Acceptance of Background Noise Levels in Bilingual (Korean-English) Listeners

Deborah von Hapsburg*
Junghwa Bahng*

Abstract

The acceptable noise level (ANL) is the maximum amount of background noise that listeners are willing to accept while listening to speech. ANL has not been studied in listeners who use languages other than English. The purpose of this study was to explore whether ANLs obtained from Korean listeners in both English and Korean were comparable to ANLs obtained from monolingual English listeners. The results showed that ANLs obtained in English (ANL-E) did not differ significantly for the bilingual and monolingual listeners. Additionally, a cross-language comparison, within bilinguals, showed that ANLs obtained using Korean (ANL-K) speech stimuli were not significantly different from ANL-E. Finally, speech perception in noise did not correlate with ANLs in English or Korean for the bilingual listeners. Results suggest that the ANL measure is language independent within bilinguals and may be of potential clinical use in minority language groups.

Key Words: Acceptable noise level, background noise, bilingual, speech perception

Abbreviations: ANL = acceptance of noise level; ANL-E = acceptance of noise level in English; ANL-K = acceptance of noise level in Korean; BNL = background noise level; HP = high predictability; KSPIN = Korean speech perception in noise; L1 = first language; LP = low predictability; LPB = low proficiency bilingual in English; LTASS = Long-Term Average Speech Spectrum; MCL = most comfortable level; ME = monolingual English; MPB = moderate proficiency bilingual in English; R-SPIN = revised speech perception in noise; SNR = signal-to-noise-ratio; SPIN = speech perception in noise

Sumario

El nivel aceptable de ruido (ANL) es la máxima cantidad de ruido de fondo que un sujeto está dispuesto a aceptar mientras escucha lenguaje. El ANL no ha sido estudiado en oyentes que hablan idiomas diferentes del inglés. El propósito de este estudio fue explorar si los ANL obtenidos de oyentes coreanos, tanto en inglés como en coreano, eran compatibles con los ANL obtenidos de oyentes monolingües en inglés. Los resultados mostraron que los ANL obtenidos en inglés (ANL-E), no era significativamente diferentes de los oyentes bilingües o monolingües. Además, una comparación cruzada de lenguas, dentro del grupo de los bilingües, mostró que los ANL obtenidos usando estímulos lingüísticos en coreano (ANL-K), no diferían significativamente de los ANL-E. Finalmente, la percepción del lenguaje en ruido no correlacionó con los ANL en inglés o coreano para los oyentes bilingües. Los resultados sugieren que la medición del ANL es independiente dentro de los bilingües y puede ser de uso clínico potencial en grupos lingüísticos minoritarios.

*Department of Audiology and Speech Pathology, University of Tennessee, Knoxville

Deborah von Hapsburg, University of Tennessee, Department of Audiology and Speech Pathology, 578 South Stadium Hall, Knoxville, TN 37996-0740; Phone: 865-974-1811; Fax: 865-974-1539; E-mail: dvh@utk.edu

Palabras Clave: Nivel aceptable de ruido, ruido de fondo, bilingüe, percepción del lenguaje

Abreviaturas: ANL = nivel aceptable de ruido; ANL-E = aceptación del nivel de ruido en inglés; ANL-K = aceptación del nivel de ruido en coreano; BNL = nivel de ruido de fondo; HP = alta predictibilidad; KSPIN = Percepción del lenguaje en ruido en coreano; L1 = primera lengua; LP = baja predictibilidad; LPB = baja aptitud bilingüe en inglés; LTASS = Promedio a Largo Plazo del Espectro del Lenguaje; MCL = nivel más confortable; ME = inglés monolingüe; MPB = aptitud moderada bilingüe en inglés; R-SPIN = percepción del lenguaje en ruido-revisado; SNR = tasa señal/ruido; SPIN = percepción del lenguaje en ruido

Recent research by Nabelek and colleagues has focused on investigating the factors that affect the acceptance of background noise levels (ANL) by listeners with normal and impaired hearing (Nabelek et al, 1991; Lytle, 1994; Freyaldenhoven et al, 2005; Nabelek et al, 2004, this issue). Nabelek et al (1991) developed a measure to determine the maximum amount of background noise that listeners are willing to accept while listening to speech at comfortable levels, referred to as the "listener's ANL." Specifically, a listener's ANL is calculated by subtracting the highest background noise level (BNL) the listener can accept while following a story from the listener's most comfortable level (MCL). In a series of studies using listeners with normal hearing and individuals with hearing loss, Nabelek and colleagues have established that there is a range of ANLs that characterizes a listener's willingness to listen in background noise. Persons with low ANLs tend to accept more noise and have been shown to be more successful users of hearing aids, whereas persons with high ANLs tend to accept less noise and have been shown to be less successful hearing aid users. Additionally, Nabelek and colleagues have found that the ANL is not related to age (Nabelek et al, 1991), hearing sensitivity (Nabelek et al, 1991), type of background noise used (Nabelek et al, 1991; Lytle, 1994; Crowley and Nabelek, 1996), and gender (Rogers et al, 2003).

