners to place less weight on accent as a cue of upcoming speech. Participants also reported frequent experiences with code-switching, which may influence the shift in weights placed on different cues presented in bilingual speech. The current results suggest that listeners do not respond to code-switches differently when speech was presented in English or Spanish accents. However, both the English and Spanish accents used in Experiment 1 were familiar to listeners. For this sample of bilinguals, it is possible both the English and Spanish accents are linked to code-switching in their experiences. Due to participants' experiences with code-switching and familiarity with the accents, listeners may treat the specific English and Spanish accents as an unreliable or inconsistent cue that an code-switch may occur in upcoming speech. Experiment 2 was designed to examine the potential effects of accent on switch costs when listeners were not familiar with the accent type.

Experiment 2

Experiment 2 aimed to expand our understanding of how accent may impact switch costs involved in speech comprehension. Listeners responses to single-language and code-switched sentences produced with English and unfamiliar accents. Overall, we predicted that as in Experiment 1, participants would respond to code-switches more slowly than single-language sentences. We again anticipated non-English accented speech to be processed more slowly than English accented speech. When comparing switch costs in the English-accented speech to Unfamiliar-accented speech, we expected there to be larger switch costs in Unfamiliar-accented speech. This would suggest that when code-switches presented with an unfamiliar non-English accent, the switches are processed differently. Experiment 2 again measured language proficiency, dominance, experiences with code-switching, and perceptions of accents. We anticipated a similar pattern to Experiment 1, that higher proficiency and dominance in the language of the code-switch would lead to smaller switch costs. We also anticipated that bilinguals with more experiences of code-switching would have smaller switch costs than bilinguals with less experiences in code-switching.

Methods

Design

To determine how bilingual listeners process code-switches produced by speakers with unfamiliar accents, Experiment 2 used the same visual world eye-tracking paradigm as the previous experiment. Experiment 2 followed a 2 (sentence type: Single-language vs. Code-switched) x 2 (accent type: Familiar vs. Unfamiliar) within-subjects design. To evaluate the influence of accent, sentences were produced by speakers with English or unfamiliar accents (Table 6).

Table 6:

Experiment 2 sample auditory stimuli

Accent Type:	Speaker:	Sentence Type:	Auditory Stimuli:
English	English 1	Code-switched	My father said that he sees **osos** outside his window.
English	English 2	Single-language	When he pays attention, he sees **bears** and other big scary animals.
Unfamiliar	Flemish	Single-language	My little brother likes **bears** and has many pictures of them.
Unfamiliar	Bulgarian	Single-language	My father and I always see **bears** and other animals.

Note. Auditory stimuli used for the target item *bear*. Each speaker presented a unique sentence containing the target word. The target was presented in three single-language sentences and one code-switched sentence.

Participants

Participants (*N* = 58) were enrolled at the University of Texas at El Paso and participated for course credit. Data from two participants were excluded for not meeting accuracy requirements (<25%). The median age was 19 years old (*SD* = 6.72, range = 18-62), 70.69% identified as female, the majority of participants (98.28%) identified as Latino/a. All participants self-reported that they had normal hearing and were proficient English-Spanish bilinguals.

Proficiency in each language was assessed using the MINT Sprint (Gollan, et al. 2023). Participants demonstrated high proficiency scores on both the English (*M* = 69.72%, *range* = 28.75%-96.25%, *SD* = 15.61%) and Spanish (*M* = 62.28%, *range* = 23.75%-82.50%, *SD* = 15.58%) assessments. Based on their MINT scores, participants were classified as dominant in English (*N* = 32) or Spanish (*N* = 26). Participants BCSP scores demonstrated high use and experiences in code-switching (*M* = 67.38, *range* = 20.28 – 94.30, *SD* = 16.97).

Materials

Auditory Stimuli.

Auditory stimuli for Experiment 2 were the same sentences used in Experiment 1. Sentences were presented by four different female speakers, two with English accents and two with unfamiliar accents. The English-accented materials were the same as those used in Experiment 1. The two Unfamiliar-accented speakers were fluent English-Spanish bilinguals with different first languages. One speaker was a Dutch (Flemish) speaker who learned English and Spanish after learning Flemish (Flemish AoA = since birth; English AoA = 11; Spanish AoA = 19) and the other was a Bulgarian speaker who learned English and Spanish after learning Bulgarian (Bulgarian AoA = since birth; English AoA = 5; Spanish AoA = 15). Each speaker self-reported their perceived accents when speaking both English and Spanish. English-accented speakers reported little to no Spanish influence when speaking English, while Unfamiliar-accented speakers reported medium to heavy influence of their first language when speaking English (Table 7). To test if accents were perceived as labeled, participants rated how likely it was that English or Spanish was the speaker's native language (Table 7).

Table 7:

Experiment 2 average accent ratings

	Self-rating: native English speaker?	Participant rating: native English speaker?	Participant rating: native Spanish speaker?
English Accent 1	5	3.93	2.54
English Accent 2	4	3.44	2.97
Flemish Accent	3	2.71	3.67
Bulgarian Accent	3.5	2.44	3.61

Note. Participants were asked how likely it was that each speaker was a native English or Spanish speaker, and responded on a 5-point Likert type scale (*1-Extremely Unlikely; 5-Extremely Likely*). Scores were averaged across participants.

Recording procedures were identical to Experiment 1. For Experiment 2, silence was added such that target nouns always occurred 2480 ms after the start of the sentence.

Visual Stimuli

Visual stimuli were the same as in Experiment 1.

Accent Rating, Language Proficiency, and Code-Switching Use

To assess participants' perception of the speakers' accents, participant language proficiency, and the influence of code-switching use the same measures from Experiment 1 were used: the MINT Sprint (Gollan et al., 2023) and BCSP (Olson, 2022). Additionally, participants responded to an open-ended question that asked them to identify the Unfamiliar-accented speakers' native language. No participants were able to correctly identify either unfamiliar accent.

Procedure

Experiment 2 followed the same procedure as Experiment 1.

Data Analysis

Data recording and processing procedures were the same as Experiment 1, 1126 trials (14.91%) were excluded from Experiment 2 analyses.

Results

After excluding trials based on predetermined requirements a total of 6298 (83.40%) observations were included in Experiment 2 analyses. Fixed factors were defined as sentence type (single-language vs code-switch) and accent type (English accent vs Unfamiliar accent). Participant and item (i.e., target word) were included as random factors in the model, and random slopes and random intercepts were included for each of the factors (Appendix B for full model). There was no significant effect of sentence type (β = 16.64, t = 0.72, p = .48); RTs for single-language and code-switched sentences were similar indicating that global switch costs were not present. However, there was an effect of accent type (β = 46.21, t = 2.18, p = .04); RTs for Unfamiliar accented speech were slower than for English accented speech. There was no interaction between sentence type and accent type (β = 77.23, t = 1.80, p = .08).

Table 8:

Experiment 2 fixed effects of LME

	Estimate	Std. Error	t-value	p-value
Intercept	1236.16	22.89	54.00	<0.001*
Sentence Type	16.64	23.18	0.72	0.48
Accent Type	46.21	21.23	2.18	0.04*
Sentence Type: Accent Type	77.23	43.14	1.80	0.08

Note. Fixed effects were sentence type (single-language, code-switch) and accent type (English, Unfamiliar).

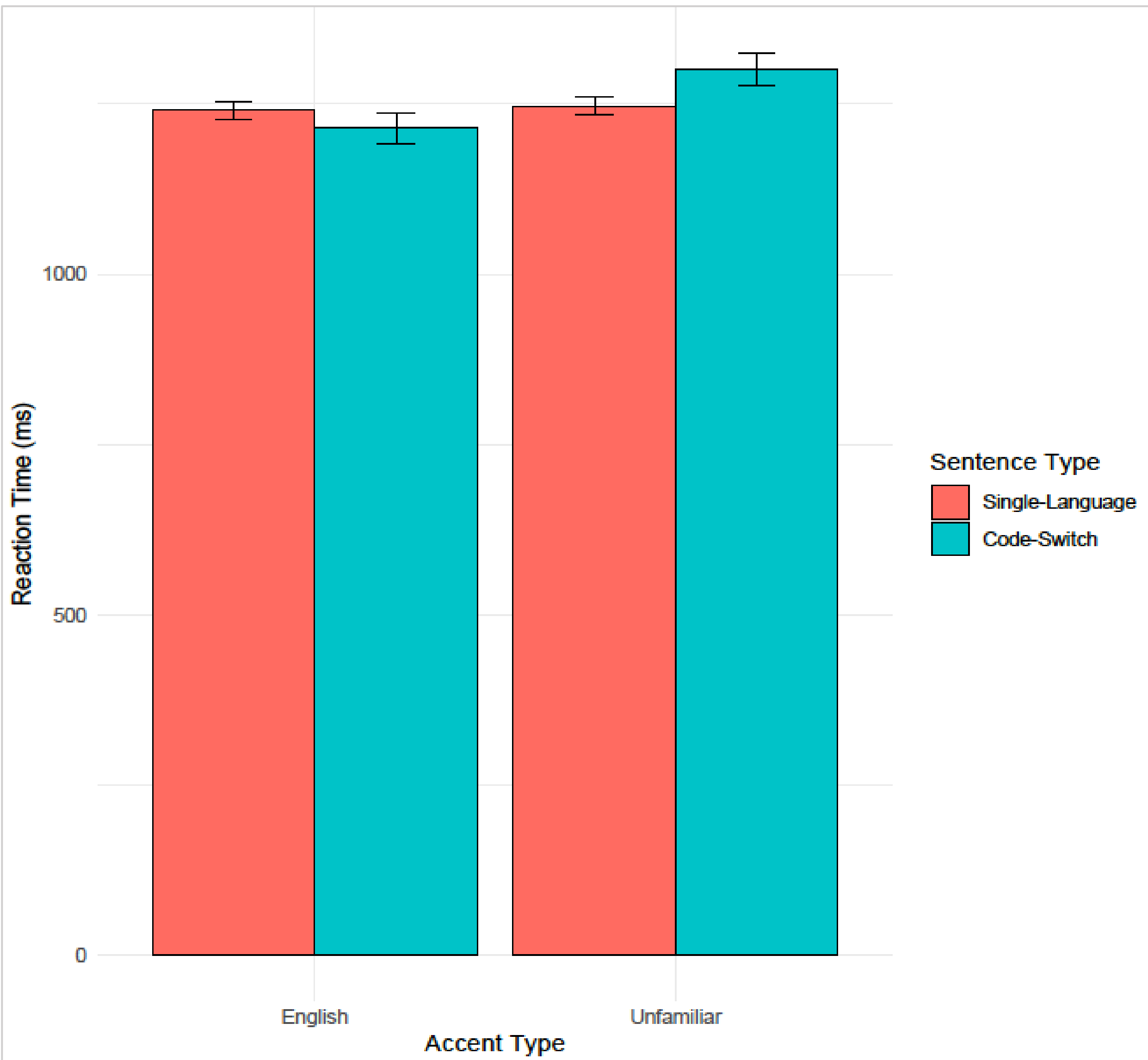
Table 9:

