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Reception Thresholds for Sentences in Bilingual (Spanish/English) and Monolingual (English) Listeners

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Abstract

Recent evidence on the perceptual performance of bilingual listeners suggests that a nonaudibility-based cost exists in processing a second language. That is, when compared to monolingual English speakers and early bilinguals, listeners who acquired English as a second language after puberty show reduced performance when listening to the second language in background noise, despite normal auditory thresholds. However, past studies have not controlled for the homogeneity of the bilingual participants used in auditory research; therefore, it is unknown whether the deficit observed in bilingual function is due to a lack of control for language-related variables. The ability of a homogeneous group of Spanish-English bilinguals and English monolingual listeners to perceive sentences in quiet and in noise at threshold levels was evaluated using the Hearing in Noise Test (HINT). Both groups performed similarly in quiet conditions. In the noise conditions, the bilingual group's performance was significantly poorer than the monolingual group's performance. However, both groups showed a binaural advantage of 7–8 dB when the signal and noise were separated by 90 degrees.

Key Words: Bilingual, speech perception, speech reception threshold

Abbreviations: HINT = Hearing in Noise Test; L1 = first language; L2 = second language; RTS = reception threshold for sentences; SSI = Synthetic Sentence Identification

Sumario

La evidencia reciente sobre el rendimiento perceptivo de sujetos bilingües sugiere que, en relación con el procesamiento de una segunda lengua, existe un costo no relacionado con la audibilidad. Esto es, cuando se les compara con hablantes monolingües del inglés y con bilingües de adquisición temprana, los sujetos que adquirieron el inglés como segunda lengua después de la pubertad, muestran una ejecución reducida cuando escuchan esta segunda lengua en medio de ruido de fondo incrementado, a pesar de tener umbrales auditivos normales. Sin embargo, los estudios anteriores no controlaron la homogeneidad de los participantes bilingües utilizados en investigación auditiva; por lo tanto, no se sabe si el déficit observado en la función bilingüe es debido a la falta de control de variables relacionadas con el lenguaje. Se evaluó la capacidad de un grupo homogéneo de sujetos bilingües en español-inglés y de sujetos monolingües en inglés para captar frases en silencio y en ruido, a niveles de umbral, con la prueba de Audición en Ruido (HINT). Ambos grupos rindieron en forma similar en condiciones de silencio. Pero en condiciones de ruido, el rendimiento del grupo bilingüe fue significativamente

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peor que el rendimiento del grupo monolingüe. Sin embargo, ambos grupos mostraron una ventaja binaural de 7-8 dB cuando la señal y el ruido fueron separados por 90 grados.

Palabras Clave: Bilingüe, percepción del lenguaje, umbral de recepción del lenguaje

Abreviaturas: HINT = Prueba de Audición en Ruido; L1 = primera lengua; L2 = segunda lengua; RTS = umbral de recepción para frases; SSI = Identificación de Frases Sintéticas

The difference between monolingual and bilingual linguistic performance has been highlighted in recent literature on bilingualism and suggests that bilingual and monolingual Spanish speakers are not functionally equivalent on a variety of language processing tasks (Grosjean, 1989; Hernandez et al, 1994). That is, bilinguals do not function as two separate monolinguals; rather, they show different patterns of language processing depending on linguistic factors such as age of second language (L2) acquisition. Current evidence indicates that bilinguals combine linguistic cues from both languages in ways that are not like that of their monolingual peers. Instead, the bilingual's two languages interact to form a unique linguistic system (Grosjean, 1989, 1997). A bilingual may use strategies from the first language (L1) to make linguistic decisions about the second language (L2) and therefore may not process information like a monolingual even when interacting with monolingual speakers of one language. For example, bilinguals do not perform the same as monolinguals on sentence tasks. Hernandez et al (1994) reported that Spanish monolingual adults used noun-verb agreement to determine the agent (who performs the action) of a sentence. On the other hand, English monolingual adults relied on word-order cues in order to determine the agent. Spanish-English bilinguals combined the two strategies, favoring noun-verb agreement in Spanish and word order cues in English but not to the same extent as their monolingual counterparts thus demonstrating an "in between" profile.