Recently, Nabelek et al (2004) also compared listeners' performance on the revised speech perception in noise test (R-SPIN) (Bilger, et al, 1984) to the ANL in the aided and unaided condition with full-time and part-time hearing aid users. As expected, they found that performance on the SPIN test improved in the aided condition for both groups of users, suggesting an effect of amplification on speech in noise processing. However, performance on the SPIN was not predictive of hearing aid use patterns (Nabelek et al, 2004). For the ANL there was no change observed across the two listening conditions (aided vs. unaided) for the two groups of hearing aid users; however, the ANL for full-time users was significantly lower than for the part-time users and rejecters, labeled together as "unsuccessful users." Contrary to results for the SPIN, they found that the ANL was very predictive of the hearing aid use patterns of listeners with hearing loss. Finally, they found that speech perception performance on the SPIN (Bilger et al, 1984) and the ANL were not significantly correlated. Overall, these results suggest that the ANL measure taps into a different aspect of listening in noise than does speech perception performance in noise testing, and that listeners may have an inherent ability to accept background noise that is not related to the listener's actual performance or understanding in noise. A study examining the electrophysiological correlates of the ANL suggests that the ANL is not correlated with the peripheral auditory system but with higher central auditory processing mechanisms (Harkrider and Tampas, this issue).

The ANL has not been examined in languages other than English, nor has it been examined in bilingual populations for whom understanding speech in noise has been documented as being particularly difficult. A series of studies on the perceptual abilities of bilingual listeners has shown that background noise significantly affects perceptual performance in the second language (L2) (Buus et al, 1986; Takata and Nabelek, 1990; Mayo et al, 1997; von

Hapsburg et al, 2004). For example, Mayo et al tested perceptual abilities of bilinguals with the R-SPIN (Bilger et al, 1984), a test composed of sentences containing words in high (HP) and low (LP) contextual predictability. Performance for the late bilingual group, who acquired the L2 after puberty, 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, those with more L2 experience, and monolinguals were able to achieve 50% accuracy at higher noise levels (up to 4–6 dB SPL higher) than the late bilingual group. Thus, the authors suggested that listeners with more language experience in L2 tended to perform better in noise than listeners with less experience.

Overall, the factors that affect a bilingual listener's ability to process L2 speech in noise are not fully understood. If the ANL taps into a different aspect of listening in noise than tests of speech perception such as the SPIN (Bilger et al, 1984), it may provide an additional method that could be useful in understanding how noise affects bilingual listeners. Prior research on bilingualism has shown that amount of L2 experience affects speech perception in noise in the L2, but no evidence exists that this may affect ANLs as well. Given the fact that ANLs do not seem to be related to speech perception (Nabelek et al, 2004), we hypothesize that the ANL might be a language-independent measure. That is, language-related factors (e.g., amount of language proficiency, or language of test) may not affect ANLs. As the population of immigrants to the United States increases, bilingual populations will also increase in the United States. The ANL has not been studied in bilingual listeners and might provide an additional measure of how bilinguals process each of their languages in noise. Additionally, because there is a shortage of bilingual audiologists in the United States, the ANL measure may prove useful in determining hearing aid candidacy in linguistically diverse populations, without the need to test speech understanding in a specific language.

The goals of the current study were to determine (a) whether ANL can be obtained in a language other than English (e.g., Korean) with results similar to those obtained when English is the language of test (b) whether ANL is language dependent within Korean-English bilinguals (that is, does ANL vary within bilinguals according to language of test or according to language proficiency in L2), and (c) whether speech perception in noise is correlated with ANLs in bilingual listeners.

METHODS

Listeners

A total of 30 listeners with normal hearing participated in this study. All listeners met the following audiological criteria: normal hearing (thresholds of 15 dB HL or better at the audiometric frequencies of 500, 1000, 2000, 3000, 4000, and 6000 Hz in both ears); normal middle ear function as determined by immitance testing (Type A tympanogram); and a negative history for otologic and neurological deficits. Listeners were divided into three groups (two groups of Korean-English bilingual listeners and one group of monolingual English listeners).

Monolingual Group

Ten monolingual-English listeners (six females) ranging in age from 24 to 34 years reported English as their first language and little to no knowledge of a second language outside of what was learned in high school. They reported not having ever consistently used another language for any of the four language functions: reading, writing, speaking, and listening. According to the functional view of bilingualism (Grosjean, 1998), these listeners do not qualify as bilinguals since their linguistic profile suggests a limited history of functional use or need for an L2.