Experiment 2 mean reaction times (ms) by condition

	English Accent *M (SE)*	Unfamiliar Accent *M (SE)*
Single-Language	1224 (25.3)	1232 (26.1)
Code-Switch	1202 (33.1)	1287 (33.6)

Note. Means and standard errors were calculated using the emmeans package in R (Lenth, 2024).

Figure 5:



Experiment 2 RT by sentence and accent type

Note. Error bars represent the standard errors of the mean by participants.

Individual Differences

To understand the associations of language proficiency, dominance, code switching use, and perceptions of accented speech, these factors were added to the model. Participant proficiency scores in English and Spanish, scores on the BCSP, and participant accent ratings were added as covariates to the model used in the previous analysis (Appendix B for full model). Participant, item, and speaker accent ratings were included as random factors, random slopes and random intercepts were included for each of the main factors.

Results showed no significant effect of English (β = 1.61, t = 0.76, p = .45) or Spanish (β = -2.87, t = -1.41, p = .16) proficiency. Additionally, there was no significant effect of language dominance (β = 117.55, t = 1.41, p = .16), BCSP scores (β = 0.89, t = 0.67, p = .50), or accent ratings on RT (β = 3.53, t = 0.36, p = .72). To better understand the associations of language experiences on comprehension of code-switches, interactions of individual differences measures and sentence type were included in the model. There were no significant interactions between sentence type and English proficiency (β = 1.90, t = 0.97, p= 0.33) or Spanish proficiency (β = 1.70, t = 0.94, p = .35). Additionally, there was no interaction between sentence type and language dominance (β = -49.20, t = -0.66, p = .51), BCSP (β = 1.50, t = 1.31, p = .20), or accent ratings (β = 9.07, t = 0.50, p = .62).

Table 10:

Experiment 2 fixed effects of LME, individual measures

	Estimate	Std. Error	t-value	p-value
Intercept	1237.42	225.44	5.49	<0.001*
Sentence Type	-353.91	213.91	-1.65	0.10
Accent Type	51.11	24.24	2.11	0.04*
English MINT	1.61	2.12	0.76	0.45
Spanish MINT	-2.87	2.04	-1.41	0.16
Dominance	117.55	83.15	1.41	0.16
BCSP	0.89	1.32	0.67	0.50
Accent Rating	3.53	9.93	0.36	0.72
Sentence Type: Accent Type	88.95	48.26	1.82	0.07
Sentence Type: English MINT	1.90	1.95	0.97	0.33
Sentence Type: Spanish MINT	1.70	1.80	0.94	0.35
Sentence Type: Dominance	-49.20	75.09	-0.66	0.51
Sentence Type: BCSP	1.50	1.15	1.31	0.20
Sentence Type: Accent Rating	9.07	18.30	0.50	0.62

Note. Fixed effects were sentence type (single-language, code-switch) accent type (English, Unfamiliar), proficiency (English and Spanish MINT), language dominance, code-switching use (BCSP), and accent perception ratings.

Experiment 2 Summary

Results showed listeners' responses did not differ when comparing single-language and code-switched sentences. Listeners responded more slowly to sentences that were presented by an unfamiliar-accented speaker. Additionally, listeners did not experience switch costs differently in English accented speech when compared to the unfamiliar non-English accented speech. Before interpreting these results, it is important to acknowledge the long reaction times in Experiment 2. When comparing RTs from Experiment 1 to RTs from Experient 2, overall RTs from Experiment 2 were much longer. To better understand accent as a cue in speech, we combined Experiment 1 and 2 datasets into one analysis. Further interpretation is discussed below.

Experiment 2 Expanded Analysis

In order to fully understand the extent of the impacts of code-switching and accented speech on speech comprehension, data from Experiments 1 and 2 were analyzed together. To do this, accent type was re-coded to combine the Spanish accent (Experiment 1) and unfamiliar accent (Experiment 2) conditions. Therefore, accent levels were coded as English-accented, or non-English-accented speech.

A total of 12,366 observations were included in the analyses. Linear mixed effects analyses were used to analyze the data, defining sentence type (single-language vs code-switch) and accent type (English vs non-English) as fixed factors. Participant and item were included as random factors, and random slopes and random intercepts were also included for each of the factors (see Appendix B for full model).

Participants' responses were slower for sentences that contained a code switch, indicating switch costs were present across experiments (β = 105.33, t = 2.75, p = .006). Additionally, RTs were overall slower for sentences presented in non-English-accented speech than English-accented speech (β = 73.06, t = 2.14, p = .03). There was a main effect of experiment (β = 616.42, t = 21.43, p < 0.001); RTs were significantly slower in Experiment 2 (M = 1236 ms) than in Experiment 1 (M = 624 ms). Importantly, there was a 3-way interaction between sentence type, accent type, and experiment (β = 78.87, t = 2.04, p = .04). This interaction reflects that the relative switch costs were higher for Unfamiliar-accented vs. English-accented speech (Experiment 2), compared to Spanish- vs. English-accented speech (Experiment 1).

Table 11:

Experiment 2 expanded analysis fixed effects of LME

	Estimate	Std. Error	t-value	p-value
Intercept	3.46	46.35	0.07	0.94
Sentence Type	105.33	38.32	2.75	0.006*
Accent Type	73.06	34.22	2.14	0.03*
Experiment	616.42	28.76	21.43	<0.001*
Sentence Type: Accent Type	-89.30	67.75	-1.32	0.19
Sentence Type: Experiment	-42.46	22.34	-1.90	0.06
Accent Type: Experiment	-13.68	19.38	-0.71	0.48
Sentence: Accent: Experiment	78.87	38.67	2.04	0.04*

Note. Fixed effects were sentence type (single language, code switch), accent type (English, non-English), and Experiment (1 vs 2).

Discussion

Experiment 2 aimed to understand how bilingual listeners comprehend code-switches produced by speakers with different accents. Participants listened to single-language and code-switched sentences presented by speakers with a typical North American English accent and unfamiliar Flemish and Bulgarian accents. Results showed listeners responded more slowly to sentences that contained a code-switch, demonstrating switch costs were present. Language proficiency, dominance, experiences with code-switching and accent perception were not associated with switch costs, showing that differences in language background and experiences did not impact the costs involved in comprehending code-switches under these conditions. When responding to unfamiliar accented speech, listeners responded more slowly than English-accented speech. When presented with an unfamiliar accent, listeners' comprehension for English-accented speech was also delayed. Findings show that when listeners were presented with an unfamiliar accent speech comprehension was globally impacted. Additionally, the relative impacts of accent on switch costs were different. Listeners processed code-switches differently when listening to an unfamiliar non-English accent than when listening to a more familiar Spanish accent or English accent.

Impacts of code-switches

As predicted, Experiment 2 showed that costs were involved in the comprehension of spoken code-switches. However, contrary to our predictions there were no associations between switch costs and language proficiency, dominance, experiences with code-switching, or accent perception. This might suggest when code-switches are presented in an unfamiliar non-English accent, the effects of language proficiency and dominance on switch costs are no longer impactful. Previous research has demonstrated when non-native accents are paired with other factors that delay processing, comprehension is further impacted (Anderson-Hsieh & Koehler, 1988). As discussed below, the unfamiliar accent greatly impacted listeners' speed when comprehending speech. Although higher proficiency and dominance in the code-switch language may be easier for bilinguals to comprehend than when switching into their weaker language (Litcofsky & Van Hell, 2017), when presented with both the difficulty of a code-switch and the difficulty of an unfamiliar accent language proficiency and dominance were no longer impactful. We also examined other characteristics of bilingual listeners that could be associated with switch costs, experiences with code-switching and perceptions of accented speech. Although listeners in Experiment 2 demonstrated high levels of experiences and frequency of code-switching, no relationship was seen with these factors and overall task performance or switch costs. These results suggest that exposure to, sense of identity with, or use of code-switching was not associated with switch costs.

