J Am Acad Audiol 17:141–146 (2006)

The Effect of Speech Presentation Level on Acceptance of Background Noise in Listeners with Normal Hearing

Clifford A. Franklin Jr.*
James W. Thelin†
Anna K. Nabelek†
Samuel B. Burchfield†

Abstract

A method has been established to measure the maximum acceptable background noise level (BNL) for a listener, while listening to speech at the most comfortable listening level (MCL). The acceptable noise level (ANL) is the difference between BNL and MCL. In the present study, the ANL procedure was used to measure acceptance of noise, first, in the presence of speech at MCL and, then, for speech presented at much lower and higher levels in listeners with normal hearing. This study used the term ANL to describe the results obtained at MCL and also at other speech presentation levels. The mean ANL at MCL was 15.5 dB, which is comparable to results obtained by previous investigators. ANL increases systematically with speech presentation level. Mean ANLs ranged from 10.6 dB when speech was presented at 20 dB HL to 24.6 dB when speech was presented at 76 dB HL. The results indicated that the acceptance of noise depends significantly on speech presentation level.

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

Abbreviations: ANL = acceptable noise level; BNL = background noise level; MCL = most comfortable listening level; SNR = signal-to-noise ratio

Sumario

Se ha establecido un método para establecer el nivel máximo aceptable de ruido de fondo (BNL) para un oyente, mientras escucha lenguaje a un nivel de audición más confortable (MCL). El nivel aceptable de ruido (ANL) es la diferencia entre el BNL y el MCL. En el presente estudio, el procedimiento de ANL fue utilizado para medir la aceptación del ruido, primero, en presencia de lenguaje a MCL, y luego, para lenguaje presentado a niveles más bajos y más altos, en sujetos con audición normal. Este estudio utilizó el término ANL para describir los resultados obtenidos a nivel de MCL y también a otros niveles de presentación. El ANL medio a nivel de MCL fue de 15.5 dB, lo cuál es comparable con los resultados obtenidos por otros investigadores. El ANL aumenta sistemáticamente con los niveles de presentación del lenguaje. Los ANL medios variaron desde 10.6 dB cuando el lenguaje fue presentado a 20 dB, hasta 24.6 dB cuando el lenguaje fue presentado a 76 dB HL. Los resultados indicaron que la aceptación del ruido depende significativamente de los niveles de presentación del lenguaje.

*University of Arkansas for Medical Sciences and University of Arkansas at Little Rock; †University of Tennessee, Knoxville

Clifford Franklin, University of Arkansas at Little Rock and University of Arkansas for Medical Sciences, Department of Audiology and Speech Pathology, 2801 South University Avenue, Little Rock, AR 72204-1099; Phone: 501-569-8912; Fax: 501-569-3157; E-mail: cafranklin@uams.edu

Palabras Clave: Nivel aceptable de ruido, nivel de ruido de fondo, nivel de audición más confortable, tasa de señal/ruido

Abreviaturas: ANL = nivel aceptable de ruido; BLN = nivel de ruido de fondo; MCL = nivel de audición más confortable; SNR = tasa de señal/ruido

Nabelek et al (1991) developed a method for determining how much background noise is considered acceptable while listening to speech by a listener in an effort to differentiate successful from nonsuccessful hearing aid users. This method of quantifying acceptable background noise while listening to speech has been named "acceptable noise level" (ANL) (Nabelek et al, 2004). The ANL is defined as the speech stimulus intensity level selected by an individual at most comfortable level (MCL) minus the maximum background noise level (BNL) that the individual is willing to accept while listening to the speech.

In the original work on ANL, the primary focus has been the application of the measure to hearing aid use. However, ANL data have been obtained on listeners with normal hearing as well as with hearing loss. For listeners with hearing loss, it has been found that ANL does not depend on the degree of hearing loss (Nabelek et al, 1991; Crowley and Nabelek, 1996; Nabelek et al, 2004) and that the ANL is a reliable measure over a three-month interval of time (Nabelek et al, 2004). For listeners with normal hearing, it has been shown that ANL does not depend on age (Nabelek et al, 1991) or gender (Rogers et al, 2003).

