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Speech Recognition in Noise Performance in Younger and Older Spanish-English bilinguals' L1 and L2

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SPEECH RECOGNITION IN NOISE PERFORMANCE IN YOUNGER AND OLDER

SPANISH-ENGLISH BILINGUALS' L1 AND L2

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Master's Program in Speech-Language Pathology

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Dedication

This is dedicated to my mother Sandra Barraza and father Alfredo Barraza. I am eternally grateful for the person you have shaped through your patience, kindness, strength, and love. I would never have made it this far in my education if it was not for you all. You two have shown me what it takes to be outstanding parents and I hope one day I can be as great as a parent as you two. To my Sister Erica, and brother in law Manny. I am eternally grateful for the example you have set for me on how to be a genuine individual inside and out. Your hard work and dedication has only inspired me and always pushed me to be a better person. My future niece or nephew will have the best home filled with love and virtue. The love for my family is endless, they truly have been my support system and have only shaped me into my best self.

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by

ELISA GUADALUPE, BARRAZA

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Abstract

Background: Previous research has shown that Spanish/English speaking bilinguals have difficulty understanding English speech in background noise compared to their monolingual counterparts. However, the effects of age on bilinguals' speech understanding performance remains unclear.

Purpose: The purpose of this study was to determine whether older Spanish/English bilingual speakers are at an increased disadvantage understanding speech in the presence of background noise compared to older English monolinguals.

Methods: 15 younger Spanish-English (S/E) bilinguals, 15 older S/E bilinguals, 15 younger English monolinguals and 15 older English monolinguals participated in the study. Speech recognition performance was measured using the Spanish and English versions of the Hearing in Noise Test (HINT) presented in quiet and in background noise.

Results: There were no significant ($p > .05$) differences between groups on the HINT in quiet. The English monolinguals performed significantly better ($p = .001$) on the English HINT in noise than the two bilingual groups. Both younger and older bilingual groups performed significantly better ($p < .001$) on the Spanish than English HINT in noise. Interestingly, younger bilinguals performed significantly ($p < .001$) better in their L1 on the English HINT in noise compared to all other participant groups.

Conclusions: Older S/E bilinguals are at an increased disadvantage understanding English in background noise compared to all other participant groups.

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CHAPTER 1: LITERATURE REVIEW

1.1 Introduction

The prevalence of different ethnicities has been on the rise in the United States such that, in 2014 the Hispanic population was 17.3 % of the total U.S population compared to 1980 where Hispanics made up only 6.5% of the total U.S. population (Stepler & Brown, 2016). Spanish speakers are projected to increase in number through 2020 to anywhere between 39 million to 43 million people (Ortman & Shin, 2011).

Speech audiometry testing, administered by audiologists, is necessary to accurately diagnose and provide treatment to individuals with hearing loss. Specifically, speech recognition testing determines an individual's ability to understand and recognize speech in different listening conditions (Weiss & Dempsey, 2008). The ability to understand speech is considered to be the most important aspect of human auditory function, as it fundamental in order for an individual to participate in our complex auditory world (Shi, 2014). Currently there are no standard clinical audiological practice protocols to evaluate and treat bilingual patients. Older bilinguals are therefore evaluated and treated the same as older monolingual patients. However, this may not be the best practice as there is strong evidence that younger bilingual speakers with normal hearing have more difficulty understanding English speech in background noise than monolinguals (Crandell, & Smaldino, 1996; Mayo, Florentine, & Buus, 1997; Rogers, Lister, Febo, Besing, & Abrams, 2006; Shi, & Sánchez, 2010). Few studies, however, have examined speech recognition in the first and second languages of older bilinguals. Therefore, evidence based practices meeting the hearing healthcare needs of older Spanish-English (S/E) bilingual adults is limited. Results from the current study will fill this gap by determining whether older S/E bilingual are at a greater

disadvantage understanding speech in noisy listening situations compared to their monolingual peers of the same age and hearing status.

1.2 Bilingualism

There is the misconception that bilinguals function as two monolinguals, and that one language does not have influence over the other (Grosjean, 1998). This is despite the fact that the evidence shows that bilinguals combine linguistic cues from both languages in ways that are not like their monolingual peers (Von Hapsburg & Peña, 2002). In the last few decades, many models and theories have been proposed on bilingualism.

Kroll and Stewart (1994) proposed a theory, the revised hierarchical model, that describes how second language learners form an asymmetrical connection of words to concept that relies on an individual's L1. According to this asymmetric connection, second language learners have a strong link between the first language lexicon and conceptual memory. This dependence on the individual's L1 aids to access meaning of L2 words and is assumed to create strong lexical level connections from the L2 to the L1. When an individual becomes more proficient in their L2, direct conceptual links are created. However, the lexical link from the L2 to the L1 is stronger than the lexical link from L1 to L2 since L2 words were initially associated to L1 (Kroll & Stewart, 1994; Dufour & Kroll, 1995; Kroll, Michael, Tokowicz, & Dufour, 2002). Furthermore, Kroll and Stewart (1994) found that translation from L1 to L2 required concept mediation and took longer to perform than from L2 to L1. This latency is due to the activation of conceptual memory in L1 then direct retrieval is activated in the L2 lexical representations before a single L2 word is chosen. Thus, translation from L1 to L2 requires conceptual access as opposed to translation from L2 to L1 which can be accomplished directly on the lexical link between words in the two languages

(Dufour & Kroll, 1995). This model shows that bilinguals go through a system every time they have to access information between the two languages.

