DO BILINGUAL SPEAKERS SHIFT FUNDAMENTAL FREQUENCY BASED ON LANGUAGE ACQUISITION OR LANGUAGE DOMINANCE?

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ABSTRACT

As Spanish-English bilingual speakers continue becoming a growing part of the population in the United States it is essential to investigate their acoustic measures. The purpose of this study was to investigate a possible shift in fundamental frequency (F0) measures in bilingual speakers, and it sought to determine whether that shift was based on language acquisition or language dominance. Eleven Spanish-English bilinguals were asked to complete the following tasks 1) answer the Language Experience and Proficiency Questionnaire (LEAP-Q) 2) complete 3 Spanish and 3 English category fluency trials by naming words belonging to a category (e.g. animals), each one minute in length 3) reading Spanish and English sentences. The speech samples were analyzed for F0, category fluency tasks were scored for number of correct answers provided, and all measurements were compared to self-reports on the LEAP-Q. The results of this study suggested there may be a shift in F0 in bilingual speakers. In at least one speech sample, 7 out of 11 participants had an increased F0 when speaking in their non-dominant language. Due to the trend in the data and the small sample size it was concluded that further investigation must be conducted to determine if there is a true shift in F0 in bilingual speakers, and if factors such as language acquisition, language proficiency, language exposure, language status and language preference.

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NOMENCLATURE

F0- Fundamental Frequency

VF- Vocal Folds

L1- First Language

L2- Second Language

TCFS- Total Category Fluency Score

CHAPTER I

INTRODUCTION

As the population of the United States continues to increase in cultural and linguistic diversity, it is important to have documented linguistic norms to fully understand the nature of linguistic differences that may transfer from one language to the other. It is well established in the literature that a person's dominant language can influence the acquisition of another language. According to Altenberg and Ferrand (2006), this information will provide speech language pathologists with the knowledge necessary to generate informed and accurate clinical goals and accurately educate patients and their families. In the clinical setting changes in the fundamental frequency of the voice can be a sign of vocal pathology. However, studies have shown that some bilingual speakers change their pitch/fundamental frequency to accommodate to the speaking environment and demands of the speaking task in the second language. Järvinen, Laukkanen, and Aaltonen (2013) investigated whether speaking a foreign language causes a shift in fundamental frequency (F0). The study was comprised of 16 native Finnish speakers and 14 native English speakers. The participants were asked to read a one-minute passage. compared to speaking in their native language. The change was not significant for English speakers in the foreign language. The results of this study suggest that changes in

F0 may be a result of adaptation to a specific pitch level in the foreign environment. These adaptations may be attributed to individual differences of sensitivity to adaptation or differences in the amount of experience speaking a foreign language.

Boka (2010) investigated whether female speakers of Japanese descent shifted their F0 when using their L1 and L2. This case study was comprised of one bilingual female speaker (Japanese/English). The participant was provided sentence stimuli mimicking daily life conversational interactions. Results found that F0 was consistently higher in English (L2) than the F0 in Japanese. Although the data were not significant, this study suggests that more research must be done based on a larger sample size, a variety of speech tasks, and with a focus on variables such as language acquisition to find any statistical significance in F0 shifts.

Nevo, Nevo, and Oliveira (2015) investigated the differences in vocal parameters when individuals spoke in Hebrew (L1) versus English (L2). The study was comprised of 40 bilingual Hebrew/English speaking individuals, 17 male and 23 female. Participants ranged from 23 to 60 years of age. The participants were asked to count from 1 to 10 in both languages and answer open-ended questions on neutral topics. Speech samples were analyzed using a nominal scale: vocal quality (roughness, breathiness, strain, and vocal fry), glottal attack (adequate, soft, hard), pitch (adequate, low, high), resonance (adequate, nasal, oral, throaty), and rate (adequate, slow, fast). Results indicated changes in resonance, vocal fry, glottal attack, fundamental frequency variation and speech rate did occur when speaking in Hebrew versus English. Males were found to have a lower mean F0 in Hebrew than in English, and female participants demonstrated a high mean F0 in Hebrew than in

English. This study reinforces findings from previous studies that report acoustic differences in voice when comparing languages among bilinguals, and also revealed that speakers may experience vocal feature changes.

Due to the paucity of research in the area of acoustic measures in bilingual speakers, it is important to continue investigating what is typical in this linguistically diverse population. In the current study, I investigated the feasibility of a possible shift in fundamental frequency measures in bilingual speakers, and sought to determine whether that shift was based on language acquisition or language dominance.

1.1 What Is Voice?

Even to the untrained listener, the voice provides a range of information such as an individual's age, sex, and emotions (DeJarnette & Holland, 2003). The voice can be defined by sounds that are created through the vibration of the vocal folds (VF) located in the larynx (Colton, Casper, & Leonard, 2006). The VF are abducted by air that is pushed up from the lungs causing subglottic pressure to blow apart the VF. This pattern is continuous while speaking and sets the vocal folds into a vibratory motion that produces what we hear as speech. Each distinctive sound created is also altered by the pharynx and other articulators, such as the palate, tongue, and lips (Colton et al., 2006). The synchronicity of the vocal folds with the lungs, vocal tract, and other articulators is imperative to producing a clear voice and intelligible speech. A more in-depth description of the voice identifies three main vocal characteristics, frequency, intensity, and vocal quality .

1.1.1 Fundamental Frequency

Fundamental frequency is the rate of vocal fold vibration. Fundamental frequency (F0) is the acoustic correlate of pitch, which is a perceptual measure. F0 is defined as the number of vocal fold vibrations completed in a cycle per second, measured in Hertz (Hz). The F0 is determined by vocal fold length, mass, and tension (Colton et al., 2006). Healthy, typical VF show a positive correlation between the length of the VF and frequency, as well as the tension of the VF and frequency. As the length or tension increases, the frequency also increases. However, VF mass and frequency display an inverse relationship. As VF mass increases, frequency decreases. All three of these factors contribute to a speaker's overall F0.

Changes in F0 can be caused by variations in the aforementioned determinants, and are also influenced by natural development and vocal pathologies. In infancy the primary method of communicating pain, pleasure, or hunger is through crying (Lester, 1985). During this period of development the infant is learning to control the vocal mechanism. Additionally, there are concomitant physical conditions, such as a low level of muscular coordination in the larynx and small, short VF (Colton et al., 2006). As the infant continues to progress, the use of the vocal mechanism becomes more intentional and skilled.

One of the most drastic changes in F0 is during puberty when rapid physical changes, such as the growth of the larynx and lengthening and thickening of the VFs, causes the voice to crack and eventually to deepen (American Academy of Otolaryngology-Head and Neck Surgery, 2015). As the body begins to change with the passing of time there are a variety of common voice-related changes that affect males and

females. As men age their pitch increases, and as women age their pitch begins to lower (American Academy of Otolaryngology-Head and Neck Surgery, 2015). Regardless of gender, the aging process contributes to tremor and shakiness in the voice and a reduction in voice volume, projection, and vocal endurance (American Academy of Otolaryngology-Head and Neck Surgery, 2015).

Although F0 is affected by a variety of factors, children, women and men tend to fall between estimated ranges. Typically, children tend to have an F0 greater than 250 Hz, women are estimated between 180 to 250 Hz and men tend to fall between 80 to 175 Hz (Fouquet, Pisanski, Mathevon, & Reby, 2016).

1.1.2 Intensity

Intensity is the acoustic measure of sound pressure level, the lowest threshold of sound heard by most people. Intensity is determined by the amount of airflow from the lungs and the amount of resistance from the vocal folds. The perceptual correlate is loudness, and it is measured in decibels (Colton et al., 2006).

1.1.3 Vocal Quality

Vocal quality can be referred to as the pleasantness or clarity of the voice, which can be assessed through the production of sustained vowels, sentences, or running speech. Voice quality can be assessed by a number of factors, such as the presence or absence of vocal roughness, breathiness, strain, pitch, loudness, resonance, phonation, and rate (American Speech-Language-Hearing Association [ASHA], n.d.). Other contributors may include vocal fry and glottal attack (Nevo et al., 2015).

1.2 What Is Vocal Pathology?

According to ASHA (1993), a vocal pathology can be determined when a person experiences abnormal symptoms in the voice that affect their daily needs regardless of others' perception of deviation from the norm. Vocal pathologies can be classified by two main categories, organic and functional. Organic meaning the pathology is physiological in nature, which alters the respiration and laryngeal mechanism. Functional meaning the pathology is caused by the inefficient use of the vocal mechanism without any physiological alterations. Vocal pathologies may have an effect on one or more acoustic voice characteristics (i.e. frequency, intensity, and vocal quality) by diverting from the speaker's age, gender cultural background or geographic location (ASHA, n.d.; Aronson & Bless, 2009; Boone, McFarlane, Von Berg, & Zraik, 2010).

1.2.1 Prevalence of Vocal Pathology

The National Institute of Deafness and Other Communication Disorders (NIDCD) (2016) estimated that 7.6% of adults 18 years or older report having had a problem with their voice in the past 12 months. Voice complications lasting one week or more were reported by approximately 4.0% of adults and 1.4% of children. The prevalence of vocal pathologies in the United States is estimated to affect 3% to 9% of the population (Ramig & Verdolini, 1998; Roy, Merrill, Gray, & Smith, 2005).