Bilingual Groups

Twenty bilingual listeners were divided into two groups according to self-reported proficiency in the L2 (English). One group consisted of moderately proficient (English) bilinguals (MPB), and the other consisted of low-proficiency English (LPB) bilinguals. All bilingual listeners were native Korean listeners who learned Korean as a first language (L1) and English as a second language (L2) after puberty or in adulthood (Table 1). They were all students at the University of Tennessee. In attempting to select as homogeneous a group of bilinguals as possible (von Hapsburg and Peña, 2002), a thorough linguistic profile was obtained for each bilingual listener, using a language-use questionnaire and a language-proficiency rating scale developed in our laboratory. The language-use questionnaire was utilized to characterize the listener's linguistic history, amount of language use, and purpose for using each language. Additionally, all listeners filled out a self-rating scale of language proficiency for each language spoken. Listeners rated their proficiency on a seven-point scale for the following language areas: (a) listening, (b) speaking, (c) reading, and (d) writing.

The MPB group consisted of eight listeners (six females), ranging in age from 25 to 34 years, who had self-reported moderate proficiency in English. The MPB group had an average age of acquisition of approximately 11 years (all began learning English in middle school in Korea), arrived in United States at an average age of 22 years, and had an average of eight years of experience with the L2 in the United States (Table 1). Additionally, all of the listeners in the MPB group had passed the University of Tennessee's SPEAK test with a score of 50 or higher. The SPEAK test is a test of speaking English proficiency offered to graduate students at the University of Tennessee. A minimum passing grade of 50 is required for international students to be allowed to teach courses at the university. In terms of proficiency for each language, the MPB group rated themselves higher on L1 (6.2) than on the L2 (4.9) when proficiency ratings on all categories (speaking, listening, reading, writing) were averaged together (Table 1).

The LPB group consisted of 12 (eight females) Korean listeners, ranging in age from 27 to 38 years, who had self-reported minimal language skills in the L2 (Tables 1). The LPB group had a mean age of L2 acquisition of 12.5 years (learned English in middle school in Korea), arrived in the United States at an average age of 27.5 years, and had an average of 2.5 years using the L2. Moreover, the majority of these listeners had taken the SPEAK test but not scored the required minimum to pass the test. The LPB group was chosen so as to resemble or approximate monolingual Korean performance as close as possible, because it was difficult to find monolingual Korean listeners in Knoxville. The LPB group's self-rating on proficiency showed an average of 6.6 on the L1 and 4.0 on the L2. The LPB group reported slightly higher proficiency than the MPB group in the L1 and relatively less proficiency in the L2 than the MPB group. These numbers are meant to show relative comfort with each of the listener's languages.

Procedures and Stimuli

ANL Procedure

The ANL measure was obtained in English and Korean using procedures established by Nabelek et al (2004). Acceptance of background noise was measured in a sound-treated booth with a

Table 1. Description of Participants in the ME (Monolingual English), MPB (Moderate Proficiency Bilingual), and LPB (Low Proficiency Bilingual) Groups

	ME	MPB	LPB
Listeners	N = 10	N = 8	N = 12
Mean age (in yrs.) (SD)	27.4 (3.5)	29.8 (4.2)	31.9 (3.5)
Gender (F, M)	6, 4	6, 2	8, 4
English experience (in yrs.)	N/A	8.4	2.5
Age of L2 acquisition (in yrs.) (SD)	N/A	11.3 (4.0)	12.5 (1.3)
Age of arrival in U.S. (in yrs.) (SD)	N/A	21.7 (6.4)	27.8 (5.5)
Self-reporting on proficiency* : L1	N/A	6.2 (0.4)	6.6 (0.2)
: L2	N/A	4.9 (0.4)	4.0 (0.6)

Note: Mean age, gender, amount of experience with L2, age of L2 acquisition, age of arrival in the U.S., and overall score of self-reporting on proficiency in L1 and L2 are provided for the MPB and LPB groups. This information is not applicable (N/A) for the ME group.

* Numbers range from 1 (nonfluent, only know several words or a few simple sentences) to 7 (fluent, very comfortable with skills like a native speaker, can be understood by a majority of listeners).

recording of running speech with a male voice as the primary stimulus and a competing stimulus of multitalker babble. The stimuli used for obtaining ANL in each language are described in detail below. The stimuli were presented from a compact disc to a Grason Stadler (GSI 61) audiometer and delivered to a loudspeaker located 1.0 meter away from the listener at zero degrees azimuth (Nabelek et al, 2004).

To establish ANL, first, the participant's most comfortable level (MCL) was determined. The listeners used a hand signal (thumbs up/thumbs down) to adjust the level up or down. The verbal and written instructions for measuring MCL were as follows:

> You will listen to a story through a loudspeaker. After a few minutes, select the loudness of the story that is most comfortable for you, as if listening to a radio. Hand signals (thumbs up or down) will allow you to make adjustments. First, turn the loudness up until it is too loud and then down until it is too soft. Finally, select the loudness level that is most comfortable for you.

