The Influence of Listener's Gender on the Acceptance of Background Noise

Deanna S. Rogers*
Ashley W. Harkrider*
Samuel B. Burchfield*
Anna K. Nabelek*

Abstract
The acceptance of background noise can be assessed by having participants select the maximum background noise level (BNL) to which they are willing to listen while following speech at their most comfortable listening level (MCL). The difference between the selected BNL and MCL is the acceptable noise level (ANL). Preliminary investigations have revealed large between-participant ANL differences that are not related to age, hearing status, preference for background noise, or uncomfortable listening level. This study investigated listener's gender as a possible factor contributing to these between-participant differences. Comfortable listening levels for speech and accepted levels of speech-babble background noise were obtained binaurally, via the sound field, from 50 (25 male, 25 female) young, acoustically naive adults with normal hearing sensitivity. Results indicate that, although males had higher comfortable listening levels and accepted higher levels of background noise than females, ANL values were not different between males and females.

Key Words: Acceptable noise levels, background noise level, gender difference, most comfortable listening level, signal-to-noise ratio

Abbreviations: ANL = acceptable noise level; BNL = background noise level; MCL = most comfortable listening level; PHAP = Profile of Hearing Aid Performance; UCL = uncomfortable listening level

Sumario:
La aceptación del ruido de fondo puede ser evaluada haciendo que los participantes seleccionen el nivel máximo de ruido de fondo (BNL) al cuál están dispuestos a escuchar, mientras escuchan lenguaje en su nivel de audición más confortable (MCL). La diferencia entre el BNL y el MCL seleccionados es el nivel de ruido aceptable (ANL). Las investigaciones preliminares han revelado grandes diferencias en el ANL entre los participantes, que no se relacionan con la edad, estado auditivo, preferencia por el ruido de fondo, o nivel poco confortable de audición. Este estudio investigó el género del oyente, como un posible factor que explicara las diferencias entre los participantes. Los niveles confortables de audición para el lenguaje y los niveles aceptables de ruido de fondo para lenguaje/conversación se obtuvieron binauralmente, a través de un campo libre, utilizando 50 adultos (25 hombre, 25 mujeres) jóvenes, sin condicionamiento acústico previo, con sensibilidad auditiva normal. Los resultados indican que, aunque los hombres tuvieron niveles confortables de audición más altos y aceptaron niveles más altos de ruido de fondo que las mujeres, los valores de ANL no fueron diferentes entre hombres y mujeres.

*University of Tennessee, Knoxville

Reprint requests: Ashley W. Harkrider, University of Tennessee, Department of Audiology and Speech Pathology, 457 South Stadium Hall, Knoxville, TN 37996; Phone: 865-974-1810; E-mail: aharkrid@utk.edu

Palabras Clave: Niveles aceptables de ruido; niveles de ruido de fondo; diferencias de género; nivel de audición más confortable; tasa de relación señal/ruido.

Abreviaturas: ANL = nivel aceptable de ruido; BNL = nivel de ruido de fondo; MCL = nivel auditivo más confortable; PAP = Perfil de Rendimiento del Auxiliar Auditivo; UCL = nivel auditivo no confortable.

Nabelek et al. (1991) developed a procedure to assess the maximum amount of background noise that individuals are willing to accept while listening to speech. In this procedure, participants adjust running speech to their most comfortable level (MCL). Next the participants adjust background noise to the maximum level that they are willing to accept while listening to and following the words of the speech (BNL). The difference in decibels between the MCL for speech and the BNL for background noise is the acceptable noise level (ANL), introduced as "tolerated noise" by Nabelek et al. (1991). Preliminary investigations have shown that ANL values are highly reliable within and between test sessions but that individuals differ widely in their acceptance of background noise (Nabelek et al., 1991; Lytle, 1994; Crowley and Nabelek, 1996; Fisher et al., 2000; Franklin et al., 2001). These individual differences are the most consistent finding in prior investigations and have not been explained.

Nabelek et al. (1991) examined the relationship between hearing aid use and ANL in three groups of 15 elderly participants with sensorineural hearing loss. They were full-time, part-time, and nonusers of their hearing aids. For control purposes, the speech and background noise stimuli were filtered to approximate hearing aid processed signals and were presented via earphones. Results revealed that full-time hearing aid users had smaller ANLs (they accepted significantly higher levels of background noise) than part-time and nonusers. For comparison, ANL was also measured in 15 young (mean age = 22 years) and 15 elderly (mean age = 71 years) participants with normal-hearing sensitivity. Average ANLs and the distribution of ANLs were not significantly different. ANLs for these normally hearing elderly participants were also not significantly different from the elderly participants with sensorineural hearing loss. These results suggest that the acceptance of background noise is related to hearing aid use but not related to age or hearing loss.