According to Cohen, Kim, Roy, Asche, and Courey (2012), gender, age, and occupation affect the prevalence of treatment among individuals with voice pathologies. Based on gender, prevalence of vocal pathology is higher in adult females with a ratio of 1.5:1.0; however, in the younger population, male children seem to have a higher prevalence (Carding, Roulstone, Northstone, & the ALSPAC Study Team, 2006;

Martins, do Amaral, Tavares, Martins, Gonçalves, & Dias, 2015). Prevalence computed by age, recorded elderly adults as the highest affected population extending from 4.8% to 29.1% in population based studies (de Araújo Pernambuco, Espelt, Balata, & de Lima, 2014). In addition, at-risk occupations such as teachers, manufacturing/factory workers, salespersons, and singers have a higher prevalence of developing a vocal pathology (Cohen et al., 2012). Through point prevalence data compiled from a U.S. claims database, ASHA (n.d.) reported that vocal pathologies only affected 0.98% of the population, which suggests that a vast amount of affected individuals do not seek treatment. Incidence of vocal pathologies among minority groups in the United States continues to await investigation on a national scale, as there is currently no ongoing cross-sectional research for race or ethnicity (Dejarnette & Holland, 2003). Due to the paucity of comprehensive voice research concentrated on minorities, there is insufficient data on acoustic measurements, including for the largest racial minority in the United States, Hispanics.

1.3 Bilingualism

More than half of the people across the globe are *bilingual* making *bilingualism* and multilingualism the norm around the world (Heath, 1989; Marian et al., 2007). What does it mean to be bilingual? Throughout the language literature the definition of bilingual varies. One definition states that speakers should have equal speaking, listening, and reading competence in both languages to qualify as a bilingual speaker (Albert & Obler, 1978) According to Bloomfield (1935), being bilingual means that you have a native competency in two languages and no loss of the native language has occurred. Theiry (1976) believed that a true bilingual had ambilingual ability, which requires a

person to be fluent in each language across all life contexts. However, ambilingual ability is very rare, and in this case makes it an unrealistic generalizable definition. A less strict definition states that a person can be considered bilingual if, in both languages, they maintain at least minimal skills in one of the following: listening, speaking, reading, and writing (MacNamara, 1967). Grosjean (1989) also proposed that the term bilingual delineates a person who can communicate in each language depending on their needs. Baetens-Beardsmore (1986) established an all-encompassing definition with various sub-definitions emerging from how the second language was learned and the proficiency of the speaker. The following definitions are based on the condition through which the second language was acquired. A *natural bilingual* speaker is one who did not receive language instruction, instead learned language out of necessity. For example, Spanish-speaking monolingual children entering schools in the United States would be considered natural bilinguals. On the other end of the continuum, the *academic bilingual* speaker chooses to receive direct language instruction in order to learn a second language.

According to ASHA (2004), bilingualism is the use of at least two languages. It is described as a fluctuating system in which the speaker's proficiency of each language is influenced by linguistic opportunities across multiple domains such as different speakers, topics, and time. For the purposes of this study bilingualism will be defined in the following terms: *simultaneous bilingualism* and *sequential bilingualism*. Simultaneous bilingualism exists when a child has been significantly exposed to two languages since birth. Simultaneous bilingual children receive exposure to both languages during infancy and early childhood (Patterson, 2002). Since there are two languages these children

naturally receive less overall exposure to each of their languages than would monolingual children (MacLeod, Fabiano-Smith, Boegner-Pagé, & Fontolliet, 2013).

Sequential bilingualism develops when an individual has been significantly exposed to the second language (*L2*) following the established development of the first language (*L1*) around the age of 3 years (Jacobson & Walden, (2013). Sequential bilingualism is the most common type of bilingualism in the United States. These speakers are referred to in the literature as *English language learners*.

Both simultaneous and sequential bilingual speakers may be proficient in their L1 and L2. However, some speaker's may have a dominant or preferred language. A speaker's dominant language may not be his or her L1 (Cardimona, Smith, & Roberts, 2016).

1.3.1 Second-Language Acquisition

The *critical period* is a salient topic in the literature of second-language acquisition, and therefore relevant to studies focused on bilingual speakers. The critical period is the time during development in which a child's response to environmental stimuli is heightened and impacts the development of a specific skill (Norman & Bylund, 2016). The development of speech sounds is impacted by the critical period due to the increase in neural plasticity that allows a child to fully learn a language. Plasticity decreases at the completion of the critical period affecting the age of language acquisition. Additionally, the critical period hypothesis suggests that once cerebral dominance has been established, which generally occurs during puberty, the automatic acquisition of language by exposure, much like in infancy, diminishes (Scovel, 1969).

According to Kroll and Tokowicz (2005), language acquisition of L1 and L2 are shaped by a number of variables, age being one of the most pertinent. Cardimona et al. (2016) described language development as a simultaneous experience by which an infant learns a language, and creates semantic representations by using the world around her. Both aspects of development combine to create a meaningful language system (Cardimona et al., 2016). Dissimilarly, a simultaneous bilingual infant is being exposed to two languages concurrently, which alters the process of language acquisition from that of a monolingual infant (Brown, 2007). De Houwer (2005) proposed that simultaneous bilingual speakers create two separate language systems in which each system has its own morphosyntax and lexicon, and neither language has a paramount influence on the other. Sequential bilinguals, however, learn the L2 system after the L1 system has been established; the development of the L2 naturally involves effects from L1 (Brown, 2007). Kroll and Stewart (1994) suggest that novice L2 learners possess weak lexicosemantic organization in the L2, and that this organization is developed and influenced by access to semantic representations derived from L1 translations. An individual's L1 provides a stronger lexicon and an active semantic foundation with more automatic links to concepts (Cardimona et al., 2016). The more advanced the development of the L1, the greater influence it will have on the L2 acquisition (Flege, Yeni-Komshian, & Liu, 1999). However, as L2 proficiency increases so too does the automaticity of semantic representations and lexicosemantic organization in L2.

1.3.2 Determining Language Proficiency in Bilingual Speakers

Speech and language diagnostic batteries presently use letter fluency (e.g., name as many words that start with A) and category fluency (e.g., names of animals) tasks to

assess developmental and acquired disorders (Begeer, Wierda, Scheeren, Teuniesse, Koot & Geurts, 2014). Shao, Janse, Visser and Meyer (2014) state that category fluency tasks measure verbal ability and executive control skills. During these tasks an individual is required to use these skills in order to retrieve words in a specific language. These words must be produced based on a specific category, and only novel, spontaneous responses count toward an individual's score. During this task individuals are accessing their lexicon, maintaining their attention on the task, and only retrieving words that qualify under the category and repetition constraints (Shao et al., 2014). However, much of the available literature has been normed on monolingual populations. There is a growing need to assess bilingual populations, specifically Spanish/English bilingual speakers due to the increasing number of students entering the United States public school system and the number of aging Hispanics in the current population (Goldstein, 2012; Shin & Kominski, 2010).

Previous findings have suggested that category fluency tasks aim to measure both lexical and semantic competence versus letter fluency tasks, which have a greater focus on attention performance (Bizzozero, Scotti, Clerici, Pomati, Laiacona & Capitani, 2013). In studies where participants were matched based on self-reported language skills and overall vocabulary, bilingual participants were likely to score lower than their monolingual counterparts (Rosselli & Ardila, 2002). Gollan and Acenas (2004) proposed that lower scores reflected a reduced exposure to the language and thus consequently decreasing the automaticity of semantic representations present in monolinguals. Sandoval, Gollan, Ferreira, and Salmon (2010) found that Spanish-English bilingual college students that were classified as English dominant or balanced bilinguals produced

fewer words in their non-dominant language and retrieved them more slowly. These findings suggest that category fluency tasks have a higher sensitivity to language proficiency than letter fluency tasks. There is a lack of research designed to investigate language proficiency's influence on acoustic measurements, such as fundamental frequency, in bilingual speakers.

1.3.3 Examining Differences in Fundamental Frequency in Bilingual Speakers

According to Dolson (1994), speakers of different languages - and across varying dialects - exhibit differences of F0 values and range. Additionally, speakers of a single language identifying with different social groups present with varying F0 (Podesva, 2007). Relevant to the present study are findings made by Xue, Hagstrom, and Hao (2002), which compared the F0 mean, standard deviation, minimum, maximum, and range of younger and older Chinese-English bilingual speakers when speaking the two languages. Xue et al. (2002) reported significant differences in F0 among the younger bilinguals, but the results of the study did not apply to the older bilingual speakers. A rise of F0 when speaking the L2 has also been attributed to uncertainty or lack of confidence in the speaker, resulting in a higher F0 (Ohala, 1984). This change in F0 is supported by studies that assert the effects of emotion on acoustic variables in speech. Pell (1999) reported that emotions are correlated to different acoustic measures with speech rate and F0 being the most highly affected. Ellgring and Scherer (1996) also stated that mean F0 and speech rate are highest for emotions that are associated with a high sympathetic arousal, such as anger and fear. In the following study, I indirectly studied emotions by investigating changes in F0 between a speaker's dominant and non-dominant languages.

1.4 Current Study

In the majority of previous studies on bilingual Spanish-English speakers, researchers have focused separately on language dominance (L1 versus L2), fundamental frequency, and measures of language proficiency. The unique contribution of the present study is the idea that each of the aforementioned research areas may in fact rely on one another. This connection may be crucial to establishing vocal norms for Spanish-English bilingual speakers, and demonstrating that acoustic differences in speaking two languages are not necessarily due to physiological differences or vocal pathologies. In this current research, I aimed to establish (1) whether there are vocal changes present across languages in Spanish-English bilingual speakers as a function of the target language, (2) whether language dominance influences F0, (3) whether being a simultaneous bilingual speaker versus a sequential bilingual speaker would affect F0 (4) whether self-reports of language dominance correspond with the total category fluency task scores (TCFS) measuring language proficiency.