Impacts of unfamiliar non-English accent

As predicted, Experiment 2 showed that a non-English accent delays a listener's speech comprehension. When listeners were presented with unfamiliar accented speech, they responded more slowly than sentences that were spoken with an English accent. This difficulty comprehending non-native accented speech replicates Experiment 1 and previous findings (Munro & Derwing, 1995, 1999). Experiment 2 also found that when listeners were presented with an unfamiliar accent (Flemish and Bulgarian), their speech comprehension was greatly delayed compared to a familiar non-English accent (Spanish). Previously, bilingual listeners have been observed adapting to accented speech and using said accent to adjust expectation of upcoming speech (Baese-Berk et al., 2013; Brunellière & Soto-Faraco, 2013; Grey & van Hell, 2017; Peng & Weng, 2016). When hearing sentences spoken with a familiar non-English accent, listeners were able to draw on their previous experiences with Spanish-accented speech to comprehend the accent. However, experiences with non-English accents seem to only assist listeners when comprehending speech produced in accents that are familiar to the listener. When hearing speech in an unfamiliar non-English accent, comprehension was globally impacted. Not only did listeners respond more slowly to unfamiliar non-English accents, the familiar English accented speech that was presented in tandem was also impacted.

Impacts of accent on switch costs

One of our primary interests in Experiment 2 was to examine how listeners processed code-switches produced by speakers with unfamiliar accents. We expected switch costs to be different when code-switches were presented in an unfamiliar accent when compared to familiar accents. Results demonstrated a significant interaction between sentence type, accent type, and experiment type. When compared to an English accent, switch costs were larger when code-switches were presented in an unfamiliar non-English accent. Listeners processed all speech differently when in the presence of an unfamiliar accent, and relatively greater differences were seen between single-language and code-switched sentences. When applying these findings to our understanding of why bilingual listeners process code-switches differently in different accents, results contrast the BIA+, which assumes that bottom-up cross language activation is unaffected by nonlinguistic factors. However, the current results demonstrate that the nonlinguistic factor accent of the speaker does impact activation.

To explain these results we can refer back to the idea that bilinguals use their experiences with code-switching to inform them which cues in speech are reliable, the Adaptive Predictability hypothesis (Valdés Kroff & Dussias, 2023). Experiment 1 results showed listeners did not respond to code-switches differently when presented in English and Spanish accents. However, Experiment 2 demonstrated listeners did respond to code-switches differently when presented in different unfamiliar accents. Due to our bilingual listeners' familiarity and experiences with both the English and Spanish accents, bilinguals were placing the same weight on each of these accent types. Essentially, the current bilinguals had experiences of both English and Spanish accent types code-switching in their environments. Therefore, for the listeners it seemed equally possible that a code-switch may occur in either the English and Spanish accented speech. When presented with an unfamiliar non-English accent, the bilingual listeners did not have experiences of this accent type code-switching, and therefore showed greater switch costs.

Another possible explanation to why listeners responded to code-switches differently in different accent types, is that another cue may be at play within the speech. Previous research has demonstrated bilinguals are sensitivity to both very subtle and easily accessible cues in speech that may help prepare them for a code-switch (Foucart et al., 2015; Grey & van Hell, 2017; Ju &

Luce, 2004; Olson, 2017). It is possible a more subtle cue of an upcoming code-switch was included in each of the accent types, but it was easier for bilinguals to access in familiar accented speech. Research has been demonstrated speakers change the phonetics prior to a code-switch to include characteristics of the code-switch language (Balukas & Koops, 2015; Bullock et al., 2006; Deuchar et al., 2014; Olson, 2016). All of the sentences in Experiment 1 and 2 were naturally produced, therefore it is likely that the speakers coarticulation prior to a code-switch incorporated Spanish phonetics. It may be possible listeners are using this coarticulation as cue of an upcoming code-switch. However, due to the impacts of unfamiliar accents listeners were unable to access this cue. Experiment 3 further explored coarticulation as a cue to better understand how listeners efficiently comprehend code-switches in speech.

Experiment 3

Experiment 3 aimed to further our understanding of what cues listeners may use when comprehending spoken code-switches. Listeners responded to single-language and code-switched sentences that were either naturally produced or manipulated coarticulation prior to the target word. We predicted that participants would respond to code-switches more slowly than single-language sentences. It was also expected that listeners would respond to manipulated speech more slowly than naturally produced speech. When comparing switch costs in in naturally produced speech to manipulated speech, we expected switch costs to be larger for manipulated speech. This would suggest that when encountering code-switches, listeners use the coarticulation prior to the switch as a cue a code-switch is about to occur. Experiment 3 again measured language proficiency, dominance, experiences with code-switching. We anticipated higher proficiency and dominance in the language of the code-switch would lead to smaller switch costs. We also expected bilinguals with more experiences of code-switching will have smaller switch costs than bilinguals with less experiences in code-switching. Experiment 3 will expand our understanding of which cues bilingual listeners find helpful when comprehending code-switches.

Methods

Design

To determine how participants made use of coarticulatory cues across different types of sentences, Experiment 3 used the same visual world eye-tracking paradigm as Experiments 1 and 2. Experiment 3 followed a 2 (sentence type: Single-language vs. Code-switched) x 2 (speech type: Natural vs. Spliced) within-subjects design. The same sentences from the previous experiments were used, but in Experiment 3, all sentences were produced by a single English-accented bilingual speaker. To evaluate the influence of coarticulation, sentences were either produced naturally to include original coarticulation or involved spliced versions of the target word inserted into the sentence frame.

Participants

Participants (*N* = 58) were enrolled at the University of Texas at El Paso and participated for course credit. Two participants were excluded because their response accuracy was lower than chance (25%). The median age was 19 years old (*SD* = 4.12, range = 18-42), 93.1% identified as women, and the majority of participants (91.4%) identified as Latino/a ethnicity. All participants self-reported that they had normal hearing and were proficient English-Spanish bilinguals. Proficiency in each language was assessed using the MINT Sprint (Gollan, et al. 2023). Participants demonstrated high proficiency scores on both the English (*M* = 62.74%, *range* = 25%-87.5%, *SD* = 14.18%) and Spanish (*M* = 62.74%, *range* = 21.25%-87.5%, *SD* = 16.24%) assessments. Based on their MINT scores, participants were classified as dominant in

English (N = 30) or Spanish (N = 28). Participants BCSP scores indicated they had high use and experiences in code-switching (M = 65.58, *range* = 10.55 – 93.05, SD = 17.53).

Materials

Auditory Stimuli

Auditory stimuli for Experiment 3 were the same sentences used in Experiment 1 and 2. All sentences were produced by a single bilingual speaker with an English accent (Speaker 1 in Experiment 1). An equal number of natural and spliced sentences were presented (64 each).

To reduce the phonetic cues provided by coarticulation prior to the onset of the target word, splicing procedures were used. To create items for the spliced condition, sentences were recorded in which target words were replaced by a dummy target. Dummy targets were English words that possessed similar phonetic beginnings to actual target words (e.g., "*bars*" instead of "*baskets*"; "*seeds*" instead of "*cestas*"). Dummy targets were then manually removed from dummy sentences and replaced with target words that were isolated from naturally produced sentences.

All sentences were recorded in a soundproof room with a Blue Snowball microphone using the computer software Praat (Boersma & Weenink, 2023). Target noun onset was standardized across sentences by adding silence to the beginning of each audio file such that target nouns always occurred 2482 ms after the start of the sentence. Intensity of audio was matched to 65 db.

Visual Stimuli

Visual stimuli were identical to those used in Experiment 1 and 2.

Speech Rating Task

To assess participants' perception of the speech, they rated how "typical" sounding the speech was. Participants were told they would hear some sentences by the same speaker as the previous task. They were asked how typical the speaker sounded. Speech was rated on a 5-point Likert type scale ranging from "*1-Different*" to "*5-Typical*". Participants listened to one single-language and one code-switched sentence for each speech type, natural (M= 4.22, SD = 0.92) spliced (M = 3.77, SD = 0.91).

Language Proficiency and Code-Switching Use

To assess language proficiency and the influence of code-switching use the same measures from the previous experiment were used, MINT Sprint and the BCSP.

Procedure

Experiment 3 followed the same procedure as Experiment 1 and 2.

Data Analysis

Data were recording and analysis was the same as Experiment 1 and 2.

Results

Based on the predetermined exclusion criteria, 1234 (16.6%) trials were excluded. A total of 6192 (83.4%) observations were included in Experiment 3 analyses. Fixed factors were defined as sentence type (single-language vs code-switch) and speech type (natural vs spliced). Participant and item (i.e., target word) were included as random factors, and random slopes and random intercepts were included for each of the factors (see Appendix B for full model).