Lytle (1994) compared the acceptance of background noise (called tolerated noise in this study) in successful and unsuccessful hearing aid users with and without their own personal hearing aids. Two experimental groups, each containing ten participants, were matched according to age, hearing sensitivity, and speech perception. They differed only in their success with hearing aids. All stimuli were presented in the sound field. Successful hearing aid users accepted significantly more background noise than unsuccessful hearing aid users. This difference was present both with and without hearing aids. These findings suggest that ANL is related to amplification outcome and that it may be useful in predicting use before hearing aids are actually tried.

Crowley and Nabelek (1996) investigated ANL as one of several other factors, which might predict success of hearing aid performance, use, and satisfaction before hearing aids are purchased. Data were collected on 46 participants (31 males and 15 females), based on 16 unaided variables including accepted (referred to as "tolerated" in this study) noise level for babble and speech spectrum noise. All stimuli were presented in the sound field. Regression analysis showed poor predictive values for most of the variables investigated. However, ANL predicted values that matched scores on the Profile of Hearing Aid Performance (Cox and Gilmore, 1990) within almost 12% for 75% of the participants. Thus, consistent with Lytle's (1994) findings, successful hearing aid use was found to be related to ANL.

Fisher et al. (2000) investigated the reliability of ANL and the relationship between ANL and preference for background noise in 12 young individuals with normal hearing. The ANL was measured, in dB HL, via earphones during three experimental sessions separated by one week. The participants responded consistently during each session and over the three-week period, yielding a strong positive correlation and indicating high test–retest reliability. The preference for background noise was established with a questionnaire that determined the preferred type and amount of background noise when engaged in a number of daily activities including doing "chores," driving, reading, sleeping, and studying. The comparison between ANL and the reported preference for background noise resulted in a weak correlation. This suggests that the ANL is a reliable measure but that the preference for background noise does not correspond with the ability to accept background noise. The data collected in this study from young participants with normal hearing and the data collected by Nabelek et al. (1991) in elderly participants with normal hearing were remarkably similar although not identical (Table 1). This suggests that the acceptance of background noise may be consistent over the life cycle.

Franklin et al. (2001) compared the relationship between ANL and uncomfortable levels (UCL) in 23 normal-hearing young adults (18–25 years old). Stimuli were presented in the sound field. Results showed that ANL and UCL are not related.

A consistent and somewhat perplexing finding in prior ANL investigations has been an unexpectedly large range of differences in the acceptance of background noise. ANL scores have ranged from near 0 dB up to 25–30 dB or even higher and have been seen in young and elderly participants, in participants with and without hearing loss, and in participants that like and dislike background noise. Our failure to understand why individuals differ so much in their acceptance of background noise provided the impetus for this study. It may be that a factor that has not previously been considered, the listener's gender, is influencing this auditory judgment.

Studies have documented numerous gender differences within physiological and psychophysical areas of the auditory system (for review see McFadden, 1998). Physiologically,

Table 1 Means (M), Ranges, and Standard Deviations (SD) for Acceptable Noise Level (ANL) (in dB) for Individuals with Normal Hearing from Nabelek et al. (1991), Fisher et al. (2000), and Franklin et al. (2001).

Study		n	Speech Babble	Speech-Spectrum Noise
Nabelek et al.	M	15	11.7	12.7
(elderly)	Range		0–27	2–23
	SD		7.6	8.1
Nabelek et al.	M	15	15.9	14.3
(young)	Range		5–37	5–28
	SD		8.5	5.8
Fisher et al.	M	12	12.5	14.0
(young)	Range		5–22	5–29
	SD		4.6	2.5
Franklin et al.	M	23	9.4	Did not test
(young)	Range		2–25	Did not test
	SD		6.4	Did not test

Note: Data are for speech-babble and speech-spectrum background noise.

gender differences are evident in otoacoustic emissions (Bilger et al., 1990; Lonsbury-Martin et al., 1990; Robinette, 1992; Kimberley et al., 1993; Talmadge et al., 1993; McFadden, 1993; Penner et al., 1993; Kulawiec and Orlando, 1995; McFadden and Loehlin, 1995; McFadden et al., 1996; Moulin and Kemp, 1996; Shehata-Dieler et al., 1999; Ferguson et al., 2000; Cassidy and Ditty, 2001), auditory brainstem responses (Jerger and Johnson 1988; Don et al. 1993; McFadden and Champlin 2000), and middle latency responses (McFadden and Champlin 2000).