To summarize, in the present study, I examined if there is a shift in F0 based on the target language in bilingual speakers. Additionally, I investigated the effects of language acquisition (i.e., sequential vs. simultaneous), language dominance, and language proficiency on F0. The following predictions were made: (1) a shift in F0 would be present between Spanish and English, (2) F0 would increase in the non-dominant language due to having less proficiency and feeling less competent in the non-dominant language, (3a) being a sequential speaker would cause F0 to differ between languages due to having learned the languages at different times, (3b) being a simultaneous speaker would cause F0 to differ between languages due to having learned the languages at the

same time, (4) self-reports of language dominance would correspond to TCFS measuring language proficiency.

CHAPTER II

METHODS

2.1 Participant Selection and Ethics Statement

The investigation, materials and procedures for this study were approved by the Institutional Review Board (IRB) at Cleveland State University. Eleven Spanish-English bilingual participants were recruited by the student investigator (who is a native Spanish speaker) by word of mouth from the local Spanish speaking community. If the prospective participant met the inclusionary criteria as outlined below, a time was established for the initial session. There were no financial incentives for participation.

All participants were 18 years and over and spoke both Spanish and English. Participants had normal hearing even if aided (i.e., hearing aids), and no one with a cochlear implant was included. Cochlear implants are usually worn by individuals who are diagnosed as profoundly deaf, and the speech in these individuals is usually initially distorted, albeit adequate. This device would introduce an anomaly of speech, which would be an unwanted variable in this study. Participants did not have any known speech, language, or voice impairments. At the time of the study participants did not have any respiratory infections that could interfere with speech or vocal production. It was also

required that each participants must have acquired L2 before the age of 16. The age of language acquisition is important, as studies have shown that after puberty, acquisition of a second language is more difficult for the learner and very rarely reaches the level of a native speaker. This may not be true of all individuals but there is enough evidence to support the critical period hypothesis of second language acquisition in which learners of the second language do not reach a native-like level in the L2 after a certain age. For the purpose of data analysis, participants were separated into two language acquisition categories, sequential and simultaneous, based on responses from the Language Experience and Proficiency Questionnaire (LEAP-Q). See Appendix A.

Participants' ages ranged from 18 to 56 years of age. Six (55%) of the participants were female. Demographic information can be seen in Table 1. Additionally, Figures 1 and 2 provide visual representations of participants by their language acquisition category, dominant language, and age group.

Table I. Participant Language Category & Demographics.

Category	**Gender**	**Age**	**Ethnicity**
Sequential	Male	26-40	Puerto Rican
Sequential	Female	26-40	Guatemalan
Sequential	Female	> 40	Guatemalan
Sequential	Female	26-40	Guatemalan
Sequential	Female	18-25	Guatemalan
Simultaneous	Female	18-25	Guatemalan
Simultaneous	Female	18-25	Guatemalan-Puerto Rican
Simultaneous	Male	18-25	Guatemalan
Simultaneous	Male	18-25	Honduran-American
Simultaneous	Male	26-40	Guatemalan
Simultaneous	Male	> 40	Puerto Rican

Figure 1. Sequential Speakers and Their Dominant Language.

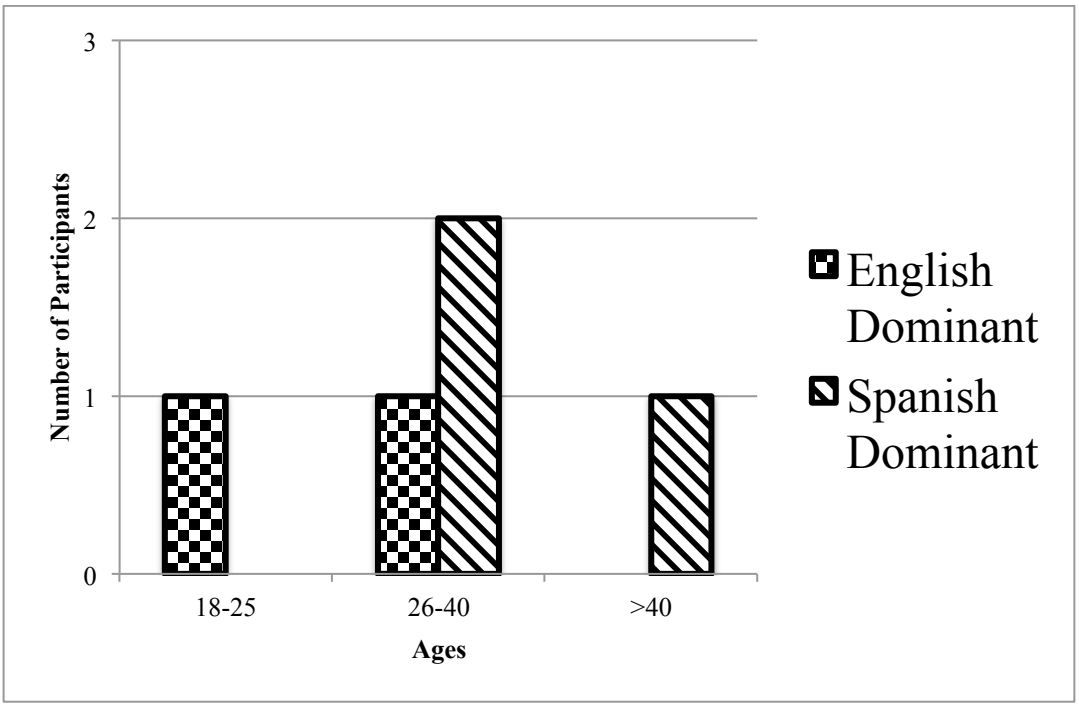
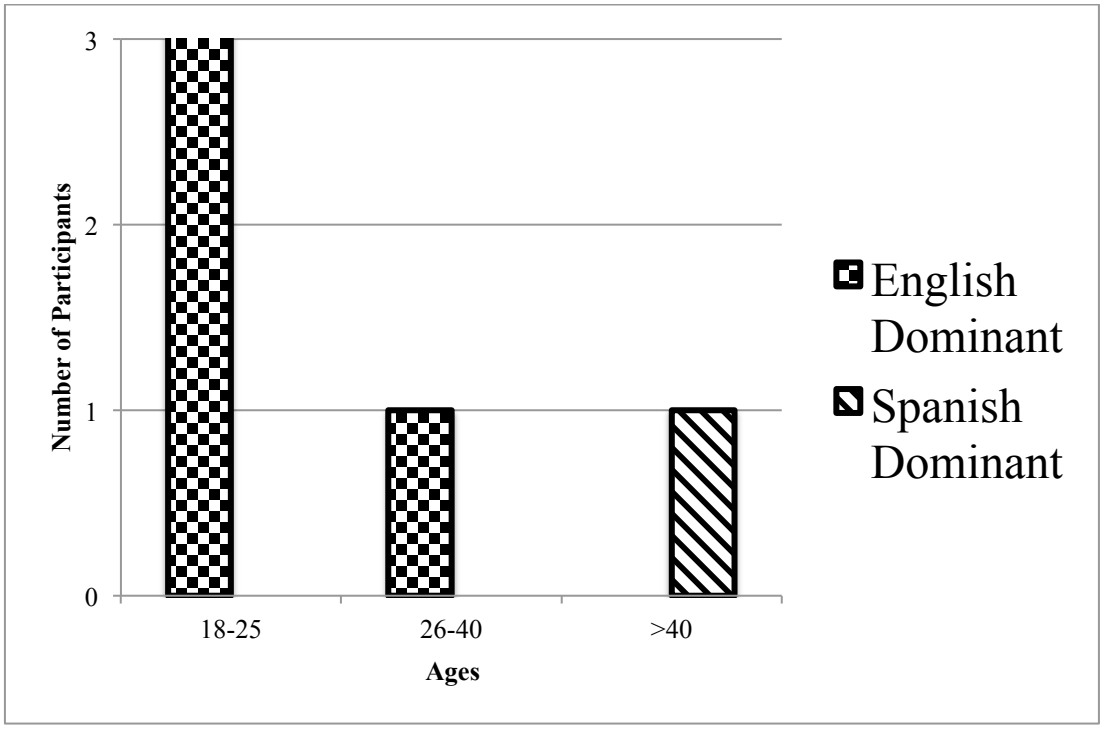


Figure 2. Simultaneous Speakers and Their Dominant Language.



2.2 Consent Form

The investigator recruited, screened, and collected data from all participants. All data were collected in the voice lab of the Cleveland State University Speech and Hearing Clinic. All participants agreed and signed the consent form after discussing all procedures and associated risks with the examiner. Participants were also offered a reference copy of the informed consent form. See Appendix B.

2.3 Language Questionnaire

The LEAP-Q by the Northwestern Bilingualism and Psycholinguistics Research Laboratory was administered to all participants. The LEAP-Q is an assessment that rates bilingual language learning and language use experiences, which research suggests, provides a more comprehensive evaluation of a bilingual speaker's linguistic profile (Marian et.al., 2007). The formulation of this assessment supports the bilingualism theory that L2 acquisition is an interaction between proficiency and experience. This questionnaire was intended to provide a more in-depth assessment of language learning and language use experiences by focusing on language acquisition and daily language usage across a variety of settings and conversational partners. Additional questions specific to this study were added to the LEAP-Q.

2.4 Instrumentation

The Praat software was utilized to record speech samples using a computer with a built in microphone. All settings remained at their default settings for both male and female participants. Pitch floor was set to 75 Hz, and pitch ceiling was set to 600 Hz.

2.5 Procedures and Scoring

Upon their arrival, participants were informed of the three different tasks and how long they would last. Participants were seated comfortably at a table opposite the investigator. The participants were asked to complete the LEAP-Q. Once completed Praat was used to record the speech samples.