Another theory of bilingualism focuses on cognitive underpinnings that occur and influence a bilingual's cognitive ability. Specifically, inhibitory control has been a suggested model that proposes bilinguals suppress the non-relevant language by the executive function used to control attention and inhibition (Green, 1998). It is thought that bilinguals practice in inhibition may provide them with an advantage over their monolingual peers in attention and inhibition. For example, Bialystok, Craik, Klein, and Viswanathan (2004) investigated processing differences between older monolingual and bilingual individuals using the Simon task, a task that measures executive control processes of inhibitory control. The results showed that bilingualism reduced the age-related increase in the Simon effect, suggesting that bilinguals lifelong experience of managing two languages may attenuate age related declines in the efficiency of inhibitory processing (Bialystok, Craik, Klein & Viswanathan, 2004).

1.3 Linguistic Proficiency

One challenge that has been noted in the bilingual literature is obtaining accurate and comprehensive language profiles for study participants. According to Von Hapsburg and Peña (2002), obtaining a thorough language background is necessary because language variables such as; age of second language acquisition, has been found to affect auditory perception of the second language. Age of acquisition is considered to be one of the strongest predictors in speech perception (Mayo et al., 1997; Von Hapsburg et al., 2004; Weiss & Dempsey, 2008). Weiss and Dempsey (2008) found that bilinguals' speech recognition performance varied depending on the age at which they acquired their L1 and L2. They found that early bilingual participants (i.e. individuals who acquired English before the age of seven) had better speech recognition

performance for English sentences than late bilingual participants (i.e. individuals who acquired English after the age of eleven). However, late bilinguals were significantly better at understanding Spanish sentences than early bilingual listeners (Shi & Sánchez, 2010; Weiss & Demsey, 2008). Thus, the findings indicate that age of acquisition has an impact on bilingual speech perception in both their first and second languages.

Linguistic proficiency has also been shown to be an important variable related to bilinguals' speech recognition performance (Von Hapsburg & Peña, 2002). Linguistic proficiency can be measured using subjective and objective measures. One objective measure that we used in the current study was the Woodcock-Muñoz Language Survey III (WMLS III; Woodcock & Muñoz-Sandoval, 1993; Woodcock, Alvarado & Ruef, 2017). The WMLS subtests, which are administered in both English and Spanish, are designed to objectively measure an individual's performance in reading, writing, and oral linguistic proficiency otherwise known as their cognitive-academic language proficiency (CALP). The WMLS test has normative data from more than 6,000 participants from various U.S. communities for the English form and data from Argentina, Costa Rica, Mexico, Peru, Puerto Rico, Spain and the U.S. to create the Spanish form (Delgado, Guerrero, Goggin, & Ellis, 1999; Woodcock & Muñoz-Sandoval, 1993). Delgado et al. (1999), evaluated participants' Spanish and English language skills using a self-rating scale and the WMLS. Each participant self-rated their language skills before taking the WMLS and self-rated their language skills after knowing their results from the WMLS. Results showed that the participants who were competent in two languages according to the WMLS were able to rate their Spanish (L1) skills more accurately than their English (L2). Their L1 scores correlated with all the self-reported measures for L1 proficiency but for L2 their scores correlated only with reading and

writing. This study shows the importance of obtaining both objective and subjective measures because only using one measure may not give an accurate representation.

1.4 Speech Recognition Task

Speech recognition, is the ability to recognize and understand a speech signal in quiet and noisy environments. Speech recognition in quiet requires less cognitive effort for an individual to understand a speech signal than listening in background noise. When an individual is in an environment with background noise, the less intense portions of the speech signal can be masked and become obscured to the individual (Rogers, Lister, Febo, Besing, & Abrams, 2006). The cognitive and neural underpinnings of speech recognition are processed through a top down effect. Top-down refers to cognition and behavior not driven purely by the stimulus but derived through expectations, and generalized knowledge based on previous experiences (Engel, Fries, & Singer, 2001). Davis and Johnsrude (2007) suggest that when top down theory is applied to the auditory domain, both frontal and periauditory regions show an elevated response to speech stimuli when listeners exert more effort to perceive distorted speech, (e.g. perceiving speech in a noisy environment) than speech in quiet.