Psychophysical differences have been found between males and females in hearing sensitivity (Chung et al., 1983; Jerger et al., 1993; Dubno et al., 1997; Pearson et al., 1997; Stelmachowicz et al., 1989), binaural listening tasks (Tobias, 1965; Langford, 1994), noise-induced hearing loss (Royster et al., 1980), and measures of MCL (Hochberg, 1975; Decker, 1978). The effects of gender on ANL have not been systematically investigated. The possible influence of gender was ambiguous after a retrospective analysis of data comparing responses from male and female, elderly normal-hearing and hearing-impaired participants (Nabelek et al., 1991; Crowley and Nabelek, 1996). In one case, hearing-impaired males had a 2 dB lower ANL than hearing-impaired females, but because gender was not an experimental factor in that study, an uneven number of males (31) and females (15) were used (Crowley and Nabelek, 1996). After randomly selecting responses from an even number of males (15) and females (15), no significant gender differences were found. However, the overall number of hearing-impaired participants per group may have been too small to reveal a significant gender difference. Similarly, existing data on ANL in normal-hearing participants were available only for a small group (15 total) of elderly males and females (Nabelek et al., 1991), and there is evidence that gender differences for behavioral (e.g., Dubno et al., 1997; Pearson et al., 1997) and electrophysiological auditory responses (e.g., Amenedo and Diaz, 1998) change with age.

The purpose of this investigation was to determine if the listener's gender influences the ANL. There have been no systematic, large-scale investigations about the role that gender differences play in our acceptance of background noise. Determining this role in the variability of ANL may permit researchers to improve the effectiveness of ANL as a clinically useful predictor of successful hearing aid use, a tool that could become an important part of the prescriptive amplification battery.

METHOD

Participants

Fifty adults (25 male, 25 female) from the University of Tennessee, Knoxville, between the ages of 19–25 years served as the experimental participants. All participants had hearing thresholds of at least 15 dB HL across a frequency range of 250 to 8000 Hz and Type A tympanograms peaking between ±30 daPa, bilaterally. All participants were naïve listeners who had not had any coursework or research experience in audition. They had no history of significant noise exposure, auditory pathology, or exposure to ototoxic medications. All females were using oral contraceptives to ensure stable hormonal levels. This minimized transient changes in auditory responses caused by certain stages of menstruation (Miller and Gould, 1967; Baker and Weiler, 1977; Dengerink et al., 1984).

Apparatus and Test Materials

The apparatus and test materials for MCL and BNL were based on the Nabelek et al. (1991) procedure. The speech and speech-babble stimuli were delivered via two compact disc players (EIKI 7070) through an audiometer (GSI-16) calibrated to American National Standards Institute (ANSI, S3. 6-1996) standards. The stimuli were routed to a loudspeaker located at zero-degree azimuth, one meter from the participant in an audiometric booth (Industrial Acoustics model 404A). The audiometric sound booth met ANSI standards (S3. 1-1991) for acceptable ambient noise levels. An Audiotech digital recording of running male discourse was used as the primary stimulus. Speech babble (SPIN test; Kalikow et al., 1977) was added as the competing stimulus.

Procedure

Prior to testing, each participant was given verbal and written instructions describing the experiment and his/her task (see below). Following the instructions, each participant practiced adjusting the level of the background noise. Both MCL and BNL were determined using a method of adjustment and bracketing.

MCL was found for each participant by using two handheld buttons that signaled the experimenter to adjust the level of the discourse. The level of the discourse started at 0 dB HL and increased in steps of 10 dB until the participant signaled the experimenter to reduce the intensity. Then, the level of the discourse was adjusted in 2 dB steps. The participant adjusted the level of the discourse below his/her MCL and then raised the level to his/her MCL. The verbal and written instructions for measuring MCL were as follows:

> You will be listening to male speech. After you listen for a few moments you will be asked to adjust the loudness to a level that is most comfortable to you. You will be given two handheld buttons that will allow you to adjust the level of the speech louder or softer, in small increments. In order to obtain a reference level, please adjust the loudness up to a level that is too loud and then down to a level that is too soft. Then, adjust the loudness of the story to a level that is most comfortable to you. Tell me when you have reached your most comfortable level.

To establish the participants' BNL, the running male discourse was continuously presented at MCL while the speech-babble noise was adjusted. The speech-babble noise started at 0 dB HL and was increased in 10 dB steps until the participant signaled the experimenter to decrease the volume. Then, the speech-babble noise was adjusted in 2 dB steps either up or down until the individual reached his/her maximum BNL. The procedure to establish BNL was completed three times, and the average of the three was used in the calculation of ANL. The verbal and written directions for measuring BNL were as follows:

> You will be listening to speech at your most comfortable level, which you have established. Then background noises, which sound like several people talking, will be added. You will be asked to adjust the level of background noise to a level, which would be deemed acceptable while listening to speech without becoming tense or tired while following the words of the story. To establish a reference please adjust the level of the background noise up to an unacceptable level, and then down to a level that is softer and then back up to the maximum amount of acceptable background noise. The amount of attention you give to the story is completely up to you. Please give the same amount of attention to the story each time the procedure is completed.