Similarly, evidence from speech perception studies suggests that bilingual participants process the second language (L2) differently from their monolingual counterparts in the presence of background noise (Bergman, 1980; Buus et al, 1986; Takata and Nabelek, 1990; Mayo et al, 1997). However, it is unclear whether the difference in performance between bilinguals and monolinguals reflects a true perceptual processing difference or instead only reflects the large variability among the bilingual listeners used in perception experiments. Thus, it may be that lack of homogeneity among bilingual participants may be contributing to the observed perceptual differences. Bilinguals in general are not a homogeneous group because the paths or experiences that lead to bilingualism vary from individual to individual (Valdes and Figueroa, 1994). Bilinguals can vary on a number of dimensions such as age of L2 acquisition, proficiency in each language, language use, and function for each language. Variability in each of these dimensions can lead to observed differences in language processing performance within a group of bilinguals (Grosjean, 1997, 1998).

Von Hapsburg and Peña (2002), in a review of the participant descriptions of Spanish speakers used in the speech audiometry literature, found that on average only two language descriptors out of approximately 21 descriptors evaluated are routinely used to describe bilingual participants. The descriptors used varied from study to study and included factors such as language status (bilingual or monolingual), age of L2 acquisition, order of acquisition, language of the parents, and geographic origin of acquisition. Few studies provided a thorough linguistic profile describing the range of linguistic experiences that can describe a bilingual speaker/listener. Thus, there was little uniformity across studies in how researchers describe the linguistic profile of bilingual participants in speech audiometry research. Grosjean (1989) suggests that inadequate descriptions of bilingual participants in the psycholinguistic literature contribute to the observed variability in bilingual group performance. He recommends that linguistic factors such as language history, status, proficiency, function, and mode should be considered when research on bilingual participants is performed. Furthermore, he suggests that homogeneous groups of bilinguals, that is, bilinguals with similar histories of acquisition, proficiency, and function should be used when studying bilinguals.

The studies documenting perceptual differences between bilinguals and monolinguals have varied in the criteria used to describe bilingual listeners. Bergman (1980), in a series of studies, noted that language background affects performance on speech perception tasks. While studying the effects of aging on perception, he tested adult bilinguals who learned Hebrew as a second language. Bergman (1980) found that the performance of both young and older bilinguals on suprathreshold word recognition tasks in quiet was comparable to the native Hebrew speakers' scores. However, in masked speech perception tests the non-native listener's performance in Hebrew was shown to decrease significantly in comparison to the native speakers of Hebrew. The effect of reduced perceptual capacities in the L2 in comparison to native performance was found in both groups of bilingual participants. However, Bergman provided limited information about the participants in that study, dividing the speakers among native and non-native speakers of Hebrew only. Information on important language descriptors such as history (languages acquired, age of acquisition, order of acquisition, length of exposure, place of acquisition), function, mode, and proficiency was not provided for the participants.

Similarly, a series of studies on the perceptual abilities of bilingual speaker/listeners by Florentine and her colleagues has shown that background noise significantly affects L2 perceptual performance (Buus et al, 1986; Mayo et al, 1997). In a recent study, Mayo et al studied the ability of three groups of Spanish-English bilinguals and one group of monolingual English speakers to perceive sentences in noise. The three bilingual groups differed in age of L2 acquisition. The bilingual-since-infancy (BSI) group (N = 3) consisted of simultaneous bilinguals (learned English and Spanish since infancy); the bilingual-since-toddler (BST) group (N = 9) consisted of sequential bilinguals (acquired English after Spanish) but before the age of six years. The bilingual postpuberty (BPP) group (N = 9) acquired L2 after the age of 14. Perceptual abilities were tested with the Speech Perception in Noise (SPIN: Kalikow et al, 1977), a test composed of sentences containing high (high predictability) and low (low predictability) contextual redundancy. Performance for the BPP group was significantly different from the monolingual group and from the two bilingual groups who acquired L2 before six years of age. Results showed that early bilinguals and monolinguals were able to achieve 50 percent accuracy at higher noise levels than the BPP group. The monolingual and early bilingual groups could tolerate an average of 4–6 dB SPL more background noise than the BPP group. Additionally, the slopes of the psychometric functions differed for the groups depending on age of L2 acquisition. That is, for the monolingual and early bilingual groups (BSI and BST), the slopes followed a predictable pattern—steeper slopes for high predictability sentences than for low predictability sentences. However, the slopes for the high and low predictability sentences did not differ significantly for the BPP group. Specifically, the slopes of the high and low predictability sentences were both shallow and overlapped. Mayo et al (1997) suggested that bilinguals who acquired L2 after puberty did not seem to benefit as much from contextual cues as monolinguals and both early bilingual groups. The standard deviations for the BPP group were larger than for the other groups. Mayo et al noted that the large standard deviations might be a reflection of the wide range of experience the group may have had with the L2 (3–26 years experience). Thus, it may be that lack of homogeneity in the BPP group, related to language function, mode, or proficiency may have influenced the results.