The loudness level of the running speech began at 70 dB SPL and was increased in 5 dB steps until the listener indicated it was "too loud." It was then decreased in 5 dB steps until the listener indicated it was "too soft." At this point, the level of the story was adjusted up and down in 2 dB increments until the listener's MCL was found.

Once the MCL was established, the speech-babble noise was added at a signal-to-noise ratio (SNR) of 15 dB to find the acceptable background noise level (BNL). As with the MCL, the listener used hand signals to adjust the volume of the background noise up or down. The listeners were instructed to find the maximum level that they could "accept" while listening to and following the words of the story. The verbal and written instructions for obtaining the BNL were as follows:

> You will listen to the same story with background noise of several people talking at the same time. After you have listened to this for a few moments, select the maximum level of the background noise that you would be willing to accept or "put up with" without becoming tense and tired while following the story. First, turn the noise up until it is too loud and then down until the story becomes very clear. Finally, adjust the noise (up and down) to the level that you would "put up with" for a long time while following the story.

The loudness level of the noise was increased in 5 dB increments until the listener indicated the noise was "too loud" to accept while following the story. The level of the noise was then decreased in 5 dB steps until the listener indicated that the noise was soft enough that the story was "very clear." At this point, the level of the noise was adjusted up and down in 2 dB increments until the listener indicated that it had reached the highest level that could be accepted while following the story without becoming tense or tired.

The ANL was calculated by subtracting the BNL from the MCL (ANL = MCL - BNL). Both groups of bilingual listeners listened to the ANL in both Korean and English. The language order was randomized in order to avoid order effects. For obtaining the ANL in Korean, the listeners were instructed in Korean, and Korean speech stimuli were used.

Stimuli for ANL

For the English ANL, the Arizona Travelogue (Cosmos Inc.) was used to obtain the MCL (Nabelek et al, 2004), and the speech-babble noise from the R-SPIN (Bilger et al, 1984) was used for obtaining the BNL. For the Korean ANL, the speech-babble noise from the Korean SPIN (Kim et al, 2000) test was used to obtain the BNL. To obtain MCL, a story about a ladybug taken from a children's book was recorded using Time-Frequency Representation (TFR) software (Avaaz Innovations) and Tucker Davis Technologies (TDT) system III. A 30-year-old Korean male read the story at a normal conversational effort. The stimuli were recorded with a Sennheiser microphone situated 30 cm from the speaker's lips at a sampling rate of 44,100 Hz. The long-term average speech spectra (LTASS) of the Korean and the English stimuli were derived using Kay Elemetrics Computerized Speech Laboratory (CSL) and are shown on Figure 1. The spectra have a similar overall shape but differ slightly in the low- and high-frequency ranges.

Speech Perception in Noise (R-SPIN)

Speech perception was evaluated in English using the R-SPIN (Bilger et al, 1984). The sentences were presented in the sound field at zero degrees azimuth, at 70 dB SPL, and at the following SNRs: -3 dB, 0 dB, +3 dB, and +6 dB. The listeners wrote down the target word and repeated the word to the experimenter, who was a bilingual Korean-English listener. The SNRs were presented in random order. To determine whether ANLs correlate with speech perception performance in Korean, the bilingual listeners were also tested on the Korean SPIN (KSPIN [Kim et al, 2000]) at an SNR of +6 dB. The Korean version of the SPIN (Kim et al, 2000) test was presented at zero degrees azimuth at 70 dB SPL. Briefly, the Korean SPIN test differs from the English SPIN test in important ways. Whereas the English SPIN test requires that the listener write down the last word of the sentence after its presentation, the Korean SPIN asks the listener to respond to specific questions about the sentence. For example, a question might ask "who/what performed the action?" The difference in task between the R-SPIN and the KSPIN results in very different performance intensity functions at different SNRs. Because the focus of this study was not on first language perception in bilinguals, we limit our discussion of the results of Korean speech perception to performance at +6 dB SNR, which closely approximates the condition used by Nabelek et al (2004) to explore the relationship between speech perception performance and ANL measures.

RESULTS

Acceptable Noise Level (ANL)

English ANL

The mean ANL obtained in English (ANL-E) for the ME (monolingual English), MPB, and LPB groups was 6.4 dB (range -2 to 20), 8.0 dB (range 4 to 14), and 6.8 dB (range 4 to 10), respectively. Table 2 shows the ANL means, ranges, and standard deviations for each group. One-way analysis of variance showed that there was no significant difference in mean ANLs among the three groups ($F[2, 29] = 0.33$, $p = .72$) (Table 2).