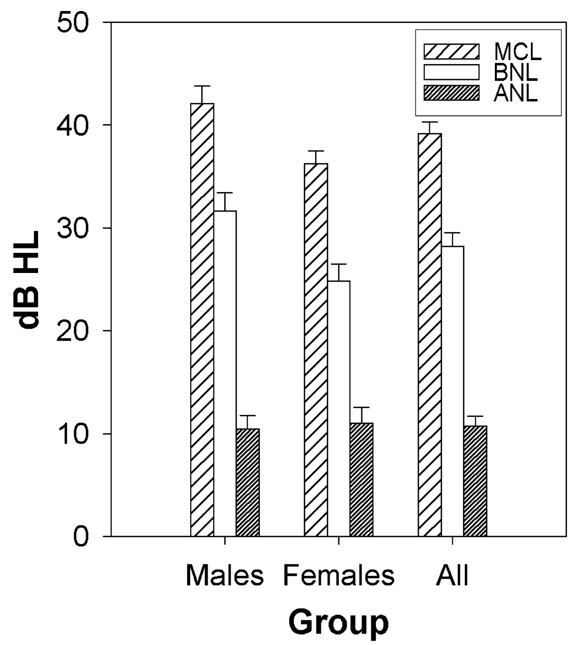

Figure 1 Mean most comfortable level (MCL), accepted background noise (BNL), and acceptable noise level (ANL) for males, females, and all subjects. Error bars denote one standard error from the mean.

Participants were tested in one thirty-minute experimental session. During this session the participant reported one judgment of MCL to speech and three judgments of BNL. The ANL was calculated by subtracting the average of the three judgments of BNL from their MCL judgment (ANL = MCL - BNL).

RESULTS

MCLs, average BNLs, and ANLs are reported for 50 normal-hearing young adults (25 males, 25 females). Means, ranges, and standard deviations for these measures are shown in Table 2 and Figure 1. A one-factor repeated measures MANOVA was conducted. The factor was gender (two levels),

Table 2 Means, Ranges (Minimum to Maximum), and Standard Deviations (SD) in dB HL for Most Comfortable Level (MCL), Accepted Background Noise (BNL), and Acceptable Noise Level (ANL) for Females, Males, and All Subjects

Group		n	MCL	BNL	ANL
Females	M		36.2	24.8	11.4
	Range	25	24–54	7.3–38.7	0–24.7
	SD		6.3	8.3	7.7
Males	M		42.1	31.7	10.4
	Range	25	28–58	11.3–46.7	0–24.0
	SD		8.7	8.8	6.6
All	M		39.2	28.3	10.9
	Range	50	24–58	7.3–46.7	0–24.7
	SD		8.1	9.2	7.1

and dependent variables were MCL, BNL, and ANL. Significance was found for the main effect of gender ($F2, 47 = 690.373$, $p=.001$) and the interaction of gender with the dependent variables ($F2, 47 = 4.354$, $p = .018$).

In order to explore the significant interaction found with the MANOVA, three one-factor ANOVAs were conducted, one for MCL, one for BNL, and one for ANL (Table 3). The factor was gender (2 levels). A significant interaction was obtained between gender and MCL ($F1, 48 = 7.44$, $p < .009$), indicating that males have significantly higher MCLs than females. Also, a significant interaction was found between gender and BNL ($F1, 48 = 7.99$, $p < .007$), indicating that males accepted a higher intensity of background noise than females. No significant interaction was found between gender and ANL ($F1, 48 = .087$, $p < .769$), indicating that males and females accepted approximately the same relative amount of background noise while listening to speech at MCL.

DISCUSSION

Gender Differences in ANL

The finding of no gender difference in ANL is in accord with a retrospective analysis of past findings for ANL in studies with a small number of elderly participants with normal hearing (Nabelek et al., 1991) and hearing impairment (Nabelek et al., 1991; Crowley and Nabelek, 1996). Nabelek et al. (1991) were not specifically looking at gender differences in ANL; however, in a small group of elderly males and females with normal hearing and hearing impairment, no significant differences were found. Similarly, a retrospective analysis of the Crowley and Nabelek (1996) results revealed no significant difference between ANLs measured from males and females of adult participants with hearing impairment. In that study, because gender was not an experimental factor, an uneven number of males (31) and females (15) were used as participants, and males had approximately a 2 dB lower ANL than females.