The relationship between the understanding of speech in noise and ANL has been studied using the SPIN test in listeners with hearing loss (Crowley and Nabelek, 1996; Nabelek et al, 2004). For speech presented at a signal-to-noise ratio (SNR) of +8 dB, no significant relationship was found between word recognition and ANL. Nabelek et al (2004) state that the "ANL measures assume that speech understanding in noise may not be as important as is the willingness to listen in the presence of noise." However, there are data to indicate how speech understanding depends on SNR. As SNR is increased for speech presented at or near MCL, word-recognition ability improves to a point of maximum performance beyond which it does not improve. Moore (1997) is of the opinion that an SNR of +6 dB is necessary for satisfactory communication. The results of a number of studies indicate that maximum word recognition is achieved at a SNR of +10 dB to +15 dB (Cooper and Cutts, 1971; Kalikow et al, 1977; Causey et al, 1984; Wilson et al, 1990; Norwood-Chapman, 1997; Studebaker et al, 1999; Bentler, 2000). The mean ANLs reported in a number of studies also have been found to be in the +10 dB to +15 dB range (for review see Rogers et al, 2003). This indicates that, on average, ANL measured at MCL occurs somewhere near the SNR for optimal word recognition. However, in extreme cases, ANLs have been obtained that are near 0 dB (a SNR for which speech understanding may be greatly reduced) and that are greater than 25 dB (well beyond the SNR required for maximum speech understanding).

In 1994, Lytle compared ANL values of successful and nonsuccessful hearing aid users in both the aided and unaided condition. For both groups of wearers, the ANL values did not differ significantly between the two conditions. This finding indicates that the ANL is an attribute of the individual and not the hearing aid. Lytle's results have been verified in a large sample study by Nabelek et al (2004).

The available ANL research has all been conducted solely when speech is presented at MCL. There are no data on the acceptance of background noise at speech presentation levels that are not optimal for speech recognition. Since listening often does not occur at optimal levels, the question arises, "How is the acceptance of background noise affected by speech presentation level?" The purpose of the present research was to study the relationship between ANL and speech presentation level for a wide range of levels for listeners with normal hearing. In order to obtain a sample of ANL values across the range of speech presentation levels at which conversation might take place, speech levels spanned from a very soft level in which an individual might attempt listening to speech (20 dB HL) to a very loud but tolerable level (76 dB HL).

METHOD

Participants

The participants were ten male and ten female university students between 19 and 30 years of age (mean age = 21.8 years). Participants were tested to ensure that they had normal hearing, bilaterally (pure-tone thresholds ≤15 dB HL at octave intervals from 250 to 8000 Hz) (ANSI S3.6-1996). Participants in this study had no formal education in the effects of noise on humans to reduce the chance of bias from prior knowledge.

Apparatus and Test Materials

The speech and noise stimuli were delivered via compact disc player through an audiometer to the same loudspeaker that was located at 00 azimuth 1 m from the subject in an audiometric test room. Like many previous ANL studies, a recording of running discourse with a male talker (Arizona Travelogue, Cosmos, Inc.) was used as the speech stimulus, and eight-person multitalker speech babble was used as the competing stimulus or background noise. Both speech and background noise levels were specified in dB HL. The speech was presented to the participants at MCL and at five fixed hearing levels: 20, 34, 48, 62, and 76 dB HL.

Procedure

Prior to testing, each participant was given verbal and written instructions describing the experiment and experimental tasks. Based on the procedure reported by Nabelek et al (1991), the participant's MCL was obtained first. A bracketing procedure allowed participants to indicate if the speech level was too low or too high. Participants used two handheld buttons to signal the examiner to vary the speech in 2 dB steps until the MCL was reached. Participants were instructed to signal the desire for the speech to increase or decrease until it reached the loudness level that was most comfortable. Participants were urged to listen to the speech at levels above and below MCL to construct perceptual references on which to base their MCL. The verbal and written instructions for MCL were as follows:

> You will be listening to speech. Your job is to adjust the level of the speech to a level louder than you would consider most comfortable, then softer than you would consider most comfortable, and finally adjust the speech to the level which is most comfortable. Say "okay" when you have reached that level.

MCL measurement was followed by a training session for the selection of BNL at a speech presentation level of 50 dB HL. To reduce any training effect involved in the procedure, the participants were given a criterion task to demonstrate the ability to adjust the background noise in a consistent manner. For inclusion into the study, participants were required to adjust the BNL to within two decibels of one another for three consecutive trials using the same bracketing procedure described for the determination of MCL. Like the training session, the criterion task was performed using a speech presentation level of 50 dB HL. All subjects met the criterion in eight or fewer attempts.

Following inclusion into the study, each participant was given written and verbal instructions. The verbal and written instructions for the acceptable noise level were as follows:

> You will be listening to speech, which will be soft sometimes and louder at other times. As you listen, you will hear background noise, which sounds like

several people talking. For each level of the speech, your job is to adjust the background noise to a level that you would be willing to accept or "put up with" without becoming tense or tired while listening to and following the words of the speech. The amount of attention that you give to the narrative is up to you. Please try to give the same amount of attention to the narrative each time the procedure is performed. In order to obtain a reference, please adjust the background noise to the level that you would consider to be unacceptably high and then to a level which is just noticeable. Finally, set the level of the background noise to the maximum level that you would accept for a long time while following the words of the speech. Say "okay" when you have reached that level.