Speech recognition can be measured using a variety of speech recognition tasks, such as the Northwestern University Auditory Test No. 6 word recognition test (NU-6; Tillman & Carhart, 1966), the Speech Intelligibility Gain—Reverberant Test (SIG-R; Koehnke & Besing, 1996), and the Speech Perception in Noise Test (SPIN; Kalikow, Stevens, & Elliott, 1977). In the current study, we used the Hearing in Noise Test (HINT; Nilsson, Soli, & Sullivan, 1994). The HINT consists of a series of sentences that are six to eight syllables in length, the sentences are cast into 25 phonemically matched and balanced lists, with 20 sentences per list that are rated at a first-grade reading level (Nilsson, Soli, & Sullivan, 1994). The HINT is available in multiple languages

and the tests are normed for difficulty across languages which allows for cross language comparisons. Individuals are instructed to repeat a series of sentences in both quiet and noisy listening conditions. The HINT uses an adaptive speech reception threshold (SRT) method. An SRT offers an alternative to measured percent intelligibility, and it is defined as the presentation level necessary for a listener to recognize speech materials correctly at a quantified performance level (e.g. 50% correct performance) (Nilsson, Soli, & Sullivan, 1994). Thus, during testing, the presentation level of the background noise (i.e. speech shaped noise) is increased or decreased in decibels depending upon the listener's response. In other words, if an individual repeats the stimulus item incorrectly, the background noise will be decreased. Conversely, the background noise is increased when the stimulus is repeated correctly while the speech stimuli remains at a fixed decibel level. Results are reported in dB using a signal to noise ratio (SNR) (Weiss & Dempsey, 2008). The SNR is the ratio of the level of the speech in relation to the level of the noise, in dB, necessary for an individual to achieve 50% correct performance on the test. For example, if the signal is presented at 65dB and the noise is presented at 65dB the SNR would be at 0 dB SNR. If the noise is presented at 65dB and the signal is presented at 75dB the SNR would be 10dB. When the noise is presented at 65dB and the signal is presented at 55dB the SNR would be -10dB. The greater the negative number of the SNR, the better the participants' HINT performance.

1.5 Bilingualism and Speech Recognition

Many studies have examined the effects of bilingualism on speech recognition performance. Overall, the literature has shown that bilingual speakers whose L1 is Spanish and L2 is English have a poorer performance on English speech recognition tasks in background noise compared to their English monolingual counterparts (Mayo et al., 1997; Von Hapsburg et al.,

2004). Interestingly, in quiet, bilinguals have been shown to have similar performance to monolinguals (Mayo et al., 1997; Von Hapsburg et al., 2004; Weiss & Dempsey, 2008).

For example, Mayo et al. (1997) evaluated S/E bilinguals and monolinguals on the SPIN test. Bilinguals in this study were classified into two groups based on their language acquisition; early bilinguals (learned English before the age of six) and late bilinguals (learned English after the age of 14). Results showed that English monolinguals and early S/E bilinguals performed similarly and both groups performed better than late S/E bilinguals. Thus, Mayo et al. (1997) concluded that learning a second language at an early age is important for speech recognition in background noise.

Von Hapsburg et al. (2004) examined speech recognition performance in S/E bilinguals and English monolinguals that all learned English after the age of 10 years on the HINT. They found that the two groups performed similarly on the HINT in quiet. However, in background noise the English monolingual group performed better than the S/E bilingual group. Specifically, the bilinguals needed an SNR that was 3.9 dB higher than the monolingual peers to achieve a 50% correct recognition score on the HINT (Von Hapsburg et al., 2004).

Rogers et al. (2006) evaluated 15 English monolinguals and 15 S/E bilinguals on the SIG-R speech recognition test (Koehnke & Besing, 1996). Each participant completed the SIG-R test at SNR presentation levels of 0, -2, and -6 dB SNR. Results showed that the monolingual group outperformed their S/E bilingual peers across all presentations. Although both groups showed a decrease in performance at the more difficult SNRs, the monolinguals obtained better scores than their S/E bilingual peers.

Weiss and Dempsey (2008), investigated bilingual listeners' speech recognition performance on the Spanish HINT (S-HINT; Soli, Vermiglio, Wen, & Filesari, 2002) and the

English HINT (E-HINT; Nilsson, Soli, & Sullivan, 1994). Participants in the study were 18-20 year old Spanish/English bilinguals that learned English before the age of seven or after the age of 11. The results showed that all bilingual participants, despite the age they learned English, scored better on the S-HINT than E-HINT. However, the bilingual individuals who acquired English before the age of seven had a better performance on the English sentences than the late bilingual listeners (Weiss & Dempsey, 2008).

1.6 Age and speech recognition

Overall, these studies show that younger bilinguals perform poorer on speech recognition in noise tasks than their monolingual counterparts (Crandell & Smaldino, 1996; Mayo, Florentine, & Buus, 1997; Rogers, Lister, Febo, Besing, & Abrams 2006; Shi 2010). However, there are no studies, to date, that have examined speech recognition performance in the first and second language of older S/E adults. Previous studies have shown that older monolingual listeners, with and without hearing impairment, have significant difficulty understanding speech, especially in noisy listening conditions, compared to their younger monolingual counterparts (Plomp,1978; Desjardins & Doherty, 2013). Older individuals are thought to be at a greater disadvantage understanding speech in the presence of background noise due to age-related changes in peripheral hearing acuity and cognitive skills (Desjardins & Doherty, 2013). Older S/E bilinguals may be at the biggest disadvantage understanding speech in background noise compared to older English monolinguals due to the combined effects of managing two languages systems and age-related auditory and cognitive changes.