During the first speech sample, the participants were given verbal directions (See Appendix C) for the category fluency task. Participants were asked to use the target language and name as many novel items as possible in a given category within a 60-second period. The participant was verbally given the target language, Spanish or English. Next the participant was verbally given the target category in the same language, and the investigator immediately started the timer. The timer was not visible to the participants. The following categories were randomly presented: animals, vegetables, and fruit. This task was done a total of six times for each participant, three in Spanish and three in English. The final speech sample consisted of reading four simple sentences, two in Spanish and two in English. Each sentence was matched using the same number of syllables in Spanish and English and shown on an index card. See Appendix D. The participant was presented with the matching sentences in both languages before going on to the next sentence. The first six participants were given English as their first target language during every task, and the remaining five participants were given Spanish as their first target language. The student investigator spoke in the appropriate target language while delivering the instructions. The data collection time per participant was approximately 30 to 45 minutes.

During the category fluency tasks, participants were asked to name as many novel items as possible in various categories, animals, vegetables, and fruits. The participants only received credit if their responses were 1) in the target language, 2) in the correct category, and 3) novel or non-repeated responses. If the response met all three criteria, it was added to the participant's raw score for each category. Each participant received three raw scores in each language for a total of six raw scores. The total category fluency score (TCFS) was calculated by adding the number of correct responses for the pooled categories. Each participant received two TCFS, one for each language. Additionally, Praat recorded and measured F0 in Hertz (Hz) for each sentence in the reading sample.

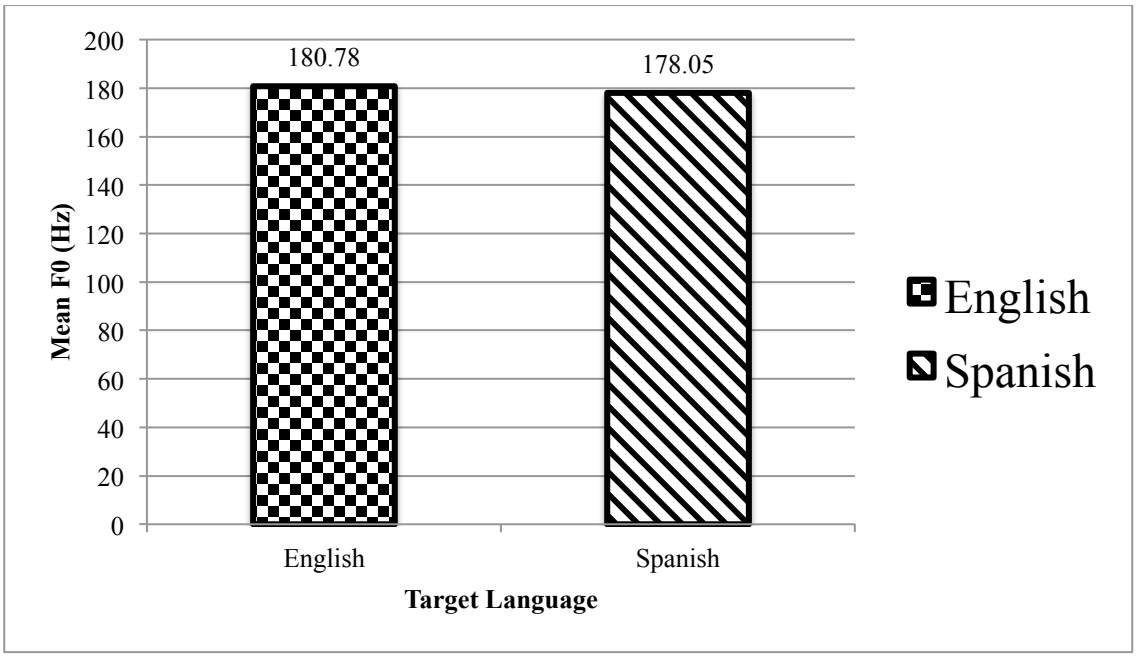
CHAPTER III

RESULTS

3.1 Fundamental Frequency

The first research question investigated was whether there was a shift in F0 based on the target language. It was predicted that a shift would occur between languages. In order to analyze the data, the F0 measurements were taken from each participant's Praat recordings. All English and Spanish speech samples were averaged for each participant, and a total mean was calculated for each language. An exact sign test was used to compare the differences in fundamental frequency for the two languages. There was not a significant difference between the English speech samples when compared to the Spanish speech samples, $z = .302$ and $p = .763$. Figure 3 shows that the total means for English and Spanish speech samples were within 2.73 Hz of each other. For a list of all raw scores for each sentence see Appendix E.

Figure 3. Mean Fundamental Frequency for English and Spanish Speech Samples.



3.2 Language Dominance

The second research question considered whether language dominance influenced F0. It was predicted that F0 would increase in the non-dominant language due to having less proficiency and feeling less competent. All dominant and non-dominant language speech samples were averaged for each participant, and a total mean was calculated for each set of data. An exact sign test was used to compare the fundamental frequency values for dominant language and non-dominant language. There was not a significant difference between the dominant and non-dominant language speech samples, $z = .905$ and $p = .183$ (see Figure 4). However, 7 out of 11 participants demonstrate a pattern, which supports the prediction that bilingual speakers increase their F0 when speaking in their non-dominant language. Table 2 shows the differences between non-dominant and

dominant language F0 for each speaker, and which speakers increased in their non-dominant language.

Figure 4. Mean Fundamental Frequency for Dominant and Non-dominant Language Speech Samples.

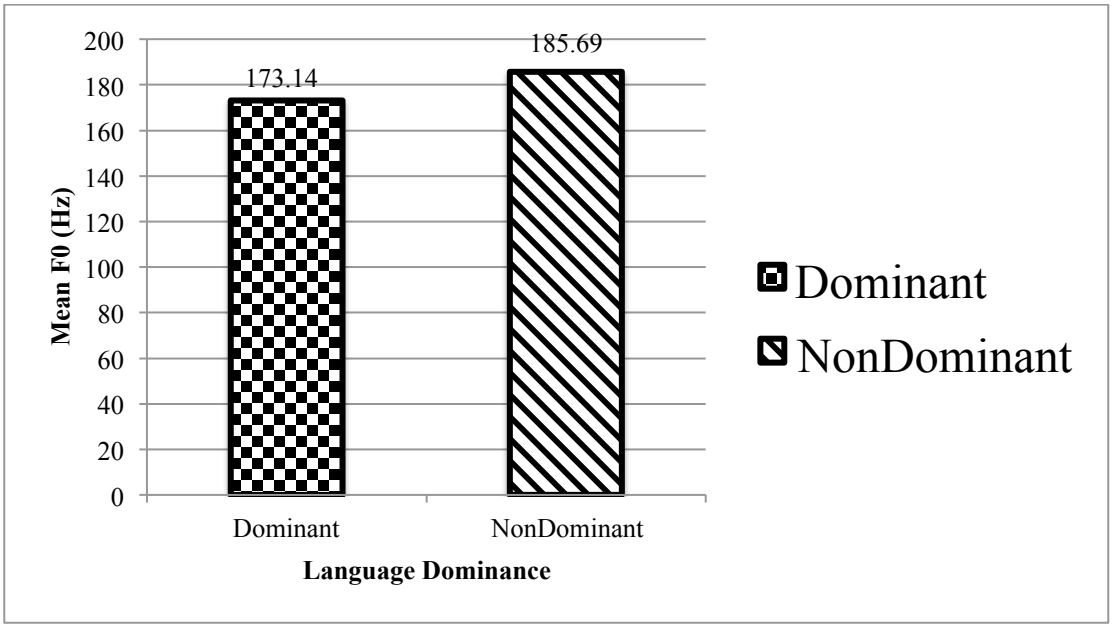


Table II. Differences Between Non-Dominant and Dominant F0 (Hz).

Dominant	Non-Dominant	Non-Dominant MINUS Dominant	Increased in Non-Dominant
135.97	115.42	-20.55	No
214.32	208.37	-5.95	No
212.34	221.03	8.69	Yes
197.47	262.05	64.58	Yes
216.21	242.55	26.34	Yes
247.65	192.55	-55.1	No
200.84	203.28	2.44	Yes
89.6	109.83	20.23	Yes
99.09	91.17	-7.92	No
108.94	197.47	88.53	Yes
182.1	198.82	16.72	Yes

3.3 Language Acquisition

The third research question examined whether being a simultaneous speaker versus a sequential speaker would affect F0. It was predicted that being a sequential speaker would cause F0 to differ between languages due to having learned the languages at different times, and being a simultaneous speaker would cause F0 to differ between languages due to having learned the languages at the same time. All English and Spanish F0s were averaged separately for sequential and simultaneous speakers.

An exact sign test was used to compare the differences in fundamental frequency between English and Spanish in sequential speakers and in simultaneous speakers. There was not a significant difference between the sequential English speech samples when compared to the Spanish speech samples, $z = .447$ and $p = .655$. Figure 5 shows that the differences for English and Spanish speech samples for sequential speakers were within 12.31 Hz of each other. There was also not a significant difference between the simultaneous English speech samples when compared to the Spanish speech samples, $z = < .001$ and $p = > .99$ Figure 6 shows that the differences for English and Spanish speech samples for simultaneous speakers were within 35.59 Hz of each other.

Figure 5. Sequential Speakers Mean Fundamental Frequency for English and Spanish Speech Samples.