Korean ANL in Bilingual Listeners

ANL was obtained in Korean (ANL-K) for both proficiency groups. The mean ANL-K for the MPB group was 7.3 dB (range 4 to 14) and for the LPB group was 7.7 dB (4 to 12), respectively. Table 2 shows the ANL means,

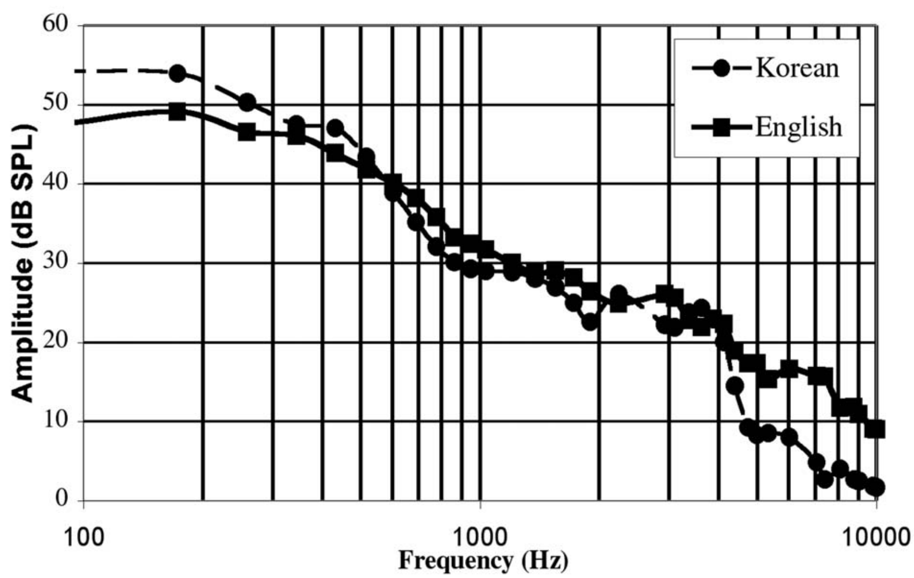

Figure 1. Long-term average-speech spectra of the English and Korean speech stimuli.

ranges, and standard deviations obtained for the bilingual groups. A two-way analysis of variance was used to determine differences between the means of the two groups. There was no significant difference among the means of the two groups ($F[1,18] = 3.23$, $p = 0.09$).

Speech Perception in Noise

The performance-intensity functions for high- and low-predictability sentences on the R-SPIN (English) are shown for the ME, LPB, and MPB groups in Figure 2. The LPB group did not benefit from sentence predictability in the same way that the MPB and ME groups do. That is, performance on the HP sentences was not better than performance on the LP sentences for all SNR conditions. The MPB group showed improved performance on HP sentences relative to the LP sentences at all SNRs, suggesting an improved ability to take advantage of contextual information in the signal over the LPB group. The ME group showed the most improvement on HP sentences, demonstrating maximal capability to benefit from contextual redundancy in the message. A mixed-design analysis of variance was used to analyze the data. The within-subject factors were SNR condition (4 levels: -3, 0, +3, and +6 dB) and sentence predictability (2 levels: HP and LP). The between-subjects factor was proficiency group (3 levels: MPB, LPB, and ME). A three-way interaction (SNR by predictability by proficiency) was significant ($F[5, 60] = 3.737$, $p = 0.004$). The performance on the KSPIN at +6 dB SNR for the LPB group was 94.17% and for the MPB group was 96.88%. A one-way analysis of variance showed no significant difference between the two groups at +6 dB SNR.

Pearson correlation coefficients were used to calculate the association between the ANL and the speech perception tests (R-SPIN and KSPIN) at +6 dB SNR for each group. This particular SNR was evaluated because it closely matches the SNR tested by Nabelek et al (2004), which was +8 dB. The correlations between ANL-Es and R-SPIN (English) scores were nonsignificant ($r = 0.51$, $r = -0.33$, $r = 0.07$) for the ME, MPB, and LPB

Table 2. Means, Ranges (Minimum to Maximum), and Standard Deviations (SD) in dB for Acceptable Noise Level in English (ANL-E) and Korean (ANL-K) for Each of the Three Groups: Monolingual English (ME), Moderate Proficiency Bilinguals (MPB), and Low Proficiency Bilinguals (LPB)

Group		N	ANL-E	ANL-K
ME	Mean	10	6.4	-
	Range		-2 to 20	
	SD		6.3	
MPB	Mean	8	8.0	7.3
	Range		4 to 14	4 to 14
	SD		3.5	3.7
LPB	Mean	12	6.8	7.7
	Range		4 to 10	4 to 12
	SD		1.8	2.8