1.7 Purpose

The purpose of this study was to examine the speech recognition performance of older Spanish/ English bilingual individuals. The aims of this study were to determine; (1) how speech

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recognition in noise performance changes with age in bilinguals, (2) if speech recognition in noise performance was greater for monolinguals than bilinguals and (3) whether speech recognition performance differs between bilinguals' L1 versus their L2. We hypothesized that Spanish/English bilingual speakers may be at a greater disadvantage understanding speech in the presence of background noise compared to English monolinguals of the same age.

CHAPTER 2: METHODS AND PROCEDURES

2.1 IRB Approval

The university's institutional review board for human subjects approved this study.

2.2 Participants

Participants were recruited from the University of Texas at El Paso and from the greater El Paso, Texas area using poster canvasing, referrals from students, and social media to establish a sample of convenience. Participants were given a $25 gift card as compensation for completing the study. The funding for the incentive was from Dodson Research Grant from the Graduate School at the University of Texas at El Paso. Each participant gave a written informed consent prior to participating in the study.

For the younger groups; fifteen English monolinguals aged 21-27 (SD= 1.85) and sixteen S/E bilinguals aged 20-28 (SD= 2.68), participated in the study. For the older groups; fifteen English monolinguals aged 49-67 (SD=6.36) and fifteen S/E bilinguals aged 54-65 (SD= 3.56) participated in the study. Participants completed a general demographic information sheet to obtain their country of origin, education, occupation status, and general health, (See Table 2.1 for participant characteristics). The Digit Span test (WMS-III, Wechsler, 1997) in both forward and backward conditions was administered to each participant. The digit span measures an individual's ability to hold a visual sequence of events in working memory (Wilde & Strauss, 2002). The results showed that there were no significant differences [F (3,60) .825, p=.49] in performance on the digit span test between the four participant groups. All older participants passed the Short Portable Mental Health Status Questionnaire (SPMSQ; Pfeiffer, 1975), a ten-question screening that assesses cognitive impairment in elderly populations; 8 or more errors shows a severe cognitive impairment. All participants in this study had hearing thresholds <25 dBHL from 250-4000 Hz bilaterally (ANSI, 2007). The Hollingshead Two Factor Index of Socioeconomic Status was obtained to measure the participants social status based on two domains; occupation and education (Hollingshead, 1957). All participants scores are shown in Table 2.1. All the

participants' scores were the same except for the younger bilinguals group because an outlier in the group increased the groups score.

Table 2.1 Mean, standard deviation, and participant demographics by group.

	YM	YB	OM	OB
Age	23.1 (1.9)	24.4 (2.7)	57.7 (6.4)	58.5 (3.6)
Years of Education	16.1 (1.4)	16.4 (1.7)	15.6 (2.8)	15.7 (2.5)
Years of Education in English	16.1 (1.4)	14.8 (2.9)	15.6 (2.8)	15.6 (2.8)
Digit Span Forward Recall	10.1 (2.0)	10.1 (1.8)	11.3 (2.2)	10.2 (1.6)
Digit span Backward Recall	6.8 (1.1)	6.9 (1.7)	6.7 (2.7)	5.9 (1.8)
Digit Span Total	16.9 (2.4)	17.0 (2.9)	17.9 (4.2)	16.1 (2.8)
Non-Hispanic (%)	40%	N/A	14 (93%)	N/A
Hispanic (%)	60%	100%	7%	100%
Hollingshead Score	24 (11)	41 (22)	29 (16)	27 (16)

Note. Mean (Standard Deviation), Younger English Monolinguals (YM), Younger S/E Bilinguals (YB), Older English Monolinguals (OM), and Older S/E Bilinguals (OB). Hollingshead Score was obtained to measure social status of the participants (Hollingshead, 1957; Hollingshead, 1975).

To obtain a linguistic profile, each participant completed the Language Experience and Proficiency Questionnaire (LEAP-Q; Marian, Blumenfeld & Kaushanskaya, 2007). The LEAP-Q is the most common self-rating questionnaire used to measure linguistic proficiency in multilinguals. The LEAP-Q considers the experience and usage of language in different settings and behaviors (i.e. reading, writing, speaking and understanding). Participants self-rate each variable using a 10 point Likert scale in reading, writing, speaking, and understanding. The LEAP-Q also obtains a percentage of use on a daily basis as well as their age of acquisition across languages. Participant responses on the LEAP-Q are shown in Table 2.2. The Woodcock-Muñoz Language Survey III (WMLS III; Woodcock, Alvarado, & Ruef, 2017) was used as the objective measure and each participant completed the oral comprehension subtest in both Spanish and English. The oral comprehension subtest measures an individual's ability to listen to and comprehend an audio-recorded passage and then provide the missing word to complete the passage (Woodcock, Alvarado, Ruef, & Schrank, 2017). There were no significant differences [F (3,60)

.2, p=.9] in performance on the English WMLS III between the four participant groups. See Table

2.2 for participants' age equivalency scores on the WMLS III.