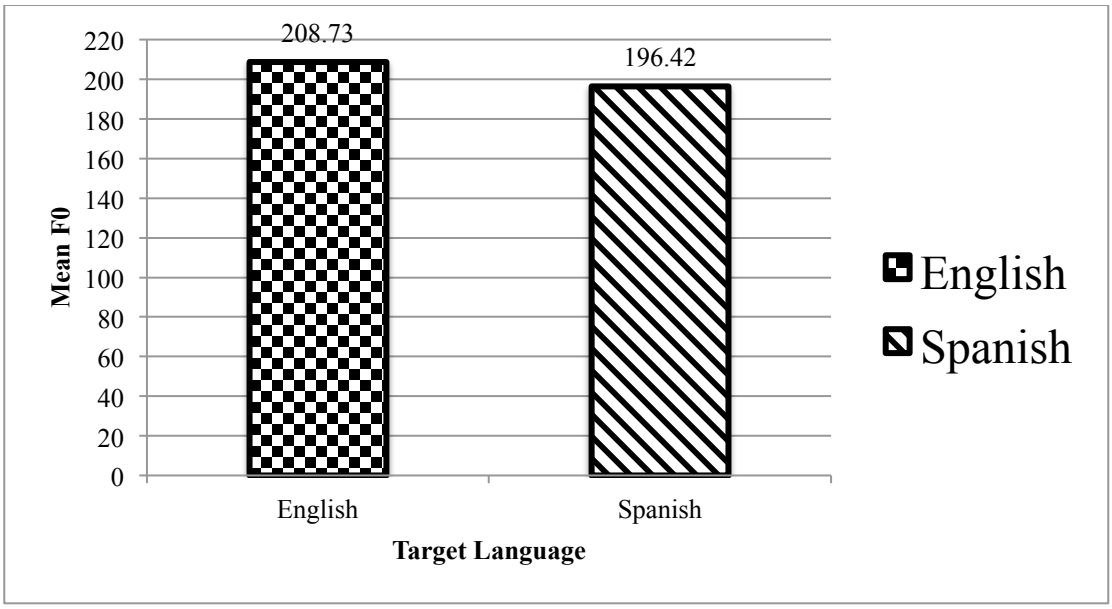
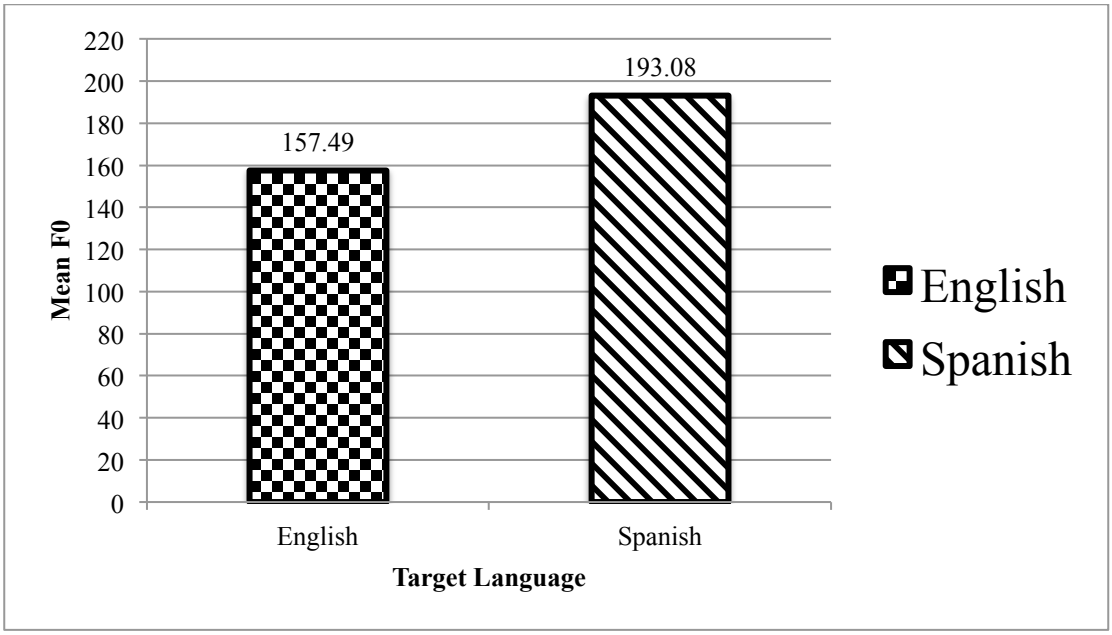
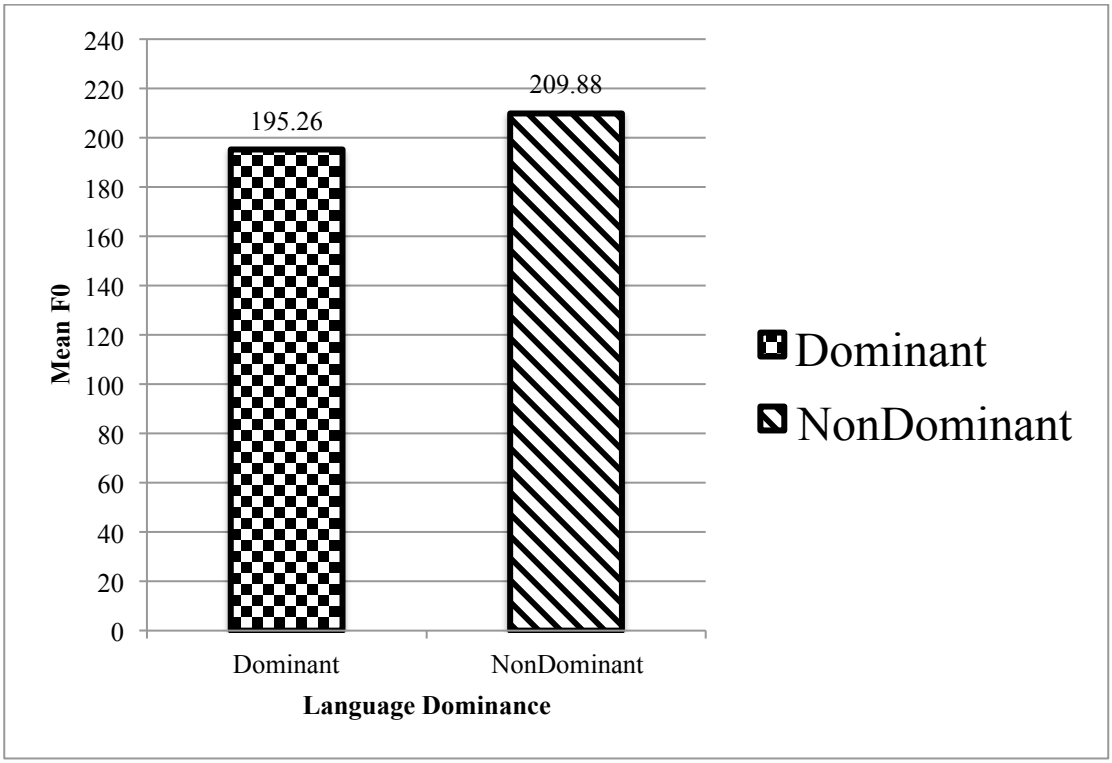


Figure 6. Simultaneous Speakers Mean Fundamental Frequency for English and Spanish Speech Samples.



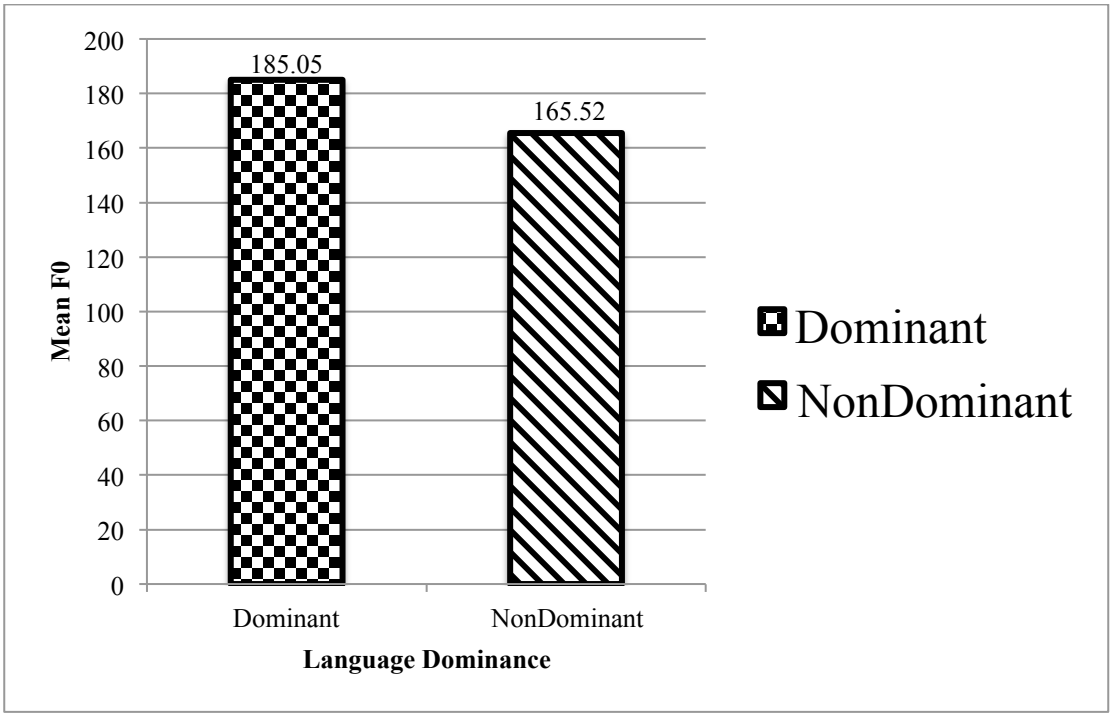
The exact sign test was also conducted to determine if the mean F0 of the dominant language when compared to the non-dominant language was affected by being a sequential or simultaneous speaker. However, there was no significant difference found in dominant versus non-dominant F0 in sequential speakers, $z = .447$ and $p = .327$. However, when examining the mean F0 value the non-dominant F0 is slightly higher than the dominant by 14.62 Hz.