Table 3 Results of Post Hoc One-Factor ANOVAs on Most Comfortable Level (MCL), Accepted Background Noise (BNL), and Acceptable Noise Level (ANL)

Dependent Variable	Degrees of Freedom	Error Degrees of Freedom	Mean Square	Total Sum of Squares	F	Significance
MCL	1	48	426.3	79852.0	7.44	.009
BNL	1	48	587.1	44022.7	8.00	.007
ANL	1	48	4.5	8219.5	.09	.769

Note: Gender is the factor.

After randomly selecting responses from an even number of males (15) and females (15), no significant gender differences were found. A comparison of data from these two studies and the present study can be found in Table 4.

The results of the present study show that males and females are judging background noise similarly while listening to speech at MCL. Despite the fact that no significant difference was found between male and female ANLs, there was a significant difference within the MCLs and BNLs of males and females in this study.

Gender Differences in MCL

Statistical significance was found between the MCLs of males and females.

Males on average had a 6 dB higher MCL than females. These results were consistent with the previous findings of Hochberg (1975) and Decker (1978), despite the fact that these studies measured MCL as a function of stimulus intelligibility. Hochberg (1975) found that when young (18 to 26 year olds) males (14) and females (16) with normal hearing listened to a message for intelligibility that males had a 5 dB higher MCL than the females. He also found that when males with normal hearing listened to speech for loudness, they had a 4 dB higher MCL than females. Decker (1978) obtained similar results with young (21 to 32 year olds), normal-hearing males and females (15/group). Males had a 5.5 dB higher MCL than females when the speech was meaningful (contained a message) but not when speech was nonmeaningful.

MCLs in this study ranged from 28–58 dB HL for males and 24–54 dB HL for females (Table 5). The gender difference in MCL and the wide range of MCLs was present also in the data from elderly participants with normal hearing in the Nabelek et al. (1991) study. In that study, there was approximately a 6 dB difference with males preferring higher MCLs than females. The range of MCLs for the male participants was from 50–85 dB SPL, and the range for female participants was 45–70 dB SPL (Table 5). For this table, data measured in dB HL in this study were converted to dB SPL and adjusted for sound field and earphone differences to facilitate comparisons to those data reported in Nabelek et al. (1991). The similarities in the data from young (present study) and elderly (Nabelek et al., 1991) normal-hearing participants suggest that the effect of gender on MCL does not change with age.

The lower MCLs measured from females versus males may be due, in part, to the overall differences in the sensitivity of their auditory systems. Females, on average, have better hearing thresholds than males at frequencies between 2000–8000 Hz (Chung et al., 1983), indicating better auditory sensitivity. The low frequencies provide 95% of speech power, whereas the high frequencies provide 95% of speech intelligibility (Gerber, 1974). Therefore, it is possible that males, who have poorer hearing in the higher frequencies, would need more speech intensity in order to fully understand the speech signal. Consistent with this behavioral finding, female cochleae produce more SOAEs (e.g., Bilger et al., 1990; Talmadge et al., 1993; McFadden and Loehlin,

Table 4 Comparison of Means and Ranges of Acceptable Noise Levels (ANL) (in dB), from Individuals with Normal Hearing (NH) (Present Study and Nabelek et al., 1991) and Individuals with Hearing Impairment (HI) (Nabelek et al., 1991 and Crowley and Nabelek, 1996).

Study		n (F/M)	Females	Male	Difference
Present (young NH)	Mean	25/25	11.0	10.4	0.6
	Range		0–25	0–24	
Nabelek et al. (elderly NH)	Mean	8/7	11.0	11.4	0.4
	Range		5–19	2–20	
Nabelek et al. (elderly HI)	Mean	22/23	11.2	11.5	0.3
	Range		3–22	2–27	
Crowley (all ages HI)	Mean	15/15	8.7	7.8	0.9
	Range		1-24	0-22	

Note: The current study is measured in dB HL, and the other studies are measured in dB SPL. Because ANL is a difference measure, no conversion is needed for appropriate comparison.

1995) and stronger CEOEAs (e.g., Robinette, 1992; Kulawiec and Orlando, 1995; McFadden et al., 1996) and DPOAEs (e.g., Lonsbury-Martin et al., 1990; Kimberley et al., 1993; Shehata-Dieler et al., 1999) than male cochleae. These results indicate that the cochleae of females are more sensitive to low to moderate level acoustic stimulation.