Table 2.2 Mean, standard deviation, and percentages of participants' linguistic profile

	YM	YB	OM	OB
LEAP-Q				
Age Spanish Acquisition	N/A	.8(1.0)	N/A	1.0(1.1)
Age English Acquisition	.3(.6)	4.8(2.8)	.9(1.1)	3.4(2.7)
L1 %	100.0%	45.3%	100.0%	55.0%
L2 %	N/A	54.7%	N/A	45.0%
L1 Understanding	9.3(.9)	8.7(1.4)	9.4(.9)	8.3(1.4)
L1 Speaking	9.6(.7)	8.1(1.6)	9.5(.8)	7.9(1.4)
L1 Reading	9.3(.7)	7.6(2.0)	9.4(.9)	7.7(2.2)
L2 Understanding	N/A	8.8(1.2)	N/A	7.9(2.0)
L2 Speaking	N/A	8.6(1.5)	N/A	7.5(2.2)
L2 Reading	N/A	8.8(1.0)	N/A	7.1(2.6)
WMLS III English				
Raw scores	30.1(2.5)	30.3(3.0)	31.5(3.4)	30.5(3.0)
AE	18.7(4.1)	18.2(4.2)	19.4(4.1)	18.9(4.4)
GE	11.4(2.6)	11.0(2.7)	11.6(2.5)	11.2(2.8)
WMLS III Spanish				
Raw scores	1.5(3.8)	27.7(4.3)	1.5(2.8)	26.9(2.2)
AE	3.1(.5)	13.4(5.2)	3.1(.4)	11.4(3.8)
GE	.0(.0)	7.3(4.0)	.0(.0)	6.3(3.4)

Note. Mean (Standard Deviation), Younger English Monolinguals (YM), Younger S/E Bilinguals (YB), Older English Monolinguals (OM), and Older S/E Bilinguals (OB). Age Equivalent (AE) Grade Equivalent (GE).

2.3 Test measures

Speech Recognition task

Speech recognition was measured in quiet and in background noise using the English

(Nilsson, Soli, & Sullivan, 1994) and Spanish (Soli, Vermiglio, Wen, & Filesari, 2002) versions

of the HINT. The HINT uses 25 lists, each list with 20 sentences rated at a first-grade reading level

(e.g. (A/the) boy fell from (a/the) window). The participant is required to listen to each sentence

and repeat it back to the examiner. The examiner scores the five to six key words in each sentence

as either incorrect or correct. The test is administered in quiet and in a speech shaped background noise. In quiet, the test is scored as the percent of correctly repeated words. In background noise, the task is scored as the signal-to-noise ratio (SNR) required for the participant to achieve 50% correct performance. HINT sentences are equated for difficulty within and across languages (Soli et al., 2002).

2.4 Procedures

Testing was performed in one 1.5-hour test session. First, all participants completed the demographic information sheet and digit span test (WMLS-III, Wechsler, 1997). Hearing thresholds were then obtained at the octave frequencies from 250 Hz to 8000 Hz (ASHA, 2003) in the right and left ears. Participants completed the oral comprehension subtest of the WMLS III in Spanish and in English (Woodcock, Alvarado, & Ruef, 2017) and the LEAP–Q questionnaire (Marian, Blumenfeld, & Kaushanskaya, 2007). Older participants completed the Short Portable Mental Health Questionnaire (Pfeiffer, 1975), that assesses cognitive impairment. Last, participants were administered the E-HINT in quiet and in noise. All the HINT sentences were presented at 65 dBSPL via a GSI speaker located 1m, at ear level, at 0-degree azimuth in a double walled sound attenuating booth. The English and Spanish versions of the HINT were administered to all bilingual participants in a counter balanced order.

2.5 Data Analysis

Statistical analysis of the data was performed using IBM SPSS v22 (SPSS Inc., Chicago Ill.) software. The data was analyzed using a Repeated Measures Analysis of Variance (RMANOVA). A 0.05 alpha level was used for all analyses in the present study. All post hoc multiple comparisons were performed using a Bonferroni adjusted critical alpha level.

CHAPTER 3: RESULTS

3.1 Performance on HINT in quiet.

There were no significant differences in performance between the four participant groups on the E-HINT in quiet [F $(3,60)$ =1.35; p =.3]. In addition, there was no significant difference] between the bilingual participants performance on the E-HINT and S-HINT in quiet [F $(1,29)$ =0.0; p =.98.] Thus, all groups performed similarly in quiet. See Table 3.1 for the participants' performance in quiet.

Table 3.1 Participants' performance in quiet. Results are obtained in a percent correct score (%)

Group	E-HINT (%)	S-HINT (%)
YM	100 (0)	N/A
YB	99.6 (1)	99.4 (.8)
OM	99.8 (.5)	N/A
OB	99.5 (.7)	99.6 (.8)

Note. Mean (Standard Deviation)