Figure 7. Sequential Speakers Mean Fundamental Frequency for Dominant and Non-dominant Language Speech Samples.



There was no significant difference found in dominant versus non-dominant F0 in simultaneous speakers, $z = .816$ and $p = .207$. The pattern in the data reinforced the opposite prediction for simultaneous speakers; the F0 increased in the dominant language (Figure 8).

Figure 8. Simultaneous Speakers Mean Fundamental Frequency for Dominant and Non-dominant Language Speech Samples.



3.4 Language Competence

The final research question considered whether self-reports of language dominance would correspond with the TCFS measuring language proficiency. It was predicted that participants' self-reports of language dominance would correspond with their TCFS. Participants were asked to self-report their dominant language. The exact

sign test was conducted to compare the differences between the dominant language TCFS and the non-dominant language TCFS. There was a significant difference found between the dominant language TCFS and the non-dominant language TCFS, $z = 2.11$ and $p = .035$. The data indicated that 9 out of 11 participants' self-reports of language dominance corresponded to their TCFS (Table 3). For a list of all self-reports and TCFS by group see Appendix F.

Table III. Dominant Total Category Fluency Task Score compared to Non-dominant Total Category Fluency Task Score.

Dominant TCFS	Non-dominant TCFS	Dominant Language Matched TCFS
33	20	YES
24	14	YES
46	49	NO
50	40	YES
60	33	YES
36	18	YES
38	19	YES
34	26	YES
41	26	YES
50	17	YES
30	42	NO

CHAPTER IV

DISCUSSION

My goal was to examine whether there was a shift in F0 in English/Spanish bilingual speakers and whether language dominance and language acquisition had an effect on F0. Previous research had suggested that shifts in F0 among bilingual speakers may be caused by adaptation to the speaking environment or due to meeting the demands of the speaking task (Järvinen et. al., 2013). Other studies suggested language proficiency and language acquisition could influence measurements of F0 in bilingual speakers (Boka, 2010; Nevo et. al., 2015). The following research questions were targeted in this study:

1. Are there vocal changes present across languages in Spanish-English bilingual speakers as a function of the target language?

2. Does language dominance influences F0?

3. Does being a simultaneous bilingual speaker versus a sequential bilingual speaker affect F0?

4. Do participants self-reports of language dominance correspond with their total category fluency task scores (TCFS) measuring language proficiency? The results from the first question did not reveal any statistical support to suggest that the mean F0

measurements shift when bilingual speakers switch between English to Spanish. Previous studies have shown acoustic differences across languages in bilingual speakers, but few studies have reported on English/Spanish bilinguals. Although no significant difference was observed when comparing mean F0 in English and Spanish for all participants, individual F0 comparisons for each participants did demonstrate some changes. The most substantial F0 shifts measured were decreases between English to Spanish ranging from 73.76 Hz to 121.87 Hz, and increases between English to Spanish ranging from 79.81 Hz to 97.26 Hz (Appendix E). These individual comparisons suggest that other factors are at play. Based on the present study, it is not clear what factors contributed to those individual shifts. A possible factor that should be considered is the nature of the speech tasks. In this study, the speech tasks were contrived and therefore removed the element of naturalness from which F0 can be derived. Future studies should consider a task in which speakers could provide spontaneous speech samples. Spontaneous speech samples would be a more natural use of language, and may provide data that could suggest a shift between English and Spanish in bilingual speakers.

The second question did not reveal any statistical evidence to suggest that the mean F0 measurements shift when bilingual speakers switch between their dominant to non-dominant language. However, 7 out of 11 participants did increase their F0 in the non-dominant language (Table 2). This pattern supports the prediction that an increase in F0 can be seen when speaking the non-dominant language. It is not clear what factors may be influencing this increase in F0. However, it was predicted that having less proficiency in the language would lead to feeling less competent or confident, therefore increasing F0. Previous studies have found that bilingual speakers show a rise in F0 when

speaking in their L2, which has been attributed to uncertainty or lack of confidence in the speaker (Ohala, 1984). The literature suggests that a speaker's emotional and physical state expresses itself in speech through paralinguistic features such as pitch, speaking rate, voice quality, and energy (Truong & Leeuwen, 2007). Pitch has been indicated as being one of the most relevant paralinguistic features for the detection of emotion, followed by energy, duration and speaking rate (Bosch ten, 2003). Other studies have found an increased pitch variability or range and an increased intensity of effort when people are in a heightened aroused emotional state (Rothganger, Hauser, Cappellini, & Guidotti, 1998), which supports the idea that feeling less competent or confident when speaking your non-dominant language may increase your pitch or F0. Future studies should consider emotional responses as well as emotion inducing speech tasks in both dominant and non-dominant languages that may cause bilingual speakers to increase or decrease their F0. In addition other factors worth investigating are language exposure and language preference. This study did not directly examine language exposure and language preference, but the LEAP-Q did have questions targeting this area of interest (See Appendices G & H for participant responses). These responses may provide data that could support the uncertainty and lack of confidence when speaking the non-dominant language, which could correlate with an increase in F0.

The third question investigated whether the order of language acquisition, being a simultaneous speaker or a sequential speaker, had an effect on F0 when speaking in English compared to Spanish or when speaking the dominant language compared to the non-dominant language. According to the data, the order of language acquisition did not reveal any significant difference on the F0 based on the target language or when looking

at dominant versus non-dominant language. However, the data pattern for sequential speakers suggest an increase in F0 in the non-dominant language, as was the case when examining the sample as a whole. Simultaneous speakers demonstrated a different pattern, where as their F0 decreased in the non-dominant language. Since there was no significant difference found in the data it is not clear what factors contributed to the pattern demonstrated between groups. However, it was noted that both groups were mostly compromised of one gender. In the sequential group, 4 out of 5 participants were female, and in the simultaneous group, 4 out of 6 were male. Gender effects could have been a confounding variable in this analysis. Additionally, the literature suggests that factors such as age of language acquisition, amount of language input, and the language status (majority/minority) in the community may affect a bilingual speakers use of two languages (Pearson, 2007). It has also been found that children who grow up in a bilingual environment may only acquire a passive knowledge of the minority language and become competent in the majority language (Fillmore, 1991). In adult second language learners, the sociolinguistic status of each language has been shown to be an important factor that impacts the need or desire for proficiency (Firth & Wagner, 2007). This may be due to the influence that language status has on attitudes and opportunities for bilingual speakers (Khattab, 2009). The language status can determine the family's access to support and services (MacLeod et. al., 2013). Within the home, the language status can also influence different family members' attitudes and approaches to the two languages (Khattab, 2009). Future studies could control more efficiently for gender, age of language acquisition, language exposure, and language status in the speakers environment.

The fourth question examined if the participants self-reports of language dominance corresponded with their TCFS that measured their language proficiency. The data were statistically significant, and demonstrated that the participants self-report of their dominant language was supported by their TCFS measuring language proficiency. This also reinforces that category fluency tasks (automatic responses to specific vocabulary categories) are efficient when measuring language proficiency with cognitively, intact individuals. The results for the category fluency task compared to self-reports were strong among participants, but they might have been different if the categories provided were not based on simple vocabulary (i.e., animals, fruits, vegetables). The literature on bilingual vocabulary acquisition, specifically for simultaneous children, reports that bilingual vocabularies may be smaller than monolingual vocabularies due to dividing language exposure time across two languages (Bialystok, Luk, Peets, & Yang, 2010). However, these children are also exposed to a more diverse set of linguistic structures than monolinguals, and research has demonstrated that these children develop comparable linguistic systems to their monolingual peers at least in one language (MacLeod, Laukys, & Rvachew, 2011). Future studies could choose to focus on more complex categories based on academics or other categories of interests to determine a more accurate language proficiency rating using this measure. Additionally, category fluency norms could be compared between cognitively, intact bilingual and monolingual participants to determine if being a bilingual or multilingual speaker could impact outcomes of category fluency tasks.

Other limitations of this study are the following. A small sample size was used due to difficulties finding participants that met the inclusionary criteria. One difficulty

arose specifically, when recruiting sequential speakers who had learned their L2 before the age of puberty. In particular, this study did not have a balance of English-dominant and Spanish-dominant speakers in the sequential and simultaneous language learner groups. Future studies should expand the participant pool while still controlling for age of language acquisition.

Further, the limited sample size also resulted in subsamples of English-dominant and Spanish-dominant speakers that were not well-matched in terms of gender and age. While the concern over these potentially confounding factors is mitigated by the fact that this study found no significant differences between the two dominance groups, it is actually feasible that a larger and more balanced sample might detect differences not seen in this study.

Another limitation is the influence of the investigator's voice on the participants. Participants may change their pitch to match that of the investigator. By using a more neutral approach for providing speech task directions, the influence of the investigators voice could be eliminated. Future studies could provide participants with written or computerized directions to decrease any outside influences.

Despite the limitations of this study, the patterns that emerge suggest a shift in fundamental frequency based on language dominance. Additionally, this study suggests that variables such as language acquisition, language proficiency, language exposure, language status and language preference may be contributors to a shift in F0 across bilingual speakers.