Gender Differences in BNL

Males accepted a higher intensity of background noise while listening to speech at MCL, by approximately 7 dB, than females. The frequency spectrum of speech babble used as the competing signal in this study is similar to that of speech, such that lower frequencies have more intensity than higher frequencies. The composition of speech babble is similar to that of speech noise, which is white noise filtered at 12 dB per octave above 1000 Hz and 3 dB per octave below 1000 Hz (Martin, 1997). Pearson et al. (1997) found that males have more sensitive hearing below 1000 Hz than females do. It would seem that since males have slightly better hearing in the lower frequencies than females, they would prefer a lower intensity level of background noise. However, the results of this study indicate the opposite. Males accepted a higher level of background noise than females.

In a review article of gender differences in the auditory system, McFadden (1998) reported several differences between males and females involving complex masking tasks. Neff et al. (1996) found that males as a group were able to detect a common signal in the presence of an array of maskers at a lower intensity than females. Wright (1994) found more lateral suppression in males than in females, indicating that inhibition is stronger in males versus females. Since background noise can serve as a masker in many circumstances, it seems that males are able to accept a higher intensity of background noise and still be able to follow the signal or message. Consistent with this, Knott (1984) found that females show more distractibility when an auditory task requires cognitive effort than when the task does not. Therefore, it is possible that, in the current study, a higher-level background noise caused greater distractibility in the female versus male participants, and, therefore, females preferred a lower level of background noise when listening to the running discourse than males. Interestingly, Garstecki and Erler (1998) report that male elderly hearing aid users who follow the recommendation to wear hearing aids are less likely to be impatient with their hearing loss, to experience negative feelings during everyday communication, and to rely on nonverbal communication than their female counterparts. Perhaps this can be attributed, in part, to the higher BNLs in males versus females reported in this study.

ANL and S/N Ratio

Even though male participants had a higher MCL and a higher BNL than females, the ANL was the same for the two

Table 5 Most Comfortable Level (MCL) Means and Ranges (in dB SPL) for Males and Females with Normal Hearing

	Females	Males	All
Current Study, Young Subjects			
Mean	56.2*	62.1*	59.2*
Range	44–74*	48–78*	44–78*
n	25	25	50
Nabelek et al. (1991), Elderly Subjects			
Mean	60.6	67.3	63.7
Range	45-70	50-85	45-85
n	8	7	15

*Converted from HL to SPL and adjusted for sound field and earphone differences.

genders, approximately an 11 dB difference between the speech signal and the competing background noise. This indicates that both males and females accept similar signal-to-noise (S/N) ratios while listening to speech presented at MCL.

It should be noted that S/N ratio and ANL are conceptually different. Traditionally, the term S/N ratio implies that speech perception is being measured in the presence of background noise. In contrast, ANL is not a measurement of speech perception in noise but a measurement of the accepted level of noise while listening to speech at MCL.

There are numerous situations that require an individual to extract a speech signal from background noise. Pearsons et al. (1977) reported S/N relationships for conversational, social, and environmental situations. They reported that in the majority of conversations the S/N ratio is between +5 to +8 dB, meaning the speech is about 5 to 8 dB more intense than the background noise. Pearsons et al. (1977) showed that the +5 to +8 dB S/N ratio is maintained by adjustment of voice effort relative to background noise. In a social situation such as a cocktail party the S/N ratio can be reduced as low as +1 dB. In many environmental situations, for example, traffic, the S/N ratio can be 0 dB or even worse. The results of the present study show that individuals accepted about an 11 dB ANL. This ANL may be due to the fact that, while individuals are used to listening at a S/N ratio of +5 to +8 dB in most conversational settings (Pearsons et al., 1977), they may be experiencing a slight difficulty extracting the signal at MCL from the background noise, and this difficulty may be considerably tiring. Therefore, even though individuals with hearing aids can, and do, function often in a poorer S/N ratio of +5 to +8 dB, they actually accept a larger difference between a signal at MCL and the background noise, as measured by the ANL of 11 dB reported in this study.

Individual Variability in S/N Ratio and ANL

There is variation among individuals in the amount of background noise that they can accept and still understand speech. Extracting speech from background noise may be an easy task for one person, and therefore, he/she can accept a poorer S/N ratio and still decipher speech. Studies evaluating acceptance of noise while listening to speech (ANL) have also found variability among individuals (Nabelek et al., 1991; Lytle, 1994; Crowley and Nabelek, 1996; Fisher et al., 2000; Franklin et al., 2001). Consistent with previously reported individual variability, ANLs ranged from 0 to 25 dB in this study and could not be explained by accounting for the listeners' gender.