Takata and Nabelek (1990) compared the effects of speech-noise and reverberation on speech perception performance on a group of Japanese-English bilinguals and a group of monolingual English speakers/listeners.

The bilinguals were considered late bilinguals, because all learned English after the age of 12–13 years and had an average of 6.7 (range 1–13 years) years experience with L2 (English) in the United States. Speech perception performance was assessed using the Modified Rhyme Test (Kreul et al, 1968) in which one English word is presented via an earphone, and the participant must choose from a list of six possible word choices, differing in either initial or final consonant. Three test conditions were assessed—quiet, noise, and reverberation.

The introduction of noise and reverberation affected both groups; however, it affected the Japanese group more than the American group. An analysis of the error patterns observed in both groups showed that the errors made by the Japanese group tended to involve consonants that are not present in the Japanese language. Additionally, the English language proficiency of the participants was not assessed, and it is likely that the participants varied in English language proficiency levels. They suggested that perhaps participants with higher proficiency levels would perform more like the monolingual participants. As in the Mayo et al study, the standard deviations of the bilingual group are much larger than the monolingual group. This may indicate the lack of homogeneity within the bilingual group, perhaps related to variability in length of exposure, mode, function, or proficiency in the L2.

Nilsson et al (1992) tested 150 participants in a study providing normative data for the Hearing in Noise Test (HINT). The HINT is a test of speech reception thresholds that uses sentences. It allows one to assess speech perception under a number of different speech-noise configurations. This test is one of a few tests of English speech perception that have been validated and for which normative data exist. This makes it a particularly attractive test to use for comparing auditory function in monolingual and bilingual participants. All participants were ranked according to their early English language acquisition experience. The categories in which participants had to characterize themselves spanned the range of "English only" to "no English in the home." Their results showed that for participants who had "no English in the home" early in language acquisition, thresholds both in noise and quiet were elevated by approximately 3 dB. Nilsson et al (1992) suggested that cognitive/linguistic factors may affect a bilingual's ability to understand speech in noise. Unfortunately, Nilsson et al did not provide additional information describing the linguistic background of the participants in their study. Factors such as age of L2, language competency, and years of experience with L2 were not provided and may prove important to how bilinguals function in the presence of background noise (von Hapsburg and Peña, 2002).

The purpose of our study was to examine speech perception performance for a group of late bilinguals (those who learned L2 after puberty). Specifically, we wanted to determine whether the 3–6 dB difference in performance noted in previous studies was also present in a group of late bilinguals with similar histories of acquisition and experience with the second language. Additionally, we wanted to see whether the bilinguals could achieve the 6–7 dB improvement in speech-to-noise ratio that is normally experienced when speech and noise are delivered from separate sources.