3.2 Performance on the English HINT

Figure 3.1 shows participants' mean performance on the E-HINT in background noise. A 2x2 (age, linguistic proficiency) RMANOVA showed a significant main effect of linguistic proficiency [F $(1,57)$ =13.25; p =.003]. In addition, there was a significant (p <.05) interaction between linguistic proficiency x age. Post hoc testing showed that monolinguals performed significantly (p =.001) better on the E-HINT than bilinguals. Older bilinguals performed poorest on the E-HINT compared to all other participant groups. There were no other significant effects.
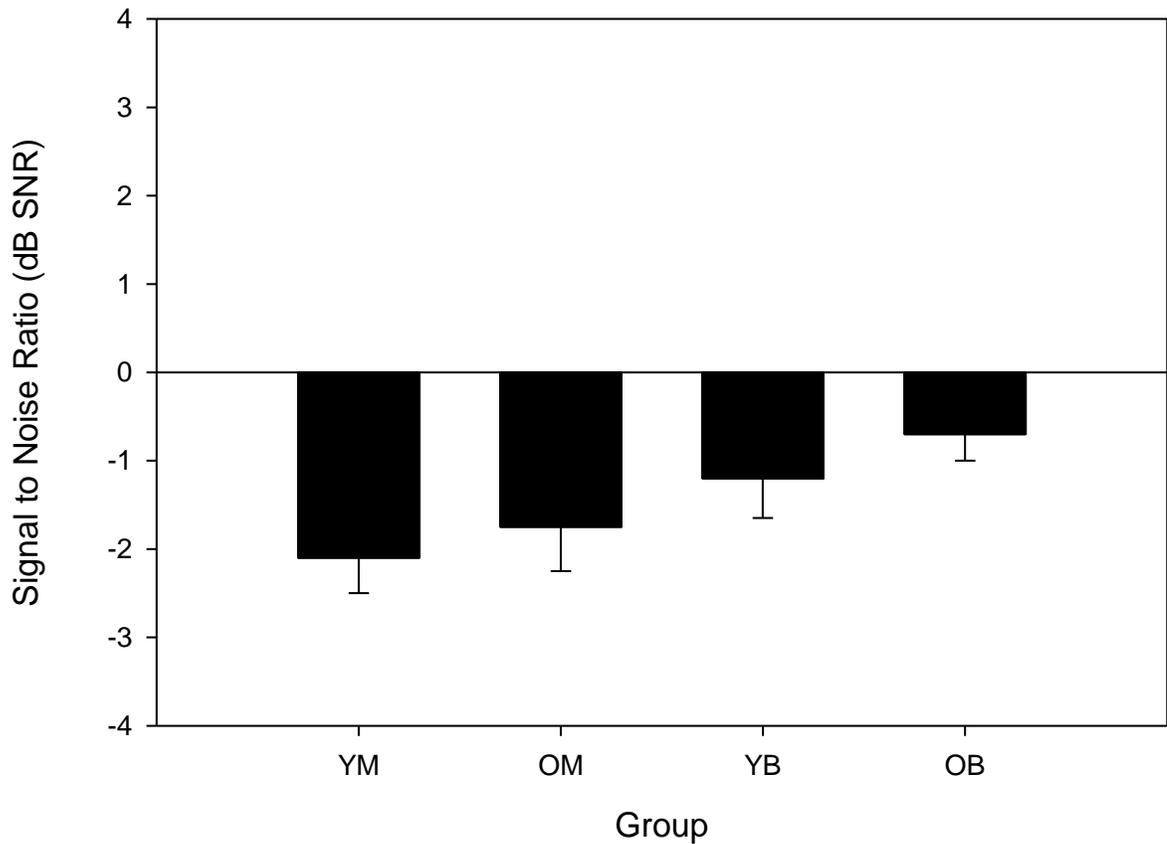
Figure 3.1 Mean performance on the E-HINT for the four participant groups.

3.3 Bilinguals performance on English HINT and Spanish HINT.

Figure 3.2 shows bilinguals' mean participants performance on the E-HINT and the S-HINT in noise. To compare participants' performance within and across the two groups a 2x2 (age, linguistic proficiency) RMANOVA showed a main effect of test language [F $(1,58)$ =34.85, $p <$ .001] and a significant main effect of age [F $(1,58)$ =5.6, $p =$.021]. Post hoc testing revealed that bilingual participants performed significantly ($p <$.001) better on the S-HINT than the E-HINT and younger bilinguals performed better, overall, than older bilinguals. There were no other significant main effects or interactions.
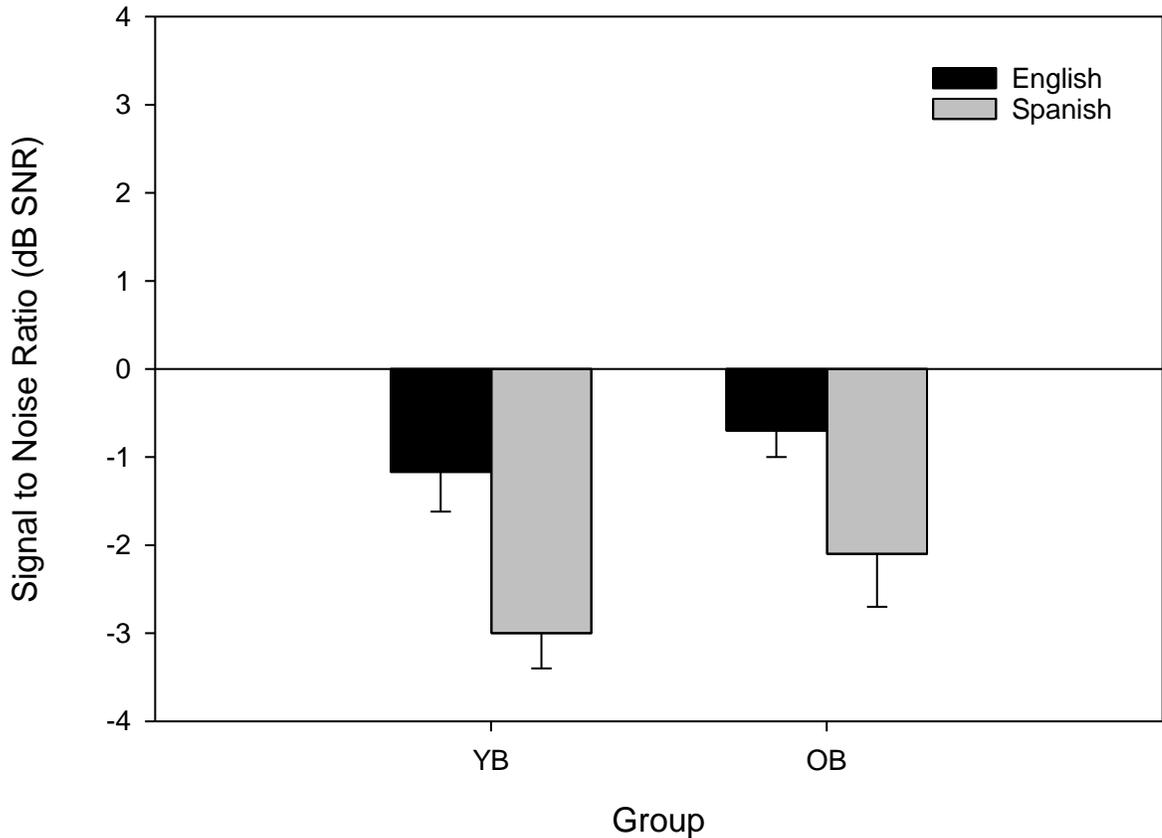
Figure 3.2 Mean performance on the E-HINT and S-HINT for the two bilingual groups.