Results demonstrated a significant effect of sentence type (β = 146.15, t = 3.82, p < 0.001) indicating switch costs were present. There was a main effect of speech type (β = 87.41, t = 2.48, p = .02); participants responded more slowly to spliced sentences. There was also an interaction between sentence type and speech type (β = 173.04, t = 2.54, p = .02), indicating the difference between single-language and code-switched sentences was greater when speech was spliced than when speech was produced naturally.

Table 12:

Experiment 3 fixed effects of LME

	Estimate	Std. Error	t-value	p-value
Intercept	716.97	33.13	21.65	<0.001*
Sentence Type	146.15	38.31	3.82	<0.001*
Speech Type	87.40	35.28	2.48	0.02*
Sentence Type: Speech Type	173.04	68.04	2.54	0.02*

Note. Fixed effects were sentence type (single-language, code-switch) and speech type (natural, spliced).

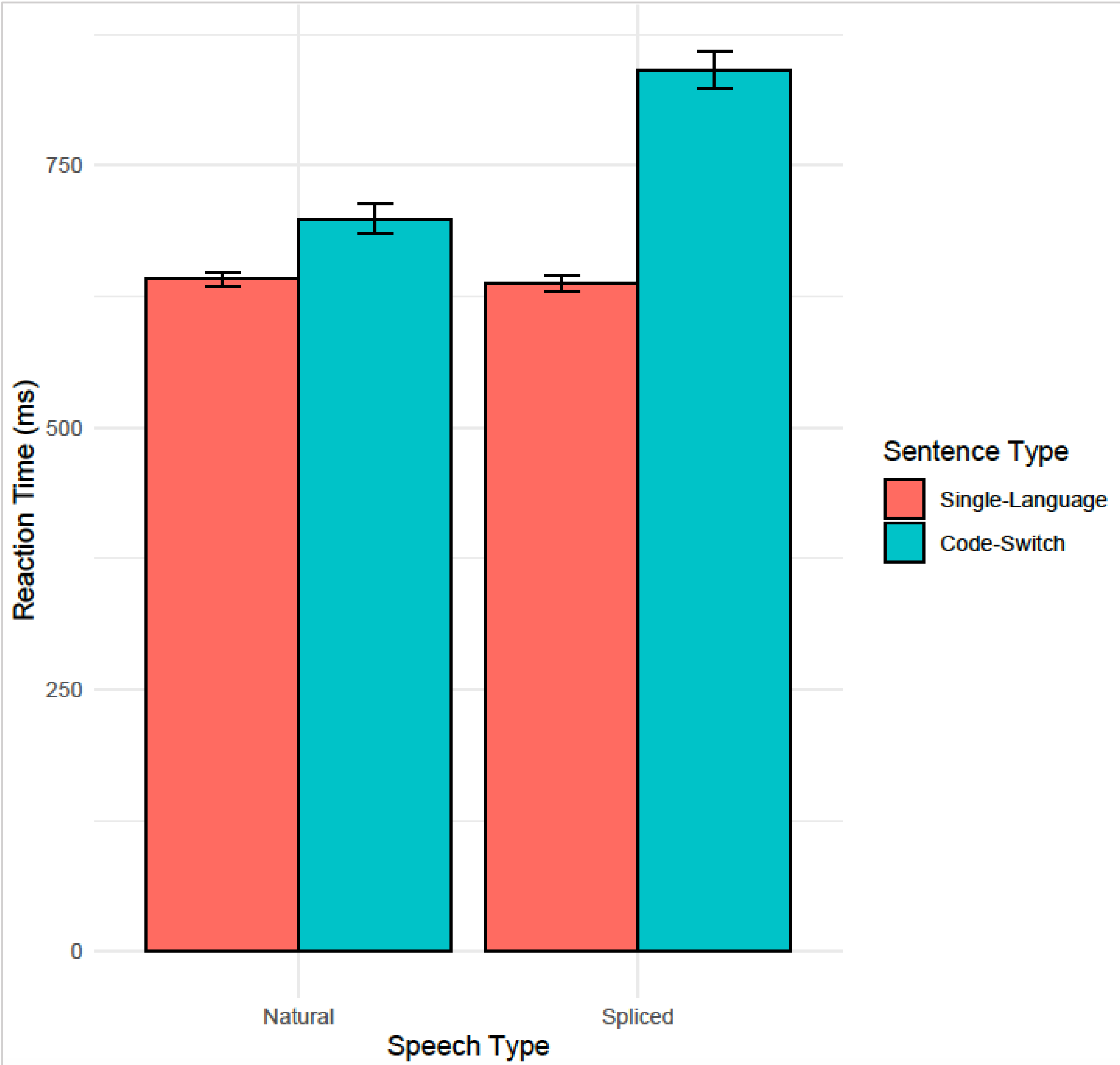
Table 13:

Experiment 3 mean reaction times by condition

	Natural Speech *M (SE)*	Spliced Speech *M (SE)*
Single-Language	643 (30.4)	644 (31.1)
Code-Switch	703 (56.6)	877 (56.3)

Note. Means and standard errors were calculated using the emmeans package in R (Lenth, 2024).

Figure 6:



Experiment 3 RT by sentence and speech type

Note. Error bars represent the standard errors of the mean by participants.

Individual Differences

As in Experiments 1 and 2, individual differences measures of language proficiency, dominance, code switching use, and perceptions of speech were added to the model. Participant and item were included as random factors, random slopes and random intercepts were included for each of the factors (see Appendix B for full model).

Results showed no significant effect of English (β = -2.72, t = -0.97, p = .33) or Spanish (β = -0.37, t = -0.12, p= 0.90) proficiency. Additionally, there was no significant effect of language dominance (β = 3.16, t = 0.03, p= 0.98), BCSP scores (β = -1.93, t = -1.03, p= 0.31), or speech ratings on RT (β = 1.82, t = 0.23, p= 0.82). Interactions of individual differences measures and sentence type were included in the model. There was no significant interaction between sentence type and English proficiency (β = 2.34, t = 1.96, p= 0.06). However, there was a significant interaction between sentence type and Spanish proficiency (β = -2.89, t = -2.29, p= 0.03); as Spanish proficiency increased, the differences between single-language and code-switched sentences decreased. Additionally, there were no interactions between sentence type and language dominance (β = 15.72, t = 0.32, p= 0.75), BCSP (β = -1.62, t = -1.99, p= 0.05), or between sentence type and speech ratings (β = -9.68, t = -0.82, p= 0.42).

Table 14:

Experiment 3 fixed effects of LME, individual differences

	Estimate	Std. Error	t-value	p-value
Intercept	1030.66	225.25	4.58	<0.001*
Sentence Type	325.39	110.13	2.96	0.004*
Speech Type	88.78	35.48	2.50	0.02*
English MINT	-2.72	2.81	-0.97	0.33
Spanish MINT	-0.37	2.97	-0.12	0.90
Dominance	3.16	116.69	0.03	0.98
BCSP	-1.93	1.89	-1.03	0.31
Speech Rating	1.82	7.81	0.23	0.82
Sentence Type: Speech Type	169.37	68.23	2.48	0.02*
Sentence Type: English MINT	2.34	1.19	1.96	0.06
Sentence Type: Spanish MINT	-2.89	1.26	-2.29	0.03*
Sentence Type: Dominance	15.72	49.69	0.32	0.75
Sentence Type: BCSP	-1.62	0.81	-1.99	0.05
Sentence Type: Speech Rating	-9.68	11.86	-0.82	0.42

Note. Fixed effects were sentence type (single-language, code-switch) speech type (natural, spliced), proficiency (English and Spanish MINT), language dominance, code switching use (BCSP), and accent perception ratings.

Discussion

Experiment 3 aimed to understand the impact of coarticulation on the comprehension of spoken code-switches. Listeners responded to single-language and code-switched sentences that were either naturally produced or included manipulated coarticulation prior to the target word. As predicted, speech comprehension was delayed when speech included code-switches. Spanish proficiency was seen to be associated with the extent of these switch costs. This relationship between switch costs and language proficiency may suggest when listeners have higher proficiency in the code-switch language, it leads to a reduction in switch costs. When sentences included manipulated coarticulation, comprehension was slower than when speech was naturally produced. This finding showed that listeners use coarticulation when processing incoming phonetic data to assist in speech comprehension. Additionally, it was seen that the costs involved in comprehending spoken code-switches were impacted by coarticulation. Bilinguals' switch costs were greater when coarticulation was manipulated in speech.

Impact of code-switches

As we predicted, Experiment 3 showed there were costs involved in the comprehension of spoken code-switches. We expected several characteristics of language background to be related to switch costs. A significant interaction between sentence type and Spanish proficiency indicated as Spanish proficiency increased the differences between single-language and code-switched trials decreased. The relationship between Spanish proficiency and switch costs suggests that language proficiency may play a role in the comprehension of code-switches. When listeners have higher proficiency in the language of the code-switch, comprehension may be easier. When bilinguals are faced with code-switches into their weaker language their comprehension is delayed (Litcofsky & Van Hell, 2017). We also expected additional language experience factors such as language dominance, experiences with code-switching, and perceptions of speech to impact switch costs. However, no associations were seen between these language background factors and switch costs. It is important to note that only one pattern of code-switches were included in the current study. We expect that if listeners also faced code-switches from Spanish into English, participants with higher English proficiency would demonstrate smaller switch costs. Further exploration will be needed to understand the relationship between language dominance, code-switching experiences, and perception of speech on the comprehension of code-switches especially in the context of different code-switch patterns.