METHOD

Participants

This study involved 20 participants (15 women). Participants were recruited from the Departments of Communication Sciences and Disorders and Spanish and Portuguese at the University of Texas at Austin. Determination of normal hearing status was established via a hearing screening using supra-aural earphones and a clinical audiometer. Screening was performed at 20 dB HL at 250, 500, 1000, 2000, 4000, 6000, and 8000 Hz in each ear. Participants were divided into two groups of 10 participants each: monolingual speakers of English and bilingual speakers of Spanish and English. A functional definition of bilingualism was adopted for purposes of classifying participants. Briefly, a functional view of bilingualism suggests that circumstantial bilinguals, those who must learn a second language out of necessity for purposes of work or social situations after immigrating to another country, are functionally different from elective bilinguals, those who chose to learn a second language for purposes of school or personal interest and are not forced to use the language in daily situations.

Monolingual Group

Ten normal-hearing participants (eight females), ranging in age from 19 to 31 (average age = 22.4 years), reported English as their first language and little to no familiarity with a second language. Language experience was assessed by a survey of their language skills. The monolingual English participants reported they were not comfortable communicating in any language other than English for all communication situations in all language areas (reading, writing, speaking, and listening). According to the functional view of bilingualism (Grosjean, 1997), these listeners did not qualify as circumstantial or elective bilinguals since their linguistic profile suggests a limited history of functional use or need for an L2. Although these listeners may have come into contact with Spanish, in Texas the exposure to that language was limited, according to self-reports. All participants were born and raised in the United States and were residing in the state of Texas at the time of the investigation.

Bilingual group

Ten normal-hearing participants (seven females), ranging in age from 26 to 33 (average age = 29.6 years), reported that they considered themselves bilingual speakers of Spanish (L1) and English (L2). Although the bilinguals were on average somewhat older than the monolinguals, both groups had similar medical and noise-exposure histories. In attempting to select as homogeneous a group of bilinguals as possible, we obtained a thorough linguistic profile for each bilingual participant utilizing two measures. A modified version of the "Synthetic Sentence Identification (SSI) Language Questionnaire" (Moore, 1995) was utilized to characterize the participants' linguistic history and use. Additionally, all participants filled out a self-rating scale of language use (Ortiz, 1995) for each language spoken. Participants rated their proficiency for the following language areas: (1) comprehension, (2) fluency, (3) vocabulary, (4) pronunciation, and (5) grammar.

In this way information regarding language history, language status, language function, and language stability was obtained for each participant (Grosjean, 1989; von Hapsburg and Peña, 2002). Table 1 shows the language descriptors used to determine a participant's language history. All members of the bilingual group were born and raised in Latin American countries and stated that they had learned English as a second language after the age of 10 years. The age of 10 years was chosen as it marks the onset of the decline in brain plasticity. All bilingual participants reported that L2 proficiency was achieved in the United States. Although these listeners might have had some exposure to English growing up (i.e., school or television), this exposure was limited, as they reported not having proficiency in the L2 nor a functional need for using the L2 prior to arriving in the United States. Additionally, none of the bilingual listeners attended English-speaking schools in their country of origin. The average age at which the participants first began to functionally acquire L2 (English) was 13.8 years (range = 10–20 years). The bilingual participants had spoken English for an average of 15.8 years (range = 11–21 years). Language function information revealed that at the time of the study, the bilingual speakers reported using English in daily interactions (i.e., in professional settings or social interactions) for an average of 50 percent of the time. Spanish was used the other 50 percent of the time for social as well as professional settings (the majority of the participants were graduate students in the Spanish/Portuguese department). This was a self-reported approximation of language function and could not be verified. Participants rated their language competency as well. All participants reported that they were still acquiring skills in all areas of English (reading, writing, listening, and speaking). All participants rated their language skills on a 5-point scale in five different areas of language: comprehension, fluency, vocabulary, pronunciation, and grammar. Participants in the bilingual group rated themselves with a 4 or 5 in their language skills for English and Spanish; however, they reported being most comfortable communicating in their native language (Spanish), and felt they were still acquiring language skills in English. Although the rating exercise did not directly

Table 1. Language Descriptors Used to Create Participant Linguistic Profiles

Language Categories	Language Descriptors
Language Status	Monolingual/bilingual
Language History Descriptors	Age of language acquisition Order of language acquisition Place of language acquisition
Language Stability	Still in the process of acquiring language skills in reading, writing, speaking, listening?
Language Competency	Reading Writing Listening Speaking
Language Demand	Function—in what situation is each language used and for what purpose?