3.4 Speech Recognition Performance in Participants L1

Figure 3.3 shows the participants' performance on the HINT in their L1(E-HINT or S-HINT). A 2x2 (age, linguistic proficiency) ANOVA showed a significant main effect of age [$F_{(1,57)} = 12.16$, $p = .001$] and a significant interaction between age x linguistic proficiency [$F_{(1,57)} = 4.65$, $p = .031$]. Post hoc testing showed that the younger bilingual participants performed significantly better in their L1 on the HINT compared to all other participant groups ($p < .001$). There were no other significant effects.
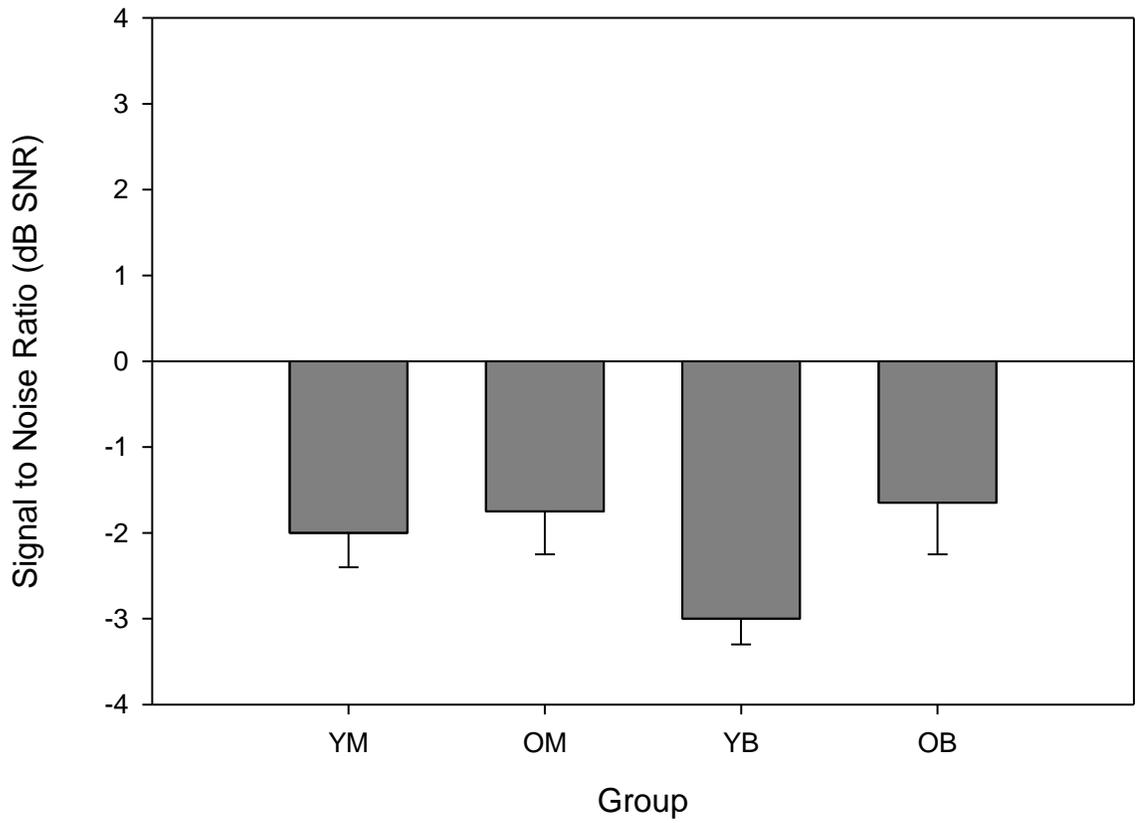
Figure 3.3 HINT L1 mean performance for the four participant groups.