Clinical Implications

In a clinical setting, patients with hearing impairment frequently complain about background noise, and this problem is not gender specific. Based on the results of the present study, it does not appear that accepted background noise levels while listening to speech (ANLs) are gender specific either. Nabelek et al. (1991), Lytle (1994), and Crowley and Nabelek (1996), in small participant groups, found that individuals who accepted a higher level of background noise while listening to speech were usually more successful with their hearing aids. Knowing an individual's ANL may objectively predict hearing aid use. This prediction would provide the clinician with valuable counseling and rehabilitation information. The most consistent finding among prior ANL studies is the large range of individual scores. Results of the present study show that this range is not related to the listeners' gender. Future research with ANL needs to address other possible reasons why individuals differ so much in their acceptance of background noise.

CONCLUSIONS

Due to the numerous gender differences previously reported within the auditory system and the large between-participant differences seen in previous ANL data, it would seem possible to see differences between male and female ANL scores. However, the results of the present study showed that no significant difference in ANL exists between males and females. Significant differences were found between the gender of the listener and MCL, as well as the gender of the listener and BNL. Male listeners had a higher MCL and accepted a higher BNL than females. Both the MCL and BNL are used to calculate the ANL. The differences between MCL and BNL were different by a consistent amount and direction, which resulted in similar ANLs for the male and female participants. These results indicate that males and females are judging background noise levels similarly and imply that they may prefer the same S/N ratios while listening to speech at MCL.

Acknowledgments. We would like to thank Jim Thelin, Ph.D., and our anonymous reviewers for their valuable input. This study was funded in part by NIH grant R01 DC 05018 from the National Institute on Deafness and Other Communication Disorders received by Anna Nabelek, Ph.D., and Samuel Burchfield, Ph.D.

REFERENCES

Amenedo E, Diaz F. (1998). Aging-related changes in processing of non-target and target stimuli during an auditory oddball task. *Biol Psychol* 48:235–267.

American National Standards Institute. (1991). *Maximum Ambient Noise Levels for Audiometric Test Rooms*. (ANSI S3. 1-1991). New York: American National Standards Institute.

American National Standards Institute. (1996). *American National Standards Specification for Audiometers*. (ANSI S3. 6-1996). New York: American National Standards Institute.

Baker MA, Weiler EM. (1977). Sex of listener and hormonal correlates of auditory thresholds. *Br J Audiol* 11:65–68.

Bilger RC, Matthies ML, Hammel DR, Demorest ME. (1990). Genetic implications of gender differences in the prevalence of spontaneous otoacoustic emissions. *J Speech Hear Res* 33:418–432.

Cassidy JW, Ditty KM. (2001). Gender differences among newborns on a transient otoacoustic emissions test for hearing. *J Music Ther* 38:28–35.

Chung DY, Mason K, Gannon RP, Wilson GN. (1983). The ear effect as a function of age and hearing loss. *J Acoust Soc Am* 73:1277–1282.

Cox RM, Gilmore C. (1990). Development of the Profile of Hearing Aid Performance. *J Speech Hear Res* 33:343–357.

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

Decker TN. (1978). The effects of informative and non-informative speech on the judgment of most comfortable listening level. *J Am Audiol Soc* 4:16–18.

Dengerink JE, Dengerink HA, Swanson S, Thompson P. (1984). Gender and oral contraceptive effects on temporary auditory effects of noise. *Audiol* 23:411–425.

Don M, Ponton CW, Eggermont JJ, Masuda A. (1993). Gender differences in cochlear response time: an explanation for gender amplitude differences in the unmasked auditory brain-stem response. *J Acoust Soc Am* 94:2135–2148.

Dubno JR, Lee F, Matthews LJ, Mills JH. (1997). Age-related and gender-related changes in monaural speech recognition. *J Speech Lang Hear Res* 40:444–452.

Ferguson MA, Smith PA, Davis AC, Lutman ME. (2000). Transient-evoked otoacoustic emissions in a representative population sample aged 18 to 25 years. *Audiol* 39(3):125–134.

Fisher D, Burchfield S, Nabelek A. (2000). Acceptance of Background Noise When Listening to Speech. Ph.D. project, University of Tennessee, Knoxville.

Franklin C, Burchfield S, Nabelek A, Thelin J. (2001). Comparison of Acceptance of Background Noise While Listening to Speech and Loudness Tolerance. Paper presented at the meeting of the American Speech-Language Hearing Association, New Orleans, LA.

Garstecki DC, Erler SF. (1998). Hearing loss, control, and demographic factors influencing hearing aid use among older adults. *J Speech Lang Hear* Res 41:527–537.

Gerber S. (1974). *Introductory Hearing Science*. Philadelphia: W.B. Saunders.

Hochberg I. (1975). Most comfortable listening for the loudness and intelligibility of speech. *Audiol* 14:27–33.

Jerger J, Chmiel R, Stach B, Spretnjak M. (1993). Gender effects audiometric shape in presbycusis. *J Amer Acad Audiol* 4:42–49.