Speech was presented at five fixed presentation levels and at MCL with the order of presentation randomized. The complete data for each speech presentation level were obtained before proceeding to the next speech presentation level. The following procedure was used for each speech presentation level condition. To determine the maximum BNL, the background noise was initially presented 30 dB below the speech presentation level and was increased in 10 dB steps until the level was judged unacceptable. The background noise was then decreased in 10 dB steps until the subject indicated the background noise was just audible. At this point, the background noise was increased in 2 dB steps until the subject selected their maximum level of acceptable background noise. This procedure was repeated for each presentation level. Due to possible temporary changes in the auditory system following intense stimulation, each subject was given a two-minute recovery period between procedures for speech presentation levels that exceeded 50 dB HL. For each speech presentation level trial, two BNLs were measured allowing for the calculation of two ANL values. As previously stated, the ANL is equal to the MCL minus the BNL. For example, if MCL is 50 dB HL and BNL is 35 dB HL, then ANL is calculated as 15 dB. The two calculated ANLs were averaged to obtain a single ANL.

RESULTS

MCL and ANL at MCL

MCL and ANL values were averaged across the 20 listeners. The mean MCL for all listeners was 42.7 dB HL (SD = 6.6 dB). The mean ANL at MCL was 15.5 dB (SD = 7.3 dB). A one-factor ANOVA (2 levels, male and female) found no significant main effect for gender on MCL ($F_{1, 18} = 0.485$, $p = .495$) or ANL ($F_{1,18} = 0.022$, $p = .883$).

ANLs at Fixed Speech Presentation Levels

Mean ANLs and SDs for the five fixed speech presentation levels are shown for all participants as a function of speech presentation level in Figure 1. The mean

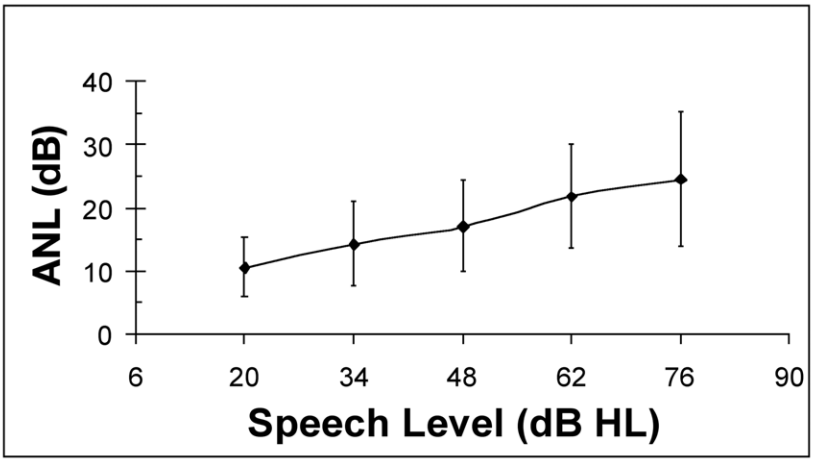

Figure 1. ANL as a function of speech presentation level. Means for all participants and SDs are shown.

ANL and SD increase systematically as a function of speech presentation level. At the 20 dB HL speech presentation level, the mean ANL equals 10.6 dB, which is approximately 5 dB less than the mean ANL of 15.5 dB at MCL. At the 76 dB HL speech presentation level, the mean ANL equals 24.6 dB, which is about 9 dB greater than the ANL at MCL. A two-factor ANOVA was performed to determine a within-subjects main effect of presentation level on ANL with gender as a between-subjects factor. The main effect for speech presentation level ($F_{4,15} = 43.02$, $p < .001$) was significant, with no significant interactions indicated. There was no significant gender effect ($F_{1, 18} = 0.05$, $p = .824$). Linear regression analysis of ANL as a function of presentation level is significantly different from zero ($F_{1, 18} = 73.519$, $p < .001$). The slope of the linear regression function was a 0.25 dB increase in ANL for each 1 dB increase in speech presentation level.

The attempt was made to determine if the systematic increase in intersubject variability in ANL was due to individual differences in the rate of growth of the ANL with increases in speech presentation level. For each participant, the ANL at the lowest speech presentation level (ANL at 20 dB HL) was compared to the change in ANL at the highest speech presentation level (ANL at 76 dB HL minus ANL at 20 dB HL). In general, those with the higher ANLs at the lowest speech presentation also showed the largest increases in ANL as speech presentation level was increased. This relationship, however, was not statistically significant ($r = .37$, $p = .109$).