Impacts of speech type

Results from Experiment 3 found that listeners responded more slowly to sentences that with manipulated coarticulation prior to a target word than sentences that were naturally produced. These results are consistent with our expectation and previous findings that demonstrated listeners use incoming phonetic data to incrementally build up representations of speech (Ju & Luce, 2004; Marian & Spivey, 2003). Additionally, previous research has demonstrated that when coarticulation was manipulated to provide misleading phonetic information, speech comprehension was delayed, suggesting the subtle phonetic information in coarticulation provides listeners with useful cues when processing speech (Tobin et al., 2010). When speech is manipulated to interfere with or remove coarticulation, the smooth stream of phonetic data is interrupted for the listener causing delays in comprehension.

Impacts of speech type on switch costs

A primary interest in Experiment 3 was to better understand the potential association between coarticulation and switch costs. Our prediction that switch costs would be greater when speech was manipulated was based on previous research that demonstrated coarticulation was a useful cue for listeners when processing incoming phonetic data to assist in speech comprehension (Tobin et al., 2010). Additionally, it has been shown that bilingual speakers introduce switch-language phonetics prior to the onset of the code-switch (Balukas & Koops, 2015; Bullock et al., 2006; Deuchar et al., 2014; Olson, 2016). Experiment 3 findings show that the differences between single-language and code-switched trials were greater when speech was manipulated than when speech was produced naturally. Coarticulation prior to a code-switch seems to quickly introduce the phonetics of the code-switch language, alerting the listener a code-switch is about to occur. The finding that bilinguals were able to exploit this cue of coarticulation to facilitate the comprehension of spoken code-switch may support the Adaptive Predictability hypothesis (Valdés Kroff & Dussias, 2023). Listeners demonstrated high frequency of experiences with code-switching, this experience may have facilitated the quick shift in weight placed the cue of coarticulation prior to a code-switch. However, when coarticulation was manipulated, comprehension was delayed. Additionally, this finding demonstrates when speech is manipulated, it is possible to artificially inflate the magnitude of switch costs. This inflation of switch costs may also be beneficial for further studies as a methodological technique to elicit other behaviors when comparing natural versus artificial manipulations.

General Discussion and Future Directions

In a series of three experiments, we aimed to better understand the cues involved in the comprehension of spoken code-switches. Across experiments, listeners processed speech that contained code-switches more slowly than single-language sentences. Individual differences such as English proficiency, Spanish proficiency, and language dominance were associated with the extent of the switch costs. Findings suggested that there is a relationship between switch costs and some combination of language background factors. However, when a Spanish code-switch in English speech was presented in the context of an unfamiliar non-English accent, the relationship between language background and switch costs was no longer present. When examining the possible association between accents and code-switches, listeners were also seen to respond to English-accented speech faster than non-English accented speech. Despite listeners being familiar with Spanish-accented speech, the Spanish accent still delayed comprehension of English sentences. When listeners were presented with unfamiliar Flemish/Bulgarian accented English speech their comprehension was globally impacted. Additionally, the relative switch costs were greater when listeners were responding to unfamiliar accents than English-accented speech. We also examined the relationship between code-switching and the coarticulation included in the phonetics prior to the onset of a code-switch. When sentences included manipulated coarticulation, listeners responded more slowly than they responded to naturally produced sentences suggesting that listeners used coarticulation to assist in processing incoming phonetic data. The differences between single-language and code-switched trials were greater when speech was manipulated than when speech was produced naturally. Coarticulation prior to a code-switch quickly introduced the phonetics of the code-switch language, and listeners were able to use this cue to anticipate an upcoming code-switch.

Switch costs in a highly bilingual environment

The current study showed there are costs involved in the comprehension of spoken code-switches. The sample consisted of bilinguals in El Paso, where most of the residents speak both English and Spanish (World Population Review, 2023). Additionally, throughout the study participants reported a high level of experience with code-switching. Due to the makeup of this sample, highly bilingual and high code-switching, it was important to examine the possible impacts of individual differences on switch costs. Our results revealed that several participant characteristics were associated with the strength of switch costs, however the extent of these associations varied across experiments. Both English and Spanish proficiency were associated with switch costs when speech was naturally produced with English and Spanish accents. As English proficiency increased, greater switch costs were shown, as Spanish proficiency increased, switch costs decreased. These interactions of language proficiency with sentence type implied that proficiency plays a role in the comprehension of code-switches. Lower proficiency levels in the language of the code-switch might lead to difficultly anticipating upcoming code-switches, previous research has also demonstrated that proficiency is associated with the ability to predict upcoming speech (Kaan & Grüter, 2021). However, the impact of proficiency on switch costs was not seen or was minimal when code-switches were presented in unfamiliar Flemish/Bulgarian accented speech and when coarticulatory cues were manipulated. This inconsistent relationship between language proficiency and switch costs may suggest when listeners are presented with additional challenges in speech the benefits of proficiency is reduced. There may be an alternate explanation for this inconsistency in proficiency findings across experiments. The reduction in switch costs seen in listeners with higher Spanish proficiency may be indicating an inflated sensitivity to the cue of coarticulation in speech. Previous research exploring second language learners has shown that as proficiency increases, sentence processing becomes more automatic (Hopp, 2010; Osterhout, Mclaughlin, Pitkänen, Frenck-mestre, & Molinaro, 2006), and different levels of proficiency may lead to sensitivities to different types of cues (Foucart et al., 2015).

In the current study, it may be possible that listeners were able to exploit coarticulation in the naturally produced sentences more efficiently. However, specific examinations on how proficiency may impact sensitivities to different cues in speech will be needed. A similar pattern was seen when examining the association between language dominance and switch costs. English-dominant participants showed larger switch costs than Spanish-dominant participants. Previous research has shown both dominance and the direction of code-switches in reading comprehension impacted switch costs, costs were higher when switching into the readers' weaker language (Litcofsky & Van Hell, 2017). This was seen in the current study where larger switch costs were found when listeners were switching into their weaker language. However, we again see that when speech contains additional challenges such as unfamiliar accents or missing phonetic data, dominance is no longer impactful when comprehending code-switches.

While switch costs similar to the current study have been demonstrated within previous code-switching literature (Bultena et al., 2015; Li, 1996; Litcofsky & Van Hell, 2017; Macnamara & Kushnir, 1971; von Studnitz & Green, 1997), the current study consisted of bilinguals from an environment where code-switching is very frequent. Despite bilinguals' experiences and familiarity with code-switching there were still costs involved in comprehension. Across all experiments, there were no observed relationships between switch costs and bilinguals' experiences with code-switching or perceptions of accented speech. It is important to consider that the Spanish-English bilingual population has been shown to code-switch more frequently than other types of bilinguals (McClure & Mir, 1995; Poplack, 1987). It is possible this demographic is familiarized with code-switching regardless of how often they experience or use code-switching in their personal and professional lives. The relationship between code-switching experiences and switch costs may not be present because these bilinguals are accustomed to code-switching, leading to no strong differences in code-switching experiences. It will be important to examine a larger range of code-switching experiences in bilinguals, and the relationship between those experiences and switch costs. Similarly, no relationship between perceptions of accents and switch costs were seen. Whether participants perceived accents to be closer to native or non-native speakers was not associated with switch costs. This lack of relationship between accent perceptions and switch costs may also be driven by the environment in which the data were collected. Previous research has demonstrated that experiences with unfamiliar accents, foreign languages, and bilingual environments with greater ecological diversity may reduce perceived intensity and negative biases of unfamiliar accents (Eisenchlas, & Tsurutani, 2011; Kutlu et al., 2022). Furthermore, listeners' experiences may be related to their sensitivity to cues and expectations of speech. Previous research has demonstrated that different patterns of code-switches may cause different magnitudes of switch costs. More frequent code-switches led to smaller switch costs, suggesting that bilinguals develop expectations regarding code-switching behavior (Salig et al., 2023). Listeners in the current study were familiar with Spanish- and English-accented speech and had experience with speakers producing code-switches in these accent types. This familiarity with both the English and Spanish accent and code-switching may have played a role in the findings that switch costs were not impacted by perception of accented speech.

Impacts of accented speech and coarticulation on bilinguals

In the current study, we found reliable processing costs are involved when speech is presented in non-English accents and when coarticulation is manipulated in the speech stream. When listeners were presented with non-English accented speech, they responded more slowly than sentences that were spoken with an English accent. Previous research has shown similar findings that non-native accented speech delays comprehension (Munro & Derwing, 1995, 1999). Even though Spanish-accented English speech was familiar to the participants, it was still processed more slowly. Research has demonstrated that listeners are not able to comprehend non-native accents the same way as native accented speech (Gass & Varonis, 1984; Mattys et al., 2012; Munro & Derwing, 1999; Van Engen & Bradlow, 2007). This variability involved in non-native speech has been demonstrated in previous research, showing additional variability both within and between speakers is presented in non-native accents (Bradlow & Bent, 2008; Cristia et al., 2012). Our findings also indicated that participants responded more slowly to unfamiliar non-English accents (Flemish/Bulgarian) than familiar non-English accents (Spanish). When hearing a familiar Spanish accent, listeners were able to use their previous experiences with Spanish-accented speech to comprehend the non-English accented speech. However, when hearing sentences spoken with an unfamiliar Flemish/Bulgarian accent, speech comprehension was globally impacted. Not only did listeners respond more slowly to unfamiliar accents, the familiar English-accented speech was also delayed. Our findings also showed that listeners responded more slowly to sentences with manipulated coarticulation than sentences that were naturally produced. Previous research that has demonstrated similar results, when coarticulation was manipulated to provide misleading phonetic information, speech comprehension was delayed (Tobin et al., 2010). These delays in speech comprehension when coarticulation is manipulated suggest that the subtle phonetic information in coarticulation provides listeners with useful cues.