CHAPTER 4: DISCUSSION

The purpose of the present study was to examine the effect of age on the speech recognition performance of S/E bilingual individuals relative to their monolingual counter parts. There were no significant differences between participant groups on the HINT in quiet across their known languages. This result was not surprising due to the fact that previous studies have shown that monolinguals and bilinguals perform similarly on speech recognition tests in quiet (Mayo et al., 1997; Von Hapsburg et al., 2004).

English monolinguals performed significantly better on the E-HINT in noise than S/E bilinguals. This finding is consistent with previous studies which showed that younger monolinguals performed better than younger bilinguals on speech recognition tests in English (Mayo et al., 1997; Von Hapsburg et al., 2004; Rogers et al. 2006; Weiss & Dempsey, 2008). Surprisingly, the older English monolingual participants performed better on the E-HINT than the younger bilingual participants in this study. Thus, it appears that linguistic proficiency may be a stronger predictor of speech recognition performance on tests in English than age.

A main finding of the current study was that older S/E bilinguals performed significantly poorer on the E-HINT than all of the other participant groups in this study. This result was consistent with our hypothesis that older bilinguals are at a greater disadvantage understanding speech in background noise due to age-related auditory and cognitive changes due to age-related auditory and cognitive changes and the need of managing two language systems (Rogers et al., 2006). This disadvantage in understanding speech in background noise goes against the inhibitory control theory in which bilinguals have an advantage in attention and inhibition (Green, 1998).

The S/E bilinguals in this study performed better on the S-HINT than in English. This was despite the fact that the bilingual groups reported having equal proficiency in both their languages

and used both languages equally on a daily basis. This result is largely consistent with findings from Weiss and Dempsey (2008) who also found that the early bilingual participants scored significantly better on the S-HINT than the E-HINT. The inhibitory control theory suggested by Green (1998) could possible explain an advantage in inhibition and attention for both bilingual groups but only on the HINT in Spanish. This result could also suggest a strong connection and reliance on their L1 which was suggested by Kroll and Stewart's revised hierarchical model (1994).

Sebastián-Gallés, Echeverría, and Bosch (2005) have suggested that the amount of initial exposure to one language may be responsible for speech processing differences that persist throughout life, and that early exposure has a profound influence on the way L1 and L2 sounds are perceived. In the present study, our bilingual participants learned Spanish before English, which could explain their better performance on the S-HINT despite the fact that they learned both of their L1 and L2 before the age of four.

Interestingly, the young bilingual group in this study performed significantly better in their L1 on the HINT compared to all other participant groups. This finding suggests that bilinguals may have an advantage in auditory processing of speech in background noise. Krizman, Marian, Shook, Skoe, and Kraus (2012) investigated S/E bilingual adolescents (14 years of age) and their performance on executive functioning tasks compared to their monolingual counterparts. Within the study they had the participants complete a sustained selective attention task and a speech recognition task in noise at the syllable level. They found that bilinguals showed enhanced encoding to the target sound presented in a noisy background compared to their monolingual counterparts. These findings suggest that bilinguals have an advantage in cognitive control since

they have an experience in continuously manipulating sounds across two languages which shows that bilinguals are highly efficient in automatically processing sound (Krizman et al., 2012).

CHAPTER 5: CONCLUSIONS

Older S/E bilinguals are at a greater disadvantage understanding English in background noise compared to their monolingual peers. This suggests that current clinical practice procedures in the evaluation and treatment of speech perception may need to be modified to better serve this population. Additionally, S/E bilinguals performed better on a speech recognition in noise task in Spanish compared to English, despite learning both languages by four years of age. This finding lends support to the theory that bilinguals may have an advantage in auditory perception of the language they were exposed to first.

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Vita

Elisa Guadalupe Barraza was born in El Paso, Texas. The second born of Sandra Barraza and Alfredo Barraza. She graduated from El Paso High School and began courses at the University of Texas at El Paso. While pursuing a bachelor's degree she worked as a babysitter, dog sitter, swim coach, house sitter, sales clerk at Bella Cora Bakery, and a research assistant for the Concussion Management Clinic. She graduated Cum Laude with her Bachelors of Multidisciplinary Studies at the University of Texas at El Paso in Spring 2016. That Fall, she entered the Graduate School at the University of Texas at El Paso Master of Science in Speech Language Pathology. Elisa began working as a research assistant under the supervision of Jamie L. Desjardins, PhD., CCC-A. She received the Dodson Research Grant to fund her research, the UTEP Graduate School Travel Grant, and the College of Health Sciences Travel Grant. During this time, she presented her research at the November 2015 American Speech-Language Hearing Association Convention in Los Angeles, California and at the Texas Speech-Language Hearing Association Convention in Houston, Texas. Elisa was an active member of the National Student Speech Language Hearing Association at the University of Texas at El Paso.

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