DISCUSSION AND CONCLUSIONS

The measures of MCL and ANL at MCL obtained for the participants in this study are comparable to those obtained in previous studies. The mean MCL in this study was 42.7 dB HL (SD = 6.6). The mean MCLs for young adult listeners in other studies were 63.8 dB SPL (44.3 dB HL, after conversion to HL) using a monaural supra-aural earphone (Nabelek et al, 1991) and 39.2 dB HL in the sound field (Rogers et al, 2003). Mean ANL at MCL in the present study was 15.5 dB (SD = 7.3) while those reported in the studies cited above were 15.9 dB (SD = 8.5) and 10.9 dB HL (SD = 7.1) respectively. These findings suggest the acceptance of noise by these participants is typical of that studied by others.

In previous research, the ANL has been used to describe differences between groups of users when speech was presented at MCL. The present research expanded the concept of the ANL to conditions in which listening is done at speech presentation levels other than MCL. As speech presentation level is increased, the acceptable level of background noise increases, but at one-fourth the rate of the increases in speech presentation level. Thus, ANL is not a single value but a set of values that depends on speech presentation level and possibly other factors as well.

In the original work by Nabelek et al (1991) on the acceptance of noise, emphasis was placed on the value of the ANL for the differentiation of successful and nonsuccessful users of hearing aids. Though research on ANL and hearing aids continues (Nabelek et al, 2004; Freyaldenhoven et al, 2005), it is clear that the acceptance of noise is a general phenomenon that potentially has broad application in understanding listener behavior in a wide variety of conditions. The ANL may be useful in understanding differences in behavior attributable to environmental factors such as the level or type of background noise, quality of the speech signal, or the presence of room reverberation. The ANL has been shown to be of value in describing differences among listeners related to the acceptance of hearing aids, but it may also be useful in describing changes in ANL with changes in conditions that may affect listeners, differentially. For example, the ANL might be used to measure changes in the willingness to accept hearing aids following auditory training, to measure the effects of background noise on individuals who are sensitive to background noise such as those with attention disorders, and to measure the effects of medical treatments that alter mental state.

REFERENCES

Bentler RA. (2000) List equivalency and test-retest reliability of the speech in noise test. *Am J Audiol* 9:84–100.

Causey G, Hood L, Hermanson C, Bowling L. (1984) The Maryland CNC Test: normative studies. *Audiology* 23(6):552–568.

Cooper J, Cutts B. (1971) Speech discrimination in noise. *J Speech Hear Res* 14(2):332–337.

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

Freyaldenhoven MC, Nabelek AK, Burchfield SB, Thelin JW. (2005) Acceptable noise level (ANL) as a measure of directional hearing aid benefit. *J Am Acad Audiol* 16(4):228–236.

Kalikow DN, Stevens KN, Elliot LL. (1977) Development of test of speech intelligibility in noise using materials with controlled word predictability. *J Acoust Soc Am* 61(5):1337–1351.

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

Moore BJ. (1997) *An Introduction to the Psychology of Hearing.* San Diego: Academic Press.

Nabelek AK, Freyaldenhoven MC, Tampas JW, Burchfield SB, Muenchen RA (2004) Acceptable noise level as a predictor of hearing aid use. Unpublished manuscript, University of Tennessee, Knoxville.

Nabelek AK, Tampas J, Burchfield S. (2004) Comparison of speech perception in background noise with acceptance of background noise in aided and unaided conditions. *J Speech Hear Res* 47(5):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 Hear Res* 34:679–685.

Norwood-Chapman ML. (1997) Evaluation of word recognition in quiet and in noise in listeners with normal hearing and listeners with hearing impairment. Unpublished doctoral project, University of Tennessee, Knoxville.

Rogers DS, Harkrider AW, Burchfield SB, Nabelek AK. (2003) The influence of listener's gender on the acceptance of background noise. *J Am Acad Audiol* 14(7):372–382.

Studebaker GA, Sherbecoe RL, McDaniel DM, Gwaltney CA. (1999) Monosyllabic word recognition at higher-than-normal speech and noise levels. *J Acoust Soc Am* 105(4):2431–2444.

Wilson R, Zizz C, Shanks J, Causey G. (1990) Normative data in quiet, broadband noise, and competing message for Northwestern University Auditory Test No. 6 by a female speaker. *J Speech Hear Disord* 55(4):771–778.