Factors that increase switch costs

A primary goal of the current study was to expand our understanding of the impact of cues on switch costs. Across three experiments, the current study showed that bilingual listeners process code-switches differently in different accented speech. When examining differences between switch costs in English-accented and Spanish-accented speech, listeners did not experience switch costs differently in the English accented speech when compared to the Spanish-accented speech. However, when responding to an unfamiliar accent the relative switch costs were different in different accents. Previously, we examined these results in the context of the Adaptive Predictability hypothesis (Valdés Kroff & Dussias, 2023) as a framework to explain why English and Spanish accents did not impact switch costs, but the relative impacts of familiar English and Spanish accents on switch costs were different from unfamiliar Bulgarian and Flemish accents. The bilingual listeners in our study have experiences with both English and Spanish accented speakers engaging in code-switching. This previous experience with different accent types code-switching may have led listeners to view each of these accents as an unreliable cue to an upcoming code-switch. For this demographic of bilinguals, it may be equally likely for an English or Spanish accented speaker to code-switch. However, participants had few experiences comprehending speech in Bulgarian and Flemish accents, and fewer or no experiences with these accent types code-switching. Therefore, when comprehending code-switches produced in these accents, the listeners had no experiences to draw upon and did not anticipate the code-switches. Additionally, the current study found that coarticulation prior to a code-switch was a useful cue for listeners. The differences between single-language and code-switched trials were greater when speech was manipulated than when speech was produced naturally. This indicated that coarticulation prior to a code-switch quickly introduces the phonetics of the code-switch language, alerting the listener a code-switch is about to occur. It is important to state that this finding that coarticulation was a useful cue for listeners does not imply listeners are only using the bottom-up cue of phonetic data to comprehend speech. There is a great deal of research demonstrating top-down cues such as speaker and sentence context are involved in speech comprehension (Chambers & Cooke, 2009; Jacoby et al. 1988; Li & Yip, 1998; Luce & Pisoni, 1998).

We suggest that to interpret accent and coarticulation findings together the hierarchical approach to speech (Mattys et al., 2005) and the Adaptive Predictability hypothesis (Valdés Kroff & Dussias, 2023) can be used to explain how top-down and bottom-up cues are accessed in bilingual speech. The hierarchical approach to speech suggests that listeners use cues in speech in a rank order, placing more weight on easily accessible lexical cues and less weight on sub-lexical cues (Mattys et al., 2005). It is possible that bilinguals comprehend speech by using this rank ordered approach in combination with previous experiences to shift the weight of cues in speech to assist in comprehension. In the context of bilingual comprehension of code-switches, listeners may try to access top-down lexical cues such as speaker context first, but when said cues are unavailable or ambiguous, they then move to access bottom-up sub-lexical cues such as coarticulation. In the current study, when listeners were presented with code-switches produced by English and Spanish accented speakers, the top-down cue of accent may have been ambiguous due to their previous experiences with both accent types being associated with code-switching. Listeners may then have turned to the sub-lexical cue of coarticulation when sentences were naturally-produced. When code-switches were presented in an unfamiliar accent, bilinguals had no related experiences to draw upon, and the overall difficulty comprehending the unfamiliar non-English accent may have caused listeners to overlook the coarticulation prior to a code-switch. When coarticulation was manipulated prior to a code-switch, listeners did not have top-down lexical or bottom-up sub-lexical cues to assist in comprehension causing delays. Further research will be needed to better understand what aspects of speech facilitate the shifts in weights that bilinguals place on the different cues in speech.

Limitations & Future Directions

While this research furthers our understanding of the speech cues that influence bilinguals' real-time processing, there are key limitations and open questions. First, Spanish-English bilinguals have been seen to code-switch more frequently than other types of bilinguals (McClure & Mir, 1995; Poplack, 1987). Additionally, code-switching in El Paso is a common occurrence in speech because the majority of residents speak both English and Spanish. It is possible our demographic is more accustomed to code-switching than other bilingual environments. Code-switching patterns are likely to be different in other bilingual environments that have different densities of bilinguals and different combinations of languages spoken. It will be important to examine the potential impacts of accent type in more variable bilingual environments.

There were several aspects of the study design that created limitations. Only one type of code-switching was included: English sentence frames with a single noun switched to Spanish. Research has demonstrated that code-switching is governed by a set of rules and grammar, but patterns of code-switches vary extensively (Sankoff & Poplack, 1981). Additionally, all code-switches in the study were pre-planned, where in natural speech code-switches are spontaneous. Previous research has demonstrated when code-switches are produced spontaneously we see differences in patterns of code-switching and influences of the code-switch language on VOT (Balukas & Koops, 2015; Fricke & Kootstra, 2016; Torres Cacoullos et al., 2022). It will be important to explore what types of cues listeners use when comprehending spontaneously produced code-switches in comparison to lab-based code-switching. Additionally, there may be limitations regarding the accent types used in the current study. Typical North American English, Juarez/El Paso, Bulgarian, and Flemish accents were used in the current study. While listeners in El Paso are exposed to a variety of accents, it may not be as variable as others. The extreme impact of Bulgarian and Flemish accents in Experiment 2 can be taken as an example. When asked to identify what type of accent the speakers had, zero participants were able to identify the accent, and the overwhelming majority were unable to provide a reasonable guess. Bilingual environments where exposure to a larger variety of accents is more common may demonstrate different patterns of results. Previous research has demonstrated location modulates perception of accents (Kutlu et al., 2022). When measuring listeners' accent judgements and transcription accuracy of accented speech in Gainesville Florida and Montreal Quebec. Researchers found perception of accents increased to 'heavier accent' and intelligibility accuracy decreased for Gainesville participants when speech was paired with South Asian faces. However, this accent and race effect wasn't seen in Montreal listeners. The researchers suggest the visual cue of race paired with accented speech is more impactful on speech perception in locations with greater ecological diversity (Kutlu et al., 2022). This pattern may extend to the current findings, bilingual listeners that have more experiences with a greater variety of accents may place different weights on accent as cue than bilinguals that had less variability in accent types in the current study.

Further research will be needed to better understand the impacts of code-switching on bilingual speech comprehension. Future directions that may address some of our limitations could explore switch costs in different environments or use different accent types. Bilinguals in the current study did not show differences between switch costs produced in the English accent when compared to the Spanish accented speech. This may be due to this bilingual population having experiences with both English and Spanish accents code-switching; therefore, it is equally plausible that both accent types will code-switch in the context of El Paso. Results also showed code-switches were processed differently when produced by unfamiliar non-English accents. These bilinguals had very little experience with unfamiliar accents in general, and presumably even fewer or no experiences with these unfamiliar accents code-switching. It is unclear if these differences were seen because the accent was unfamiliar, or because the accent was unfamiliar in code-switching contexts. Future directions may be able to separate these concepts by examining code-switches in a familiar accent that is not associated with code-switches. Alternatively, examining these effects in different bilingual environments may also separate the idea that unfamiliar accents is causing switch cost differences, or accents not associated with code-switches are causing differences.

Conclusion

The current study expanded our understanding of listener comprehension of spoken code-switches. Across three experiments, we demonstrated that switch costs are involved in the comprehension of code-switches, non-English accents impacts a listeners speech comprehension, and the impact of accent on switch costs may be dependent on a listener's familiarity with the accent. Additionally, the subtle cue of coarticulation helps listeners comprehend code-switches. We suggest that bilingual listeners approach code-switching by using speech cues in a flexible hierarchical order. When easily accessible cues such as sentence and speaker context are available, bilinguals will access the cues in a top-down approach. However, when top-down cues are ambiguous or unavailable, listeners will access more subtle cues such as coarticulation to assist in the comprehension of speech. These results demonstrate bilinguals are very adaptable listeners and can use the subtleties in speech to help them in comprehension. Paired with previous literature, a variety of cues and speaker information have been shown to influence speech comprehension. Understanding the effects of speech and speaker characteristics such as accent will further our understanding of switch costs and how listeners make use of the cues in their environment.

References

Anderson-Hsieh, J., & Koehler, K. (1988). The Effect of Foreign Accent and Speaking Rate on Native Speaker Comprehension. Language Learning, 38(4), 561–613. https://doi.org/10.1111/j.1467-1770.1988.tb00167.x

Baese-Berk, M. M., Bradlow, A. R., & Wright, B. A. (2013). Accent-independent adaptation to foreign accented speech. The Journal of the Acoustical Society of America, 133(3), EL174–EL180. https://doi.org/10.1121/1.4789864

Balukas, C., & Koops, C. (2015). Spanish-English bilingual voice onset time in spontaneous code-switching. International Journal of Bilingualism, 19(4), 423–443. https://doi.org/10.1177/1367006913516035

Bates, D., Maechler, M., Bolker, B., & Walker, S. (2015). Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software*, 67(1), 1-48. doi:10.18637/jss.v067.i01.