Source: Adapted from Grosjean, 1997.

assess language competency, it allows us to estimate competency of each language relative to the other language. The results of the ratings show something very important about our participant group; that is, although they did not consider themselves to be equally proficient in both languages, they felt relatively confident about their language skills in both languages, all showing more confidence in Spanish, the L1.

Stimuli

The test stimuli were sentences and speech-shaped noise taken directly from the compact disc that is included in the materials for the HINT (distributed by Starkey Laboratories). There were 250 sentences divided equally into 10-sentence lists. Each sentence contained six to seven syllables. Each list was phonemically balanced and was designed to approximate actual conversational speech in its spectral and temporal characteristics. The language level of the sentences was typical of first graders. A male native English speaker spoke the sentences. The noise matched the average long-term spectrum of the sentences.

The setup used for the experiment was in accordance with the procedures described in Manual Two for the HINT (Koch et al, n.d.). Briefly, the listener was seated in a single-wall booth (1.8 x 2.0 meters), facing one of two loudspeakers (0 degrees azimuth). The second speaker was positioned directly across from the right ear of the listener (90 degrees azimuth). Both speakers were elevated one meter off the floor and were placed one meter from the listener. The stimuli were delivered via a CD player. The output channels of the CD player were routed to separate channels of an audiometer that was connected to two loudspeakers. The sentences and noise could be presented from the same speaker (at 0 degrees azimuth) or from separate speakers (sentences and noise at 0 and 90 degrees azimuth, respectively). Stimuli and participants' responses were audible to the experimenter via the talkback system of the audiometer.

Calibration of the system involved a two-step process. First, a 1000 Hz tone, scaled to match the average level of the speech, was played through the audiometer, and both channels were referenced to a VU level of 0 dB. Next, the output of each speaker was adjusted so that the level of the noise at the reference test position was 65 dB SPL (A). The reference test position corresponds to the location of a microphone on a sound-level meter that approximates the center of the listener's head when seated in the room.

Procedures

Participants were instructed to repeat the sentences they heard. Guessing was encouraged if they were uncertain. Bilingual participants were instructed in the language they preferred, English or Spanish, but were only permitted to repeat answers in English. Sentences were scored as correct if the listener repeated all the key words.

The stimuli were presented via speakers under the following conditions: (1) in quiet at

0 degrees azimuth, (2) with the noise and signal at 0 degrees azimuth (noise at 65 dB [A]), and (3) with noise at 90 degrees azimuth and signal at 0 degrees azimuth (noise at 65 dB [A]). The reception threshold for sentences (RTS) was found using an adaptive method. In the quiet condition, the intensity of the first sentence was raised until the sentence was repeated aloud correctly, and then the intensity was raised or lowered by 4 dB for sentences one to five and by 2 dB for sentences six to 20. The RTS was recorded as 2 dB below or above the final response, depending on whether that response was repeated correctly or not. In the noise conditions (speech and noise presented together), a slightly different method was used. The beginning presentation level of the speech was 61 dB when the noise and signal were in the same speaker and 55 dB when the noise and signal originated from different speakers.