This study is just a small contribution to learning more about voice norms in linguistically diverse populations within the United States. Future research will provide

current knowledge on the diversity in the voice and voice features in order to provide accurate diagnosis, evidenced based treatment and effective education for professionals treating multilingual speakers.

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APPENDIX

APPENDIX A

Participant Questionnaire

Last Name		First Name		Today's Date	
Age		Date of Birth		Male □	Female □

1. At this time do you have a cold or sinus infection? YES NO
2. To your knowledge do you have a voice disorder? YES NO If yes, which one?

   _____

   _____
3. Have you ever seen a medical professional for problems with your voice? YES NO

   If yes, what professional and what type of problems?

   _____

   _____
4. Are you on any medications that may affect your voice quality? YES NO

(5) Please list all the languages you know **in order of dominance**:

1	**2**	**3**	**4**	**5**

(6) Please list all the languages you know **in order of acquisition and setting where you learned it** (your native language first):

Order of Acq	**1**	**2**	**3**	**4**	**5**
Setting					

(7) Did you learn any of those languages simultaneously? YES NO

If so, which ones?

_____

_____

_____

(8) Please list what percentage of the time you are **currently** and **on average** exposed to each language. (Your percentages should add up to 100%):

List language here:					
List percentage here:					

(9) When choosing to read a text available in all your languages, in what percentage of cases would you choose to read it in each of your languages? Assume that the original was written in another language, which is unknown to you. (Your percentages should add up to 100%):

List language here:					
List percentage here:					

(10) When choosing a language to speak with a person who is equally fluent in all your languages, what percentage of time would you choose to speak each language? Please report percent of total time. (Your percentages should add up to 100%):

List language here:					
List percentage here:					

(11) Please name the cultures with which you identify. On a scale from zero to ten, please rate the extent to which you identify with each culture. (Examples of possible cultures include US-American, US- Puerto Rican, Chinese, Jewish-Orthodox, etc):

List cultures here:					
List rating:					

0- no identification identification
1- very low identification
2- low identification
3- very mild identification
4- mild identification
5- moderate identification
6- slightly more than moderate
7- slightly high identification
8- high identification
9- almost complete identification
10- complete identification

(12) How many years of formal education do you have? _____
Please check your highest education level (or the approximate US equivalent to a degree obtained in another country):

□ Less than High School □ Some college □ Masters
□ High School □ College □ Ph.D./M.D./J.D.
□ Professional Training □ Some Graduate School □ Other:

(13) Date of immigration to the USA, if applicable _____. Have you ever immigrated to another country, if so please provide the name _____.

(14) Have you ever had a vision problem □, hearing impairment □, language disability □, or learning disability? (Check all applicable). If yes, please explain (including any corrections):

_____

Language- English

(15) This is my _____ language. Please Circle One:

Native Second Third Fourth Fifth

All questions below refer to your knowledge of English.

(16) Age when you _____English.

Began Acquiring:	Became Fluent in:	Began Reading in:	Became Fluent Reading in:

(17) Please list number of years and months you spent in each language environment:

	Years	**Months**
A country where English is spoken.		
A family where English is spoken.		
A school where English is spoken.		
A working environment where English is spoken.		

(18) On a scale from zero to ten, please select your level of proficiency in speaking, understanding, and reading English:

Speaking		**Understanding spoken language**		**Reading**	

0- none
1- very low
2- low
3- fair
4- slightly less than adequate
5- adequate
6- slightly more than adequate
7- good
8- very good
9- excellent
10- perfect

(19) On a scale from zero to ten, please select how much the following contributed to you **learning** English:

Interacting with friends		Language tapes/self instruction	
Interacting with family		Watching TV	
Reading		Listening to radio	

0- not a contributor
1- minimal contributor
2- low contributor
3- very mild contributor
4- mild contributor
5- moderate contributor
6- slightly more than moderate contributor
7- slightly high contributor
8- high contributor
9- very high contributor
10- highest contributor

(20) Please rate to what extent you are currently **exposed** to English in the following contexts:

Interacting with friends		Language tapes/self instruction	
Interacting with family		Watching TV	
Reading		Listening to radio	

0- never
1- almost never
2-
3-
6-
7-
8-
9-

4- 10- always
5- half of the time

(21) In your perception, how much of a foreign accent do you have in English?

_____

0- none 6- considerable
1- almost none 7- heavy
2- very light 8- very heavy
3- light 9- extremely heavy
4- some 10- pervasive
5- moderate

(22) Please rate how frequently others identify you as a non-native speaker based on your accent in English? _____

0- never 6-
1- almost never 7-
2- 8-
3- 9-
4- 10- always
5- half of the time

Language- Spanish

(23) This is my _____ language. Please Circle One:

Native Second Third Fourth Fifth

All questions below refer to your knowledge of Spanish.

(24) Age when you _____ Spanish:

Began Acquiring:	Became Fluent in:	Began Reading in:	Became Fluent Reading in:

(25) Please list number of years and months you spent in each language environment:

	Years	**Months**
A country where Spanish is spoken.		
A family where Spanish is spoken.		
A school where Spanish is spoken.		
A working environment where Spanish is spoken.		

(26) On a scale from zero to ten, please select your level of proficiency in speaking, understanding and reading Spanish:

Speaking		**Understanding spoken language**		**Reading**	

0- none
1- very low
2- low
3- fair
4- slightly less than adequate
5- adequate
6- slightly more than adequate
7- good
8- very good
9- excellent
10- perfect

(27) On a scale from zero to ten, please select how much the following contributed to you **learning** Spanish:

Interacting with friends		Language tapes/self instruction	
Interacting with family		Watching TV	
Reading		Listening to radio	

0- not a contributor
1- minimal contributor
2- low contributor
3- very mild contributor
4- mild contributor
5- moderate contributor
6- slightly more than moderate contributor
7- slightly high contributor
8- high contributor
9- very high contributor
10- highest contributor

(28) Please rate to what extent you are currently **exposed** to Spanish in the following contexts:

Interacting with friends		Language tapes/self instruction	
Interacting with family		Watching TV	
Reading		Listening to radio	

0- never
1- almost never
2-
3-
4-
5-
6-
7-
8-
9-
10- always

(29) In your perception, how much of a foreign accent do you have in Spanish?

_____

0- none	5- moderate	10- pervasive
1- almost none	6- considerable	
2- very light	7- heavy	
3- light	8- very heavy	
4- some	9- extremely heavy	

(30) Please rate how frequently others identify you as a non-native speaker based on your accent in Spanish? _____

0- never	6-
1- almost never	7-
2-	8-
3-	9-
4-	10- always
5- half of the time	

(31) Do you consider yourself bilingual? YES NO OTHER
(Please explain below.)

_____

(32) Please rate your level of competence in English:

BEGINNER INTERMEDIATE/MODERATE ADVANCED
NATIVE

(33) Please rate your level of competence in Spanish:

BEGINNER INTERMEDIATE/MODERATE ADVANCED
NATIVE

APPENDIX B

Informed Consent

We are Dr. Violet Cox and Nydia Mendez, Assistant Lecturer and graduate student, in the Department of Speech and Hearing at Cleveland State University. We are requesting your participation in a research study.

This study aims to understand changes in Bilingual speaker's speech production in both English and Spanish. We will ask that you read sentences and describe pictures in both English and Spanish. We will record your speech samples using a computer with a built-in microphone.
The data collected will be confidential. Your name and other identifying information will not be linked with the data collected. Every effort will be made to maintain privacy. Results of this study will not be traced back to you.
You will be tested at the Cleveland State University Voice and Swallowing lab located in CIM 211. Participation in this study is voluntary. You may withdraw at any time. There is no reward for participating, or consequence for not participating. Risks associated with participation are considered to be minimal. To minimize such risks, no personal identifying information will be collected.

You may withdraw from this study at any time without any consequence whatsoever. Only summary results may be published, presented or used for instruction. There are no direct benefits available to you as a participant in this research. However, your participation should help us understand changes in Bilingual speaker's speech production. This study will take about 60 minutes to complete.

For more information, please contact Nydia Mendez, graduate student, at (440) 429-0831 or n.mendez@vikes.csuohio.edu, or Dr. Violet Cox, Assistant Lecturer, at (216) 687-6909 or v.cox@csuohio.edu.

A copy of this Informed Consent will be provided to you for your records.
Please read the following: ***"I understand that if I have any questions about my rights as a research subject, I can contact the Cleveland State University Institutional Review Board at (216) 687-3630."***

There are two copies of this form. After signing them, keep one copy for your records and return the other one to the researcher.
Your signature below means that you understand the contents of this document. You also are at least 18 years of age. Finally, you voluntarily consent to participate in this research study.

_____
Signature

_____
Name (Please Print)

_____
Date

APPENDIX C

Instructions from the investigator to the participant for measuring F0 in speech samples:

English-

I will show you six different index cards. Each one has a sentence. Please read each sentence exactly how it is written.

Spanish-

Te ensenare seis diferentes tarjetas. Cada una tiene una oración. Por favor lee cada oración exactamente como esta escrita.

Instructions from the investigator to the participant for measuring the TCFS:

I am going to give you a category and ask you to name all the different examples that you can think of from that category in one minute. For instance, if I said flowers you might say rose, daisy, etc. Do you understand? This task will be completed six different times. Each time the task will be timed and a specific target language will be assigned. All your answers must be in novel and non-repeated and spoken in the assigned language in order to receive credit. You have 60-seconds to give as many examples as you can.

APPENDIX D

Speech Prompts

Español	English
1. El es un juez. (He is a judge.)	1. This is a book.
2. Es mio.	2. It’s mine.