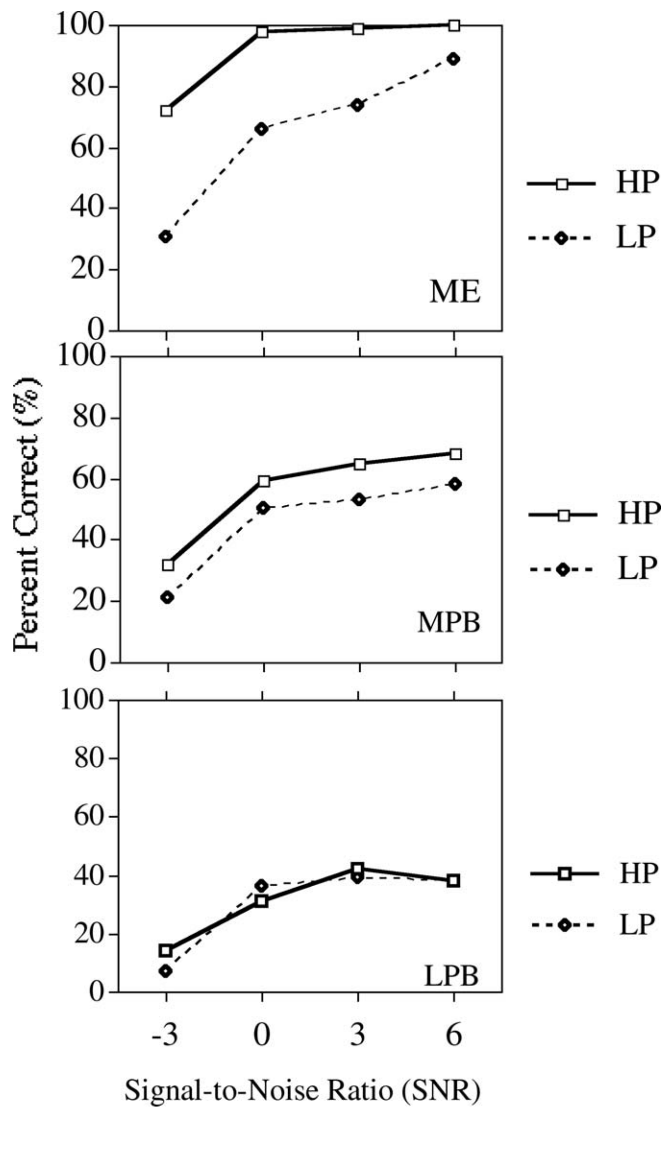

Figure 2. Percent correct scores for the HP (high predictability) and LP (low predictability) sentences on the Revised SPIN test for the LPB (low proficiency bilingual), MPB (moderate proficiency bilingual), and ME (monolingual English) groups.

groups, respectively. Also, the correlation coefficients between R-SPIN scores and ANLs were calculated separately for high- and low-predictability sentences for all 30 listeners. Both correlations were nonsignificant for HP and LP sentences ($r = -0.06$ and $r = 0.01$, respectively). Additionally, the correlation between ANL-K and KSPIN scores were nonsignificant ($r = .28$ and $r = .38$) for the MPB and LPB groups, respectively. Similarly, the correlation coefficients between KSPIN and ANL-K, calculated separately for high- and low-predictability sentences for the bilingual listeners, were nonsignificant for HP and LP sentences ($r = .24$ and $r = .28$, respectively). Taken together, these results suggest no significant correlations between the speech perception in noise tests and the ANL measures obtained in either language.

DISCUSSION

Acceptable Noise Levels in L2 (English)

The present study examined the characteristics of acceptable noise levels (ANLs) in bilingual listeners with different self-reported English proficiency in comparison to a monolingual group of English listeners. The characteristics of the ANL have been studied only with English listeners but have not been studied in listeners with diverse linguistic backgrounds. Thus, a first goal of this study was to determine whether ANLs obtained in a bilingual's L2 (English in this case) were significantly different from those of their monolingual counterparts, as it has been shown that speech perception in noise is significantly affected in bilingual listeners (Mayo et al, 1997). The mean ANLs obtained in English in bilingual listeners were not significantly different from ANLs of monolingual English listeners in the present study. Previous research on ANL-E in monolingual English listeners has consistently shown high variability in ANL across individuals, with an approximate range of 2–25 dB. The variability observed for the monolingual speakers in the present study is consistent with previous research yielding a large range of ANL-E scores (-2 to 20 dB); however, the range and standard deviations of the ANL-E in bilinguals shows a more truncated range (4–14 dB) of ANLs. At this point, it is unknown why these Korean-English bilinguals evidence a smaller range of ANLs than monolinguals. Is it possible that cultural factors may account for the difference in the range of acceptable noise levels between monolingual American listeners and bilingual Korean listeners? Research in the area of pain perception suggests that cultural factors may account for differences in how pain is experienced across cultures, and can affect pain-related behavioral responses such as the decision to adhere to treatment or to seek treatment (Bates, 1996). Thus, future studies should examine whether a person's willingness to listen to background noise is influenced by sociocultural factors as this may affect hearing aid outcome patterns cross-culturally. Another factor that may account for the reduced variability observed in bilinguals may be related to the method of instruction given in the present study. That is, the majority of bilingual individuals were instructed twice, once in English in verbal and written format, and then verbally in Korean, whereas the listeners in the ME group were only instructed in English.