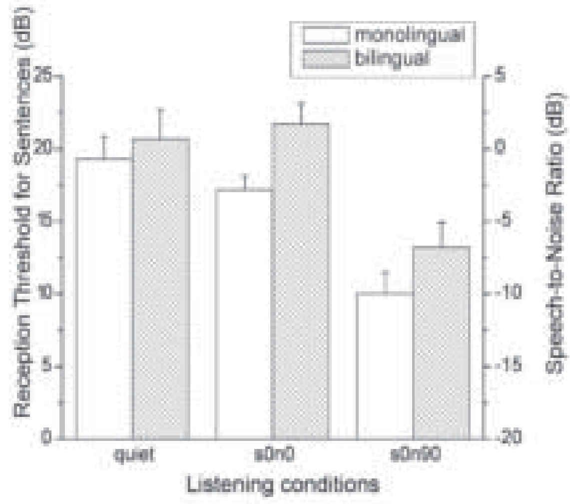

Figure 1. Mean data for two groups of listeners (monolingual, bilingual) in three listening conditions (quiet; speech and noise at 0 degrees azimuth; speech at 0 degrees azimuth, noise at 90 degrees azimuth). In the quiet condition (referred to the left ordinate), means are given as reception thresholds for sentences (in dB SPL). In the two noise conditions (referred to the right ordinate), means are given as speech-to-noise ratios (in dB). Error flags indicate one standard error from the mean.

RESULTS

The data from the study are summarized in Figure 1 where the means for the two groups (monolinguals; bilinguals) are plotted for the three listening conditions (quiet; speech and noise at 0 degrees azimuth; speech at 0 degrees azimuth, noise at 90 degrees azimuth). In the quiet condition, the mean RTS for the monolingual group is 19.3 dB, and the mean for the bilingual group is 20.7 dB. A two-tailed t-test revealed that the between-group means were not significantly different [$t(18) = 1.725$, $p > 0.05$]. The results suggested that bilingual Spanish-English listeners and monolingual English listeners perform similarly when no noise is present.

Between-group comparisons were made for the noise condition at 0 and 90 degrees azimuth. Signal-to-noise ratios (SNR) were used for comparisons. For the noise condition at 0 degrees azimuth (the more difficult listening condition), the monolingual group required a SNR of -2.2 in order to achieve 50 percent performance, whereas the bilingual group required a SNR of 1.7. That is, the monolingual group was able to achieve 50 percent accuracy at a lower SNR than the bilingual group. For the 90 degrees azimuth noise condition (the easiest of the two noise conditions) the monolingual group achieved 50 percent accuracy at a SNR of -10.0, whereas the bilingual group required a higher signal-to-noise ratio, -6.8. Thus, for both noise conditions the bilingual group required a higher SNR than the monolingual group in order to achieve 50 percent accuracy.

Table 2. Analysis of Variance—Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-value	P-value
Group	1	124.962	124.962	79.044	.0001
Subject (Group)	18	28.457	1.581		
Condition	1	665.040	665.040	277.843	.0001
Condition x Group	1	1.260	1.260	0.527	.477
Condition x Subject (Group)	18	43.085	2.394		

A mixed design analysis of variance (ANOVA) with one between-subjects factor (group), and one within-subjects factor (noise condition), was carried out for the two noise conditions. As shown in Table 2, the ANOVA revealed significant main effects for group, $F = 79.04$, and noise conditions, $F = 277.84$, $p < .05$. However, the two-way interaction was not significant.

Normative data for the HINT, based on results from young adults with normal hearing, have been presented (Nilsson et al, 1992). In the present study, the RTS for each listener was compared to the normative value associated with the 5th percentile as reported by Nilsson et al. Of the monolingual listeners, only one had an RTS that fell below the percentile boundary (0 degree condition). Of the bilingual listeners, all ten had RTSs that fell below the boundary in the 0 degree condition; their performance was somewhat better in the 90 degree condition where six listeners had RTSs that were outside the normal range.

The improvement in SNR when the signal and noise originate from different sources compared to when sounds come from the same source is known as the binaural advantage. The binaural advantage for the monolingual and bilingual listeners was 7.8 dB and 8.5 dB, respectively. This suggests that the condition where speech and noise are coming from the same source is relatively difficult for both groups and that separation of noise and signal benefits both groups.

DISCUSSION

Results from this study showed that late bilinguals perform the same as monolinguals in quiet on the HINT. However, bilingual performance is reduced compared to that of monolinguals in noise, regardless of the speech-noise configuration. These results are consistent with previous research that suggests bilinguals have diminished capacity when listening to sentence materials presented in noise. Specifically, our study revealed that bilinguals required a signal-to-noise ratio up to 3.9 dB higher than the monolingual controls on the HINT lists. Additionally, we showed that like the monolinguals, the bilinguals present with a binaural advantage consistent with those of normal listeners. These results indicate that binaural hearing affords the same advantage to bilingual listeners as to monolingual listeners and suggests that a mechanism other than binaural hearing per se may be responsible for the reduced performance in noise observed in bilinguals.