Jerger J, Johnson K. (1988). Interactions of age, gender, and sensorineural hearing loss on ABR latency. *Ear Hear* 9:168–176.

Kalikow DN, Stevens KN, Elliot LL. (1977). Development of a test of speech intelligibility in noise using sentence materials with controlled word predictability. *J Acoust Soc Am* 61:1337–1351.

Kimberley BP, Brown DK, Eggermont JJ. (1993). Measuring human cochlear traveling wave delay using distortion product emission phase responses. *J Acoust Soc Am* 94:1343–1350.

Knott VJ. (1984). Noise and task induced distraction effects on information processing: sex differences in smokers and non-smokers. *Addict Behav* 9:79–84.

Kulawiec JT, Orlando MS. (1995). The contribution of spontaneous otoacoustic emissions to the click-evoked otoacoustic emissions. *Ear Hear* 16:515–520.

Langford TL. (1994). Individual differences in sensitivity to interaural disparities of time and level. *J Acoust Soc Am* 96:3256–3257.

Lonsbury-Martin BL, Harris FP, Stagner BB, et al. (1990). Distortion product emissions in humans. I. Basic properties in normally hearing subjects. *Ann Otol Rhinol Laryngol Suppl* 147:3–14.

Lytle SR. (1994). A Comparison of Amplification Efficacy and Toleration of Background Noise in Hearing-Impaired Elderly Persons. Master's thesis, University of Tennessee, Knoxville.

Martin FN. (1997). *Introduction to Audiology*. Boston: Allyn and Bacon.

McFadden D. (1993). A masculinizing effect on the auditory system of human females having male co-twins. *Proc Natl Acad Sci USA* 90:11900–11904.

McFadden D. (1998). Sex differences in the Auditory System. *Dev Neuropsy* 14:261–298.

McFadden D, Champlin CA. (2000). Comparison of auditory evoked potentials in heterosexual, homosexual, and bisexual males and females. *J Assoc Res Otolaryngol* 1:89–99.

McFadden D, Loehlin JC. (1995). On the heritability of spontaneous otoacoustic emissions: a twins study. *Hear Res* 71:208–213.

McFadden D, Loehlin JC, Pasanen EG. (1996). Additional findings on the heritability and prenatal masculinization of cochlear mechanisms: click-evoked otoacoustic emissions. *Hear Res* 71:208–213.

Miller MH, Gould WJ. (1967). Fluctuating sensorineural hearing impairment associated with menstrual cycle. *J Aud Res* 7:373–385.

Moulin A, Kemp DT. (1996). Multicomponent acoustic distortion product otoacoustic emission phase in humans. I. General characteristics. *J Acoust Soc Am* 100(3):1617–1639.

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

Neff D, Kessler CJ, Dethlefs TM. (1996). Sex differences in simultaneous masking with random-frequency maskers. *J Acoust Soc Am* 100:2547–2550.

Pearson JD, Morrell CH, Gordon-Salant S, et al. (1997). Gender differences in a longitudinal study of age-associated hearing loss. *J Acoust Soc Am* 97:1196–1205.

Pearsons K, Bennett RS, Fidell S. (1977). Speech levels in various noise environments. Bolt, Beranek, and Newman, Inc., Report No. 3281. Prepared for the Office of Resources and Development, Environmental Protection Agency. EPA-600/1-77-025.

Penner MJ, Glotzbach L, Huang T. (1993). Spontaneous otoacoustic emissions: measurements and data. *Hear Res* 68:229–237.

Robinette MS. (1992). Clinical observations with transient evoked otoacoustic emissions: measurement and data. *Hear Res* 68:229–237.

Royster LH, Royster JD, Thomas WG. (1980). Representative hearing levels by race and sex in North Carolina industry. *J Acoust Soc Am* 68:551–566.

Shehata-Dieler WE, Dieler R, Teichert K, Moser LM. (1999). Intra- and intersubject variability of acoustically evoked otoacoustic emissions. II. Distortion product otoacoustic emissions. [In German.] *Laryngorhinootologie* 78:345–350.

Stelmachowicz PG, Beauchaine KA, Kalberer A, Jesteadt W. (1989). Normative thresholds in the 8 to 20-kHz range as a function of age. *J Acoust Soc Am* 86:1384–1391.

Talmadge CL, Long GR, Murphy WJ, Tubis A. (1993). New off-line method for detecting spontaneous otoacoustic emissions in human subjects. *Hear Res* 71:170–182.

Tobias JV. (1965). Consistency of sex differences in binaural-beat perception. *Int Audiol* 4:179–182.

Wright BA. (1994). Individual, sex, and ear differences in measures of overshoot and psychophysical two-tone suppression. *J Acoust Soc Am* 95:2942–2943.