Research on bilingual speech perception has highlighted the fact that listeners who learn the L2 later in life can experience moderate levels of difficulty understanding speech in the presence of background noise, relative to their monolingual peers, despite having up to 16 years of experience with the L2 (i.e., Mayo et al, 1997; von Hapsburg et al, 2004). The present study is consistent with previous research in this regard, showing poor performance for both bilingual groups relative to the monolingual group on speech understanding in noise. Although the three groups differed in the extent to which they could take advantage of sentence predictability, presumably related to their L2 proficiency, a difference in ANLs was not observed for these groups. Moreover, consistent with previous research on ANL (e.g., Nabelek et al, 2004), there was no significant relationship between ANL and performance on the SPIN at +6 dB SNR for both the HP and LP conditions. Taken together, the results of the present study suggest that although bilinguals may have difficulty understanding speech in noise, their willingness to listen to, or their ability to accept, background noise when listening to the L2 may be determined by other factors not related to speech understanding. These results suggest that the ANL measure may not be mediated by language experience in emerging bilingualism.

According to the U.S. Census Bureau, approximately 3.4 million children with limited English proficiency lived in the United States between the years 1997 and 2000 (U.S. Census Bureau, 2003). Concerns have been raised about the educational impact of poor speech understanding in the presence of background noise in the classroom environment (Crandell and Smaldino, 1996). Thus, it may be the case that a child's potential for success in the scholastic environment (noisy and reverberant) might also be influenced by the child's ability to accept background noise when listening to speech. The results of this study suggest that as a bilingual's proficiency improves with exposure to the L2, speech understanding in noise may also improve, but ANLs may remain stable. Future research should examine the relationship between ANL and learning outcomes in bilinguals.

Acceptable Noise Levels in the L1 (Korean)

A second goal of this study was to determine whether the ANL could be obtained in a language other than English. ANLs were obtained in Korean for two groups of Korean listeners. The mean, range, and standard deviation of Korean ANLs obtained for the two bilingual groups did not differ significantly, despite the fact that the LPB group ranked their Korean language skills higher than the MPB group. This suggests that the ANL is a potentially stable measure of a person's noise acceptance that is not affected by changes in language use patterns within bilinguals. The ANL-K should be studied in Korean monolinguals in order to determine whether bilingual patterns of noise acceptance differ from those of monolinguals, as it has been shown that bilingual linguistic processing often shows evidence of interaction among the languages used by an individual (Hernandez et al, 1994; von Hapsburg and Peña, 2002). The results of the present study may or may not apply to tone languages that have been shown to depend heavily on frequency resolution and that may ultimately require a different approach to how hearing aids are fitted to this linguistic population (Fu et al, 2004).

Additionally, when compared cross-linguistically (Korean ANL to English ANL), within bilinguals, the Korean ANLs were very similar to the English ANLs (obtained in bilinguals). The means and ranges for the Korean ANLs were highly similar to the English ANLs obtained from the same listeners (but the ranges were different from the monolingual English listeners). This preliminary examination of potential language effects suggests that the ANL may yield consistent measures (mean and range) regardless of language of test in a bilingual listener. The results from this study suggest that although the ANL may have large variability, it is consistent across languages within bilinguals. Taken together, these results suggest that the ANL measure is a language-independent measure as neither L2 proficiency differences nor language of test seemed to affect ANLs in these listeners.

Clinical Implications

The ANL in English listeners has correlated well with hearing aid use patterns in listeners with hearing impairment (Nabelek et al, 2004). For example, full-time hearing aid users have relatively lower ANLs (are willing to put up with more noise) than part-time hearing aid users and nonusers. If indeed the ANL measure taps into a different aspect of listening in noise than does speech understanding in noise, it may prove to be beneficial in predicting hearing aid use in listeners who speak languages other than English. Future studies should examine how the ANL correlates with hearing aid use in other language communities. According to the U.S. Census Bureau (2004), the Asian population accounts for the second largest minority group in the United States, accounting for 11.9 million people. Currently there is a shortage of bilingual audiologists in the United States and a shortage of audiometric materials in Asian languages. The preliminary results of this study suggest that the ANL could be reliably obtained in the L2, English, for language users with minimal L2 experience of at least 2.6 years. Thus, a measure such as the ANL that does not rely on the assessment of speech understanding may facilitate hearing aid service delivery to linguistic minorities in the United States. Additionally, studies with monolingual Korean hearing aid users are needed to confirm whether hearing aid success correlates with ANL measures in Korean and whether there are sociocultural factors that influence listeners' willingness to accept noise.