APPENDIX E

Table EII. Sequential Speakers' F0 measures of all speech samples.

Participants	English S1	Spanish S1	English S2	Spanish S2
M1 English Dominant	177.29	97.98	94.65	132.86
F1 Spanish Dominant	224.31	205.69	192.42	222.95
F2 Spanish Dominant	264.14	247.77	177.91	176.9
F3 Spanish Dominant	304.76	231	219.34	163.93
F4 English Dominant	229.47	253.24	202.95	231.86

Table EII. Simultaneous Speakers' F0 measures of all speech samples.

Participants	English S1	Spanish S1	English S2	Spanish S2
F5 English Dominant	193.38	205.04	301.92	180.05
F6 English Dominant	218.42	200.7	183.26	205.86
M2 English Dominant	97.7	135.9	81.5	83.76
M3 English Dominant	103.92	92.51	94.26	89.82
M4 English Dominant	112.91	210.17	104.96	184.77
M5 Spanish Dominant	239.12	212	158.51	152.19

APPENDIX F

Table FI. Sequential Speakers' Dominant Total Category Fluency Task Score compared to Non-dominant Total Category Fluency Task Score.

Dominant TCFS	Non-dominant TCFS	Dominant Language Matched TCFS
33	20	YES
24	14	YES
46	49	NO
50	40	YES
60	33	YES

Table FII. Simultaneous Speakers' Dominant Total Category Fluency Task Score compared to Non-dominant Total Category Fluency Task Score.

Dominant TCFS	Non-dominant TCFS	Dominant Language Matched TCFS
36	18	YES
38	19	YES
34	26	YES
41	26	YES
50	17	YES
30	42	NO

APPENDIX G

Figure G1. Sequential Speakers and Percentage of Daily Language Exposure.

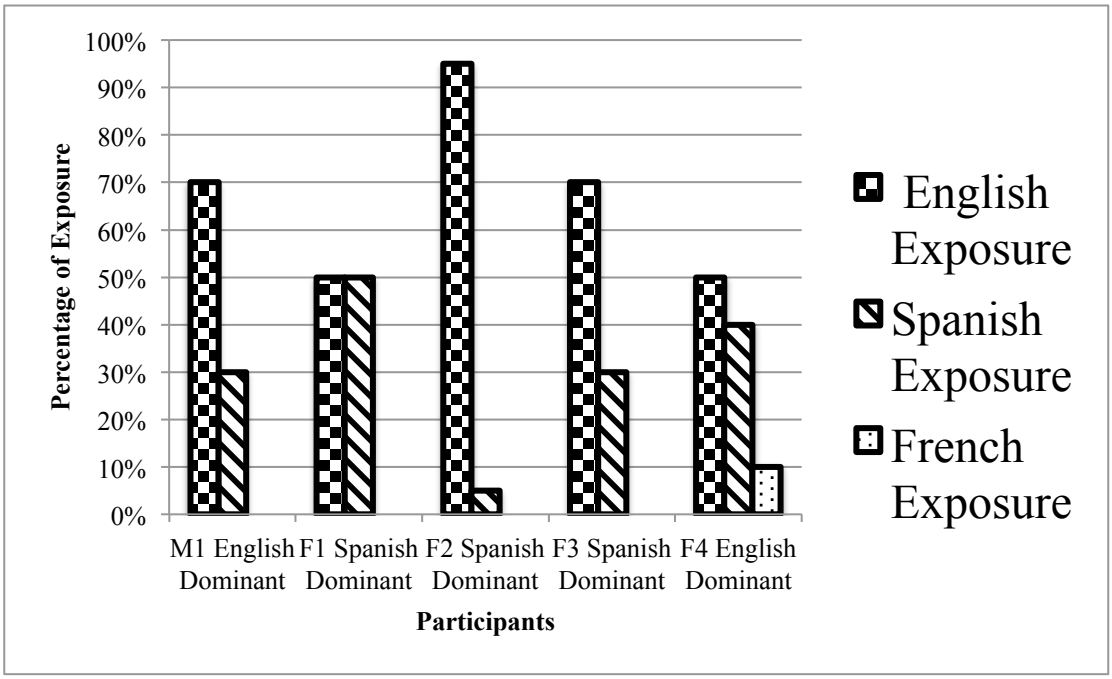
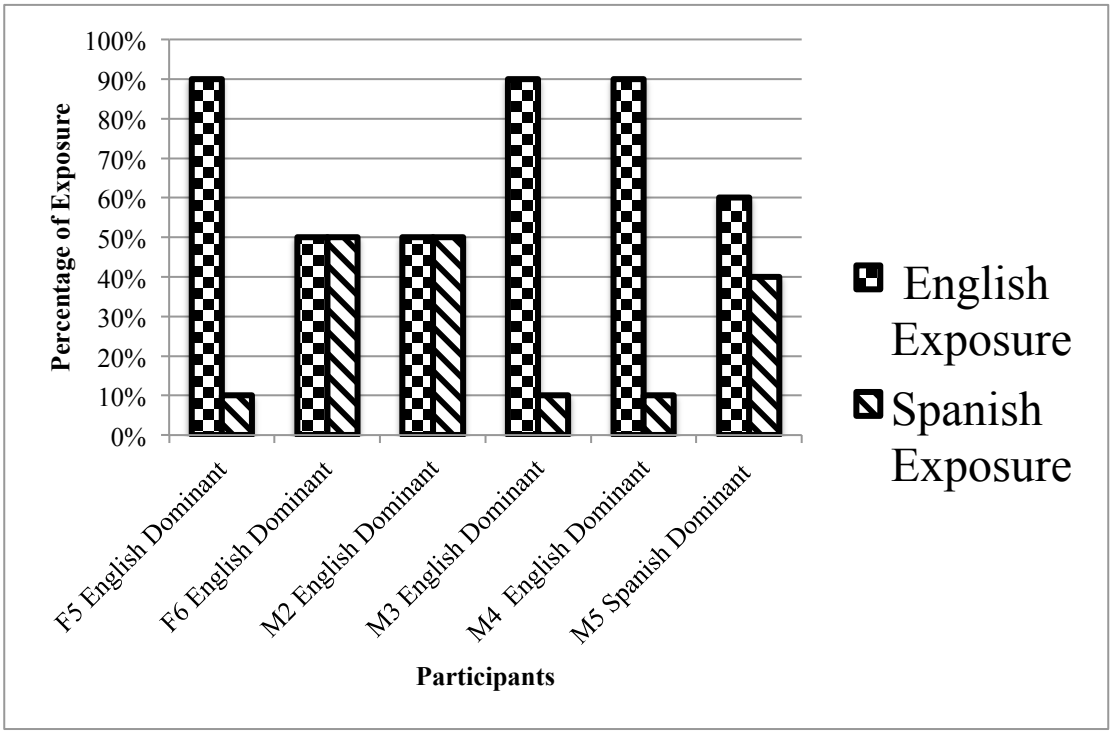


Figure G2. Simultaneous Speakers and Percentage of Daily Language Exposure.



APPENDIX H

Figure H1. Sequential Speakers' Language Preference When Speaking and Reading.

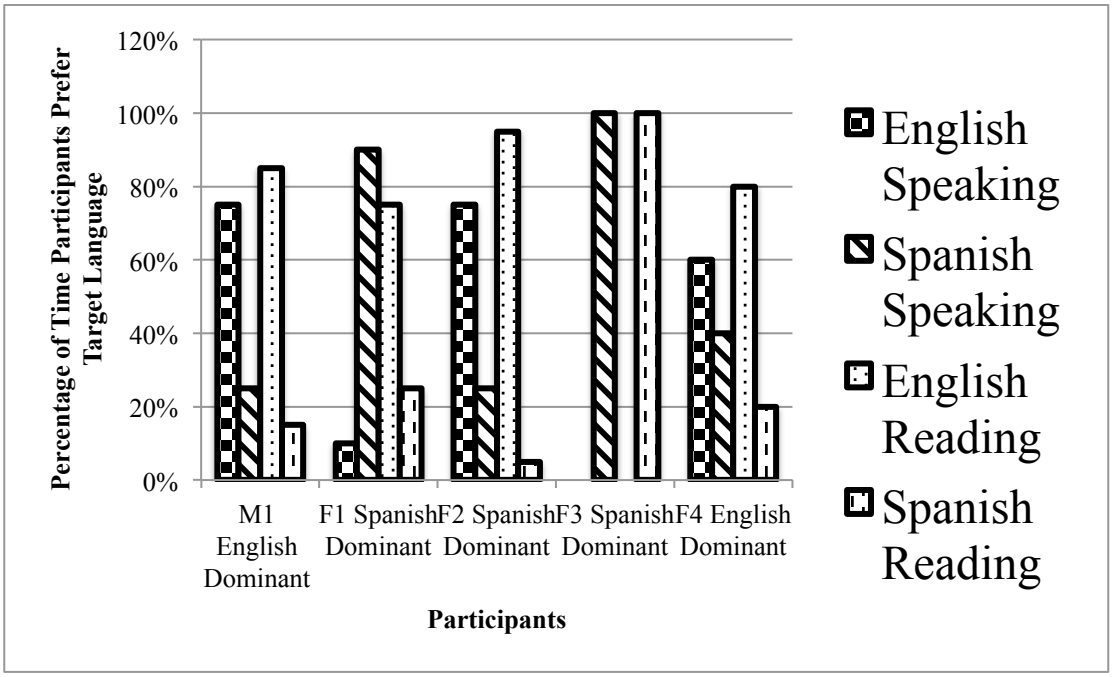


Figure H2. Simultaneous Speakers' Language Preference When Speaking and Reading.