Bent, T., & Frush Holt, R. (2013). The influence of talker and foreign-accent variability on spoken word identification. The Journal of the Acoustical Society of America, 133(3), 1677–1686. https://doi.org/10.1121/1.4776212

Blumenfeld, H. K., & Marian, V. (2011). Bilingualism influences inhibitory control in auditory comprehension. Cognition, 118(2), 245–257. https://doi.org/doi:10.1016/j.cognition.2010.10.012

Blumenfeld, H. K., & Marian, V. (2013). Parallel language activation and cognitive control during spoken word recognition in bilinguals. Journal of Cognitive Psychology, 25(5), 547–567. https://doi.org/10.1080/20445911.2013.812093

Bradlow, A. R., & Bent, T. (2008). Perceptual adaptation to non-native speech. Cognition, 106(2), 707–729. https://doi.org/10.1016/j.cognition.2007.04.005

Brunellière, A., & Soto-Faraco, S. (2013). The speakers' accent shapes the listeners' phonological predictions during speech perception. Brain & Language, 125, 82–93. http://dx.doi.org/10.1016/j.bandl.2013.01.007

Bullock, B. E., Toribio, A. J., González, V., & Dalola, A. (2006). Language Dominance and Performance Outcomes in Bilingual Pronunciation.

Bultena, S., Dijkstra, T., & Van Hell, J. G. (2015). Language switch costs in sentence comprehension depend on language dominance: Evidence from self-paced reading. Bilingualism: Language and Cognition, 18(3), 453–469. https://doi.org/10.1017/S1366728914000145

Chambers, C. G., & Cooke, H. (2009). Lexical competition during second-language listening: Sentence context, but not proficiency, constrains interference from the native lexicon. Journal of Experimental Psychology: Learning, Memory, and Cognition, 35(4), 1029–1040. https://doi.org/10.1037/a0015901

Cooper, R. M. (1974). PII: 0010-0285(74)90005-X | Elsevier Enhanced Reader. Cognitive Psychology, 6, 84–107. https://doi.org/10.1016/0010-0285(74)90005-X

Cristia, A., Seidl, A., Vaughn, C., Schmale, R., Bradlow, A., & Floccia, C. (2012). Linguistic Processing of Accented Speech Across the Lifespan. Frontiers in Psychology, 3. https://www.frontiersin.org/articles/10.3389/fpsyg.2012.00479

Declerck, M., & Philipp, A. M. (2015). A review of control processes and their locus in language switching. Psychonomic Bulletin & Review, 22(6), 1630–1645. https://doi.org/10.3758/s13423-015-0836-1

Deuchar, M., Davies, P., Herring, J., Parafita Couto, M. C., & Carter, D. (2014). Building bilingual corpora. In: E. M. Thomas and I. Mennen (Eds.), Advances in the Study of Bilingualism (pp. 93 – 110). Bristol, U.K.: Multilingual Matters.

Dewaele, J.-M., & McCloskey, J. (2015). Attitudes towards foreign accents among adult multilingual language users. Journal of Multilingual and Multicultural Development, 36(3), 221–238. https://doi.org/10.1080/01434632.2014.909445

Dijkstra, T., & Van Heuven, W. J. B. (2002). The architecture of the bilingual word recognition system: From identification to decision. Bilingualism: Language and Cognition, 5(3), 175–197. https://doi.org/10.1017/S1366728902003012

Eisenchlas, S. A., & Tsurutani, C. (2011). You sound attractive! Perceptions of accented English in a multilingual environment. *Australian Review of Applied Linguistics*, *34*(2), 216-236.

El Paso, Texas Population. World Population Review. (n.d.). https://worldpopulationreview.com/us-cities/el-paso-tx-population

Fadlon, J., Li, C., Prior, A., & Gollan, T. H. (2019). Using what's there: Bilinguals adaptively rely on orthographic and color cues to achieve language control. Cognition, 191, 103990. https://doi.org/10.1016/j.cognition.2019.06.002

Fricke, M., & Kootstra, G. J. (2016). Primed codeswitching in spontaneous bilingual dialogue. Journal of Memory and Language, 91, 181–201. https://doi.org/10.1016/j.jml. 2016.04.003.

Flege, J. E., Munro, M. J., & MacKay, I. R. A. (1995). Factors affecting strength of perceived foreign accent in a second language. The Journal of the Acoustical Society of America, 97(5), 3125–3134. https://doi.org/10.1121/1.413041

Foucart, A., Costa, A., Morís-Fernández, L., & Hartsuiker, R. J. (2020). Foreignness or Processing Fluency? On Understanding the Negative Bias Toward Foreign-Accented Speakers. Language Learning, 70(4), 974–1016. https://doi.org/10.1111/lang.12413

Foucart, A., Garcia, X., Ayguasanosa, M., Thierry, G., Martin, C., & Costa, A. (2015). Does the speaker matter? Online processing of semantic and pragmatic information in L2 speech comprehension. Neuropsychologia, 75, 291–303. https://doi.org/10.1016/j.neuropsychologia.2015.06.027

Fricke, M., Kroll, J. F., & Dussias, P. E. (2016). Phonetic variation in bilingual speech: A lens for studying the production-comprehension link. Journal of Memory and Language, 110–137. https://doi.org/10.1016/j.jml.2015.10.001

Gass, S., & Varonis, E. M. (1984). The Effects of Familiarity on the Comprehensibility of Nonnative Speech. Language Learning, 34(1), 65–87. https://doi.org/10.1111/j.1467-1770.1984.tb00996.x

Gollan, T. H., Stasenko, A., Garcia, D. L., & Murillo, M. (2023). MINT Sprint 2.0 Test. Retrieved from osf.io/7r9mq

Green, D. W., & Abutalebi, J. (2013). Language control in bilinguals: The adaptive control hypothesis. Journal of Cognitive Psychology, 25(5), 515–530. https://doi.org/10.1080/20445911.2013.796377

Grey, S., & van Hell, J. G. (2017). Foreign-accented speaker identity affects neural correlates of language comprehension. Journal of Neurolinguistics, 42, 93-108.

Grosjean, F. (2013). Bilingual and monolingual language modes. *The encyclopedia of applied linguistics*, 489-493.

Grosjean, F., & Li, P. (2013). Speech perception and comprehension. Grosjean, F. & Pi, L.(reds). In The psycholinguistics of bilingualism (pp. 29–49). Chichester: Wiley-Blackwell.

Hopp, H. (2010). Ultimate attainment in L2 inflection: Performance similarities between non-native and native speakers. Lingua, 120(4), 901–931. doi:10.1016/j.lingua.2009.06.004

Huettig, F., & McQueen, J. M. (2007). The tug of war between phonological, semantic and shape information in language-mediated visual search. *Journal of memory and language*, *57*(4), 460-482.

Jacoby, L. L., Allan, L. G., Collins, J. C., & Larwill, L. K. (1988). Memory Influences Subjective Experience: Noise Judgments. Journal of Experimental Psychology: Learning, Memory, and Cognition, 14(2), 240–270.

Ju, M., & Luce, P. A. (2004). Falling on Sensitive Ears: Constraints on Bilingual Lexical Activation. Psychological Science, 15(5), 314–318. https://doi.org/10.1111/j.0956-7976.2004.00675.x

Kaan, E., & Grüter, T. (2021). Prediction in second language processing and learning. *Prediction in second language processing and learning*, 1-24.

Kroll, J. F., Bobb, S. C., Misra, M., & Guo, T. (2008). Language selection in bilingual speech: Evidence for inhibitory processes. Acta Psychologica, 128(3), 416–430. https://doi.org/10.1016/j.actpsy.2008.02.001

Kutlu, E., Tiv, M., Wulff, S., & Titone, D. (2022). Does race impact speech perception? An account of accented speech in two different multilingual locales. *Cognitive Research: Principles and Implications*, *7*(1), 7.

Lenth R (2024). _emmeans: Estimated Marginal Means, aka Least-Squares Means_. R package version 1.10.0, https://CRAN.R-project.org/package=emmeans.

Li, P. (1996). Spoken Word Recognition of Code-Switched Words by Chinese–English Bilinguals. Journal of Memory and Language, 35(6), 757–774. https://doi.org/10.1006/jmla.1996.0039

Li, P., & Yip, M. (1998). Context effects and the processing of spoken homophones. Reading and Writing, 10, 223–243. https://doi.org/10.1023/A:1008091816322

Litcofsky, K. A., & Van Hell, J. G. (2017). Switching direction affects switching costs_ Behavioral, ERP and time-frequency analyses of intra-sentential codeswitching | Elsevier Enhanced Reader. Neuropsychologia, 97, 112–139. http://dx.doi.org/10.1016/j.neuropsychologia.2017.02.002

Luce, P. A., & Pisoni, D. B. (1998). Recognizing Spoken Words: The Neighborhood Activation Model: Ear and Hearing, 19(1), 1–36. https://doi.org/10.1097/00003446-199802000-00001

Macnamara, J., & Kushnir, S. (1971). Linguistic Independence of Bilinguals: The Input Switch. Journal of Verbal Learning and Verbal Behavior, 10(5), 480–487. https://doi.org/10.1016/S0022-5371(71)80018-X

Mahr, T., McMillan, B. T. M., Saffran, J. R., Ellis Weismer, S., & Edwards, J. (2015). Anticipatory coarticulation facilitates word recognition in toddlers. Cognition, 142, 345–350. https://doi.org/10.1016/j.cognition.2015.05.009

Marian, V., & Spivey, M. (2003). Competing activation in bilingual language processing: Within- and between-language competition. Bilingualism: Language and Cognition, 6(2), 97–115. https://doi.org/10.1017/S1366728903001068

Mattys, S. L., Davis, M. H., Bradlow, A. R., & Scott, S. K. (2012). Speech recognition in adverse conditions: A review. Language and Cognitive Processes, 27(7–8), 953–978.