CONCLUSIONS

Bilingual listeners experience difficulty with speech perception in noise even when they have substantial experience listening to and using the L2 (Florentine, 1985; Mayo et al, 1997; von Hapsburg et al, 2004). It has been shown that bilingual listeners need improved SNR in order to perceive the L2 in noise like their monolingual counterparts. At this point, it is unknown whether there is a correlation between any aspect of second language acquisition/learning and ANL. That is, do bilinguals with lower ANLs report less frustration with learning or using L2? Do bilinguals with lower ANLs consider themselves more successful L2 language users than those who have higher ANLs? Are the effects of noise on bilingual students with lower ANLs less deleterious to learning outcomes than on those with higher ANLs? Understanding the variables that influence listening in noise is not only crucial to our understanding of hearing aid outcome but may help us understand factors that affect second-language perception and patterns of language use as well.

REFERENCES

Bates MS. (1996) *Biocultural Dimensions of Chronic Pain: Implications for Treatment of Multiethnic Populations.* Albany: State University of New York Press.

Bilger RC, Neutzel JM, Rabinowitz WM, Rzeczkowski C. (1984) Standardization of a test of speech perception in noise. *J Speech Lang Hear Res* 27:32–48.

Buus S, Florentine M, Scharf B, Canevet G. (1986) Native French listeners' perception of American-English in noise. *Internoise* 21–23:895–898.

Crandell CC, Smaldino JJ. (1996) Speech perception in noise by children for whom English is a second language. *Am J Audiol* 5:47–51.

Crowley HJ, Nabelek IV. (1996) Estimation of client-assessed hearing aid performance based upon unaided variables. *J Speech Hear Res* 39:19–27.

Florentine M. (1985) Non-native listeners' perception of American-English in noise. *Internoise* 18–20:1021–1024.

Freyaldenhoven MC, Nabelek AK, Burchfield SB, Thelin JW. (2005) Acceptable noise level as a measure of directional hearing aid benefit. *J Am Acad Audiol* 16:228–236.

Fu QJ, Chuan-Jen H, Mei-Ji H. (2004) Effects of speech processing strategy on Chinese tone recognition by nucleus-24 cochlear implant users. *Ear Hear* 25:501–508.

Grosjean F. (1998) Studying bilinguals: methodological and conceptual issues. *Bilingualism Lang Cogn* 1:131–149.

Hernandez AE, Bates EA, Avila LX. (1994) On-line sentence interpretation in Spanish-English bilinguals: what does it mean to be "in between." *Appl Psycholinguist* 15:417–446.

Kim JS, Pae SY, Lee JH. (2000) Development of a test of Korean speech intelligibility in noise (KSPIN) using sentence materials with controlled word predictability. *J Speech Sci* 7:37–50.

Lytle SR. (1994) A comparison of amplification efficacy and toleration of background noise in hearing impaired elderly persons. MA thesis, University of Tennessee, Knoxville.

Mayo LH, Florentine M, Buus S. (1997) Age of second-language acquisition and perception of speech in noise. *J Speech Lang Hear Res* 40:686–693.

Nabelek AK, Tampas JW, Burchfield SB. (2004) Comparison of speech perception in background noise with acceptance of background noise in aided and unaided conditions. *J Speech Lang Hear Res* 47:1001–1011.

Nabelek AK, Tucker FM, Letowski TR. (1991) Toleration of background noises: relationship with patterns of hearing aid use by elderly persons. *J Speech Lang Hear Res* 34:679–685.

Rogers DS, Harkrider AW, Burchfield SB, Nabelek AK. (2003) The influence of listeners' gender on the acceptance of background noise. *J Am Acad Audiol* 14:374–385.

Takata Y, Nabelek AK. (1990) English consonant recognition in noise and in reverberation by Japanese and American listeners. *J Acoust Soc Am* 88:663–666.

U.S. Census Bureau. (2003) *Language Use and English-Speaking Ability: 2000. Census 2000 Brief.* U.S., C2KBR-29. http://www.census.gov/prod/2003pubs/c2kbr-29.pdf (accessed June 20, 2004).

U.S. Census Bureau. (2004) *Hispanic and Asian Americans Increasing Faster Than Overall Population.* http://www.census.gov/Press-Release/www/releases/archives/race/001839.html (accessed June 20, 2004).

von Hapsburg D, Champlin CA, Shetty SR. (2004) Reception thresholds for sentences in bilingual (Spanish/English) and monolingual (English) listeners. *J Am Acad Audiol* 15:88–98.

von Hapsburg D, Peña ED. (2002) Understanding bilingualism and its impact in speech audiometry. *J Speech Lang Hear Res* 45:202–213.