Because the HINT test provides normative data, it is a useful tool for comparing an individual's performance to that of a normal group of monolingual speakers. However, researchers and clinicians should be aware that the performance of a late bilingual typically falls out of the normal range given by the HINT for monolingual speakers of English with normal auditory thresholds. This test can be employed routinely for the assessment of speech understanding in noise in bilingual populations where a normal pure-tone audiogram or speech reception thresholds in quiet may not reveal the true perceptual abilities experienced by the bilingual listener when listening to L2 in noise.

An additional goal of this study was to examine perceptual performance of a group of bilinguals with similar histories of acquisition. That is, care was taken to control for age of L2 acquisition, language history, language function, and language competency to obtain as homogeneous a group of bilinguals as possible and to determine whether the discrepancy observed between bilinguals and monolinguals diminished when these factors were controlled. Mayo et al (1997) compared performance of a subgroup of early bilinguals and late bilinguals with similar length of exposure to L2. They found that despite equal length of exposure in the two groups, bilinguals who acquired the L2 before puberty performed significantly better than bilinguals that acquired the L2 after puberty. Thus, they concluded that "even extensive exposure will not result in native-like speech perception in noise if the second language is not learned in early childhood" (1997:691). Additionally, the standard deviations in the full group of late bilingual listeners were large compared to the other groups. Mayo et al suggested that the large standard deviations probably reflected the wide range of experience with the L2 in that group (3–26 years), indicating lack of homogeneity in the bilingual group.

Takata and Nabelek (1990) proposed that language competency might be a factor contributing to reduced performance in bilinguals. Although not specifically assessed, the amount of experience with a language over time was taken as an indicator of competence. Their participants had an average of 6.7 years experience with L2. They suggested that the participants with more experience with L2 (those with 8–13 years of experience) performed almost as well as the American participants in background noise. The large standard deviation noted in that group might have been indicative of variability in competency. The relatively low variability exhibited by our bilingual group suggests that the establishment of a thorough linguistic profile likely facilitated group homogeneity.

The present study revealed that despite a relative high level of self-rated skill in L1 and L2 (rated a 4 or a 5 in both languages, in all language skill areas) and extensive experience with L2 (average experience 16 years), late bilinguals continued to show an average difference of up to 3.9 dB in SNR compared to monolingual listeners. Regarding experience with L2, our results suggest that even when participants have an average of 16 years experience, perceptual performance does not increase. Future studies are needed to determine whether there is an amount of experience (greater than 16 years) when L2 performance in bilinguals matches that of monolinguals. We relied primarily on participants self-rating and reporting of language skills and time spent using each language. It may be important to confirm competency to corroborate and establish actual skill relative to perceived skill. Regardless, our method seemed to be appropriate in allowing us to find a more homogeneous sample of bilingual speakers and listeners.

The statistical difference reported here is certainly clinically significant. According to the HINT manual (Koch et al, n.d.), a 1 dB SNR difference is equivalent to nine percentage points in the intelligibility of sentences. Thus, a 3.9 dB difference in SNR between groups implies speech intelligibility scores approximately 36 percent poorer in the bilingual than the monolingual group when L2 is being used. Such diminished ability is bound to cause communication difficulties and to be perceived as problematic. Similar results have been observed in different subpopulations with normal hearing, such as individuals with normal hearing with positive history of otitis media with effusion (OME), and individuals with the obscure auditory dysfunction (OAD) or auditory dysfunction with normal hearing (ADN) (Saunders and Haggard, 1989, 1992; Saunders et al, 1992).