Mattys, S. L., White, L., & Melhorn, J. F. (2005). Integration of Multiple Speech Segmentation Cues: A Hierarchical Framework. Journal of Experimental Psychology: General, 134(4), 477–500. https://doi.org/10.1037/0096-3445.134.4.477

McClure, E., & Mir, M. (1995). Spanish-English Codeswitching in the Mexican and Spanish Press. *Journal of Linguistic Anthropology*, *5*(1), 33-50.

Munro, M. J., & Derwing, T. M. (1995). Processing Time, Accent, and Comprehensibility in the Perception of Native and Foreign-Accented Speech. Language and Speech, 38(3), 289–306. https://doi.org/10.1177/002383099503800305

Munro, M. J., & Derwing, T. M. (1999). Foreign Accent, Comprehensibility, and Intelligibility in the Speech of Second Language Learners. Language Learning, 49(s1), 285–310. https://doi.org/10.1111/0023-8333.49.s1.8

Olson, D. J. (2016). The role of code-switching and language context in bilingual phonetic transfer. Journal of the International Phonetic Association, 46(3), 263–285. https://doi.org/10.1017/S0025100315000468

Olson, D. J. (2017). Bilingual language switching costs in auditory comprehension. Language, Cognition and Neuroscience, 32(4), 494–513. https://doi.org/10.1080/23273798.2016.1250927

Orfanidou, E., & Sumner, P. (2005). Language switching and the effects of orthographic specificity and response repetition. Memory & Cognition, 33(2), 355–369. https://doi.org/10.3758/BF03195323

Osterhout, L., Mclaughlin, J., Pitkänen, I., Frenck-mestre, C., & Molinaro, N. (2006). Novice Learners , Longitudinal Designs , and Event-Related Potentials: A Means for Exploring the Neurocognition of Second Language Processing. Language Learning, 56, 199–230.

Peirce, J. W., Gray, J. R., Simpson, S., MacAskill, M. R., Höchenberger, R., Sogo, H., Kastman, E., Lindeløv, J. (2019). PsychoPy2: experiments in behavior made easy. *Behavior Research Methods.* 10.3758/s13428-018-01193-y

Peng, Z. E., & Wang, L. M. (2016). Effects of noise, reverberation and foreign accent on native and non-native listeners' performance of English speech comprehension. The Journal of the Acoustical Society of America, 139(5), 2772–2783. https://doi.org/10.1121/1.4948564

Poplack, S. (1988). Contrasting patterns of code-switching in two communities. *Codeswitching: Anthropological and sociolinguistic perspectives*, *48*, 215-244.

R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Salig, L. K., Kroff, J. R. V., Slevc, L. R., & Novick, J. M. (2024). Linking frequency to bilingual switch costs during real-time sentence comprehension. *Bilingualism: Language and Cognition*, *27*(1), 25-40.

Salverda, A. P., Kleinschmidt, D., & Tanenhaus, M. K. (2015). Immediate effects of anticipatory coarticulation in spoken-word recognition. Journal of Memory and Language, 71(1), 145–163. https://doi.org/doi:10.1016/j.jml.2013.11.002

Sankoff, D., & Poplack, S. (1981). A formal grammar for code-switching 1. Paper in Linguistics, 14(1), 3–45. https://doi.org/10.1080/08351818109370523

Sidaras, S. K., Alexander, J. E. D., & Nygaard, L. C. (2009). Perceptual learning of systematic variation in Spanish-accented speech. The Journal of the Acoustical Society of America, 125(5), 3306–3316. https://doi.org/10.1121/1.3101452

Tobii Pro. (2014). X2-30 eye tracker. Tobii Pro Spectrum. https://www.tobiipro.com/product-listing/tobii-pro-x2-30/

Tobin, S. J., Cho, P. W., Jennett, P. M., & Magnuson, J. S. (2010). Effects of Anticipatory Coarticulation on Lexical Access. In Proceedings of the Annual Meeting of the Cognitive Science Society, 32(32).

Torres Cacoullos, R., Dion, N., LaCasse, D., & Poplack, S. (2022). How to mix: Confronting “mixed” NP models and bilinguals’ choices. Linguistic Approaches to Bilingualism, 12, 628–656. https://doi.org/10.1075/lab.20017.tor.

Valdés Kroff, J. R., & Dussias, P. E. (2023). Production, processing, and prediction in bilingual codeswitching. In *Psychology of learning and motivation* (Vol. 78, pp. 195-237). Academic Press.

Valdés Kroff, J. R., Dussias, P. E., Gerfen, C., Perrotti, L., & Bajo, M. T. (2017). Experience with code-switching modulates the use of grammatical gender during sentence processing. Linguistic Approaches to Bilingualism, 7(2), 163–198. https://doi.org/10.1075/lab.15010.val

Valles Jr, B. (2015). *The impact of accented English on speech comprehension*. The University of Texas at El Paso.

Van Engen, K. J., & Bradlow, A. R. (2007). Sentence recognition in native-and foreign-language multi-talker background noise. The Journal of the Acoustical Society of America, 121(1), 519–526.

von Studnitz, R. E., & Green, D. W. (1997). Lexical Decision and Language Switching. International Journal of Bilingualism, 1(1), 3–24. https://doi.org/10.1177/136700699700100102

Weber, A., & Culter, A. (2004). Lexical competition in non-native spoken-word recognition. Journal of Memory and Language, 50, 1–25. https://doi.org/10.1016/S0749-596X(03)00105-0

Appendix

Appendix A

Target words were grouped into sets of four controlling for semantic and phonological relatability. Visual stimuli were presented using the sets below.

Set	**Noun 1**	**Noun 2**	**Noun 3**	**Noun 4**
1	cloud	bear	envelope	sheep
2	box	finger	hammer	spider
3	bed	foot	hair	table
4	chair	corn	dog	needle
5	broom	helmet	pencil	suitcase
6	candle	fish	grapes	hand
7	basket	frog	house	rooster
8	clock	fence	leaf	pot

Appendix B

Linear mixed effects models were used to analyze data in the current study. Full models for each analysis are defined.

Experiment 1 Model 1: RT ~ sentence type + accent type + sentence type: accent type + (1 + sentence type + accent type | participant) + (1 + sentence type + accent type |item)

Experiment 1 Model 2: RT ~ sentence type + accent type + English proficiency + Spanish proficiency + language dominance + BCSP + accent ratings + sentence type: accent type + sentence type: English proficiency + sentence type: Spanish proficiency + sentence type: BCSP

+ sentence type: BCSP + sentence type: accent ratings + (1 + sentence type + accent type | participant) + (1 + sentence type + accent type |item)

Experiment 2 Model 1: RT ~ sentence type + accent type + sentence type: accent type + (1 + sentence type + accent type | participant) + (1 + sentence type + accent type |item)

Experiment 2 Model 2: RT ~ sentence type + accent type + BCSP + English proficiency + Spanish proficiency + language dominance + accent ratings + sentence type: accent type + sentence type: BCSP + sentence type: accent rating + (1 + sentence type + accent type | participant) + (1 + sentence type + accent type |item)

Experiment 1&2 Model 1: RT ~ sentence type + accent type + experiment + sentence type: accent type + sentence type: experiment + accent type: experiment + sentence type: accent type: experiment (1 + sentence type + accent type | participant) + (1 + sentence type + accent type |item)

Experiment 3 Model 1: the model was defined as RT ~ sentence type + speech type + sentence type: speech type + (1 + sentence type + speech type | participant) + (1 + sentence type + speech type |item)

Experiment 3 Model 2: RT ~ sentence type + speech type + BCSP + English proficiency + Spanish proficiency + language dominance + speech ratings + sentence type: speech type + sentence type: BCSP + sentence type: speech rating + (1 + sentence type + speech type | participant) + (1 + sentence type + speech type |item).

Vita

Liam Gleason received a Bachelor's of Science in Psychology with a minor in Spanish from Tennessee Technological University in 2018, a Masters in Experimental Psychology from the University of Texas at El Paso in 2022, and the Graduate Certificate in Quantitative Methods in Psychology in 2024. Liam is a member of Dr. Wendy Francis' Bilingual Cognition Laboratory and Dr. Chris Potter's laboratory, Children's Learning Project. His research interests involve bilingualism, memory, and cognition. Primarily focusing on the different aspects of memory and processing involved in speech comprehension.

Liam has taught undergraduate courses Intro to Statistics and General Experimental in the Psychology department at the University of Texas at El Paso. Additionally, he has work published in the journal Memory, and the journal Proceedings of the Annual Meeting of the Cognitive Science Society.