In addition, we compared our data to those from older listeners with mild hearing impairment. Hanks and Johnson (1998) evaluated HINT list equivalency in 24 listeners between 60 and 70 years of age, as the original HINT list equivalency had only been obtained on younger adult listeners. All of the participants in the study exhibited a mild sensorineural hearing loss. In the quiet condition, the RTS measured in the Hanks and Johnson study was approximately 10 dB higher than those obtained in the present study. This outcome is expected, based on differences in absolute sensitivity. However, in the 90 degree azimuth noise condition, the bilingual listeners from the present study and Hanks and Johnson's listeners with hearing impairment showed similar capabilities as indicated by SNR, falling slightly outside the normal range given by the HINT norms. For the 0 degree azimuth condition, the monolingual and hearing impaired listener's performance both fell within the normal range given by the HINT, whereas the bilingual group performed significantly poorer than both the hearing impaired and the monolingual listeners.

These informal comparisons provide an index of the degree of difficulty experienced by bilingual listeners who acquire their second language after puberty. The results suggest that, in the presence of noise and depending on the location of the noise in relation to speech, the normal-hearing bilingual performs similar to or worse than the mildly impaired older individual. Moreover, the bilingual listener has an advantage over the hearing-impaired listener in quiet situations. However, in the presence of noise and depending on the location of the noise in relation to the stimuli, the bilingual performs more like the mildly hearing impaired individual and at times worse than the mildly hearing impaired individual. Unfortunately, these comparisons do not provide an estimate of the perceived difficulty that bilinguals may experience in background noise, and do not allow us to draw conclusions about how bilinguals with hearing impairment might perform.

It has been shown that late bilinguals

realize different perceptual performance skills than early bilinguals. The reasons why processing differences exist among bilinguals and monolinguals are unknown; however, a number of different explanations have been proposed. For example, proponents of a critical-period hypothesis suggest that age is the mechanism involved in determining the end-state of bilingual function. For example, Weber-Fox and Neville (1992, 1999) studied language processing in a group of early and late bilinguals using event-related potentials. They found that late-learning bilinguals show slower linguistic processing than early-learning bilinguals do and that language-related neural systems of later learners are different in locus and function from those of early learners. Although these studies show that age is an important factor affecting language performance, others suggest that cognitive and linguistic factors interact with age to determine end-state second-language processing outcomes. Consistent with this alternate view, it has been suggested that bilinguals may not be as efficient at processing certain aspects of language because of the interaction of the two language systems. Flege (1999) suggested that the L1 and L2 phonetic systems within a bilingual interact and are not easily separated. Likewise, Soares and Grosjean (1984) stated that even when tested in the monolingual mode, a bilingual may search both lexicons and may require more "processing" time. The patterns observed in bilinguals are typically manifested in a processing cost, whether it involves grammaticality judgments, speed of processing, or speech perception, and production. It is uncertain whether the auditory perceptual processing cost observed in bilinguals is due to an inability to separate the two language systems or to some other mechanism related to the process of second language acquisition.

For this study, inferences about the mechanism driving the perceptual differences observed in late bilinguals could not be evaluated as the HINT test is not an expansive test. That is, it does not allow us to evaluate other facets of language processing. Differences in processing skills at the auditory, phonetic, lexical, syntactic, and semantic levels may be responsible for the observed perceptual differences. It may also be the case that the poor perceptual performance observed in bilinguals may be due to contributions from any number of cognitive factors affecting the processing of linguistic knowledge such as resource allocation and memory (Dornic, 1980). In order to make inferences about the mechanism behind the perceptual differences observed in bilingual listeners, future studies should attempt to do a battery of tests that assess multiple aspects of auditory processing skills.

In summary, late bilinguals with similar second-language acquisition histories and normal hearing showed a significant auditory processing cost when listening to the second language in the presence of background noise, requiring improved signal-to-noise ratio in order to reach comparable thresholds to the monolingual listeners in this study. It remains uncertain whether late bilinguals with normal hearing consider the experimentally observed auditory processing deficit in the L2 a problem to real-life communication situations in which the L2 is used. It also remains unclear how auditory processing skills are affected in bilinguals with hearing impairment. It is recommended that researchers develop as thorough a linguistic profile of participants as possible so that the linguistic factors contributing to auditory performance in noise can be better understood in bilinguals with normal and impaired hearing.

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