Acceptance of Background Noise in Children with Normal Hearing

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The present study measured acceptance of noise in 32 children (age 8 and 12 years) with normal hearing sensitivity. Results demonstrated that acceptable noise levels (ANLs) are not dependent on type of noise distraction, gender, or age of the child, at least for children 8 and 12 years of age. Results further demonstrated that ANLs can be obtained reliably in children in 2-4 minutes and are normally distributed. Clinical implications and applications are discussed.

INTRODUCTION

In 1991, Nabelek, Tucker, and Letowski introduced a procedure to measure the amount of background noise individuals are willing to accept while following the words of a story. This procedure was termed acceptable noise level (ANL). Originally, ANL was designed to examine the acceptance of background noise in individuals who wear hearing aids (Nabelek et al., 1991). Results demonstrated that ANLs were directly related to hearing aid use. Specifically, individuals with small ANLs (e.g., 6 dB) were willing to accept large amounts of background noise and were more likely to wear their hearing aids on a full-time basis. Individuals with large ANLs (e.g., 14 dB) were, however, less willing to listen in background noise and more likely to wear hearing aids on a part-time basis or not at all (Nabelek, Freyaldenhoven, Tampas, Burchfield, & Muenchen, 2006).

ANLs are not related to gender, type of noise distraction, hearing sensitivity, middle ear characteristics, speech perception in noise performance, or age for individuals from college-aged (i.e., approximately 20 years) to elderly individuals (i.e., approximately 80 years) (Harkrider & Smith, 2005; Nabelek et al., 1991; Nabelek, et al., 2006; Rogers, Harkrider, Burchfield, & Nabelek, 2003). ANLs are also reliable within a session, consistent over time, and normally distributed in adults with normal and impaired hearing (Freyaldenhoven, Smiley, Muenchen, & Konrad, 2006; Nabelek, Burchfield, Tampas, & Freyaldenhoven, 2004; Nabelek, Tampas, & Burchfield, 2004). Most importantly, ANLs can predict successful hearing aid use with 85% accuracy in the adult population (Nabelek et al., 2006). Additionally, ANLs are thought to be mediated at the level of the central auditory nervous system (Harkrider & Tampas, 2006; Tampas & Harkrider, 2006). Based on these results, it is hypothesized that ANLs are an inherent characteristic of the individual.

ANLs have not been measured in the pediatric population. If ANL is an inherent characteristic of the individual, it is hypothesized that ANLs in children will manifest similarly as ANLs in the adult population. If this is the case, ANLs may aid in the evaluation of success with hearing aids in children. Consequently, the purpose of the present study was to determine if ANLs could be measured in the pediatric population (Note: Since ANLs have never been measured in the pediatric population, children with normal hearing were evaluated). The following research questions were addressed:

1) What are typical ANLs in children with normal hearing?
2) Are ANLs dependent on age, gender, or type of noise distraction in children with normal hearing?
3) Are ANLs reliable in children with normal hearing?
4) Is the distribution of ANLs in children normal?

METHODS

Participants

Thirty-two children (sixteen 8-year olds [mean age = 8.6 years] and sixteen 12-year olds [mean age = 12.4 years]) with normal hearing sensitivity were recruited from area schools in Conway, Arkansas to participate in this study. Within each age group, half of the participants were male and half were female. Criteria for inclusion were as follows:

1) age 8 or 12 years.
2) pass a hearing screening (pure tone hearing screening at 20 dB HL at 0.5, 1, 2, & 4 kHz in each ear).
3) placement in a regular classroom setting for the entire school day.

Materials and Procedures

Pure tone hearing screenings were administered with a Maico MA40 portable audiometer using supra-aural headphones. For the duration of the screening, all participants were seated in a quiet room with their back to the examiner (ANSI, S3. 6- 1996). ANLs were then measured in a sound-treated booth (IAC) with acceptable ambient noise levels (ANSI, S3. 1- 1991). Speech and noise stimuli were delivered through a cassette tape deck (Pioneer CT-W205R) and a compact disk player (GPX

C3855M) respectively, which were routed through an audiometer (GSI-61) to an ear-level loudspeaker located at 0° azimuth. An Auditec audio recording of female running speech (i.e., a story) served as the speech stimulus[1]. Two noise stimuli were used: speech spectrum noise (generated by the GSI-61 audiometer) and speech babble noise (Auditec recording) (Note: Each participant completed the ANL using both noise stimuli while the Auditec recording of female running speech served as the speech stimulus).

To obtain ANLs, most comfortable listening levels (MCLs) and maximum acceptable background noise levels (BNLs) were measured using a modified version of the procedures described by Nabelek et al. (1991). The major modification included altering the ANL instructions for language more appropriate for children (Appendix A). Two response buttons were given to the participant. The buttons were connected to flashlights, which signaled the examiner to manipulate the intensity of the given stimulus up or down in 1-dB steps. The participant first adjusted the level of the story to their MCL (see Appendix A for MCL instructions). Then background noise (i.e., either speech spectrum noise or speech babble noise) was added, and the participants adjusted the noise to the maximum level of background noise they were willing to accept or 'put-up-with' without becoming tense or tired while listening to and following the words of the story (called background noise level or BNL; see Appendix A for BNL instructions). The ANL was then calculated by subtracting the BNL from the MCL. For example, if the participant set the story (MCL) at 25 dB HL, the ANL would equal 13 dB.

The participants were evaluated at the University of Central Arkansas Speech-Language-Hearing Clinic. Six experimental trials were completed within one session, lasting approximately 30 minutes. Three ANLs were obtained using speech spectrum noise as the competing stimulus, and three were obtained using speech babble noise as the competing stimulus. ANLs obtained using speech spectrum and speech babble noises were counterbalanced. An average of the three trials served as the mean ANL for that participant in the given condition.

RESULTS

ANLs in Children

One purpose of the present study was to determine typical mean ANLs in the pediatric population. ANLs were obtained three times for each noise type, and a mean ANL was determined for each participant for each condition. Mean ANLs, standard deviations, and ranges for each age group and noise type are shown in Table 1.

A three way repeated-measures analysis of variance (ANOVA) was completed to determine the effect of age, gender, and noise type on ANLs in children with normal hearing. The dependent variable was ANL. The within-subject factor was type of noise distraction with two levels (speech spectrum noise and speech babble noise), and the between-subject factors were age with two levels (8 or 12 years) and gender with two levels (male or female). The analysis revealed no significant main effects for type of noise distraction ($F[1,28] = 3.38$, $p = 0.076$), age ($F[1,28] = 0.70$, $p = 0.424$), gender ($F[1,28] = 0.28$, $p = 0.603$) or the noise distraction by age ($F[1,28] = 0.60$, $p = 0.446$), noise distraction by gender ($F[1,28] = 0.51$, $p = 0.480$), age by gender ($F[1,28] = 0.12$, $p = 0.735$), or noise distraction by age by gender ($F[1,28] = 0.55$, $p = 0.463$) interactions. These results suggested that ANLs in children are not dependent on gender or type of noise distraction. Results further indicated that ANLs are not significantly different for children 8 and 12 years of age. Therefore for subsequent analysis, data from all 32 children were collapsed, and speech babble noise was utilized as the competing stimulus. Speech babble noise was chosen because (a) it better represents daily listening situations, and (b) recent ANL studies have used speech babble as the noise distraction (Harkrider & Smith, 2005; Nabelek, et al., 2006; Tempas & Harkrider, 2006).

Table 1: Means (standard deviations) and ranges for ANLs (in dB) obtained using speech spectrum noise (SSN) and speech babble noise (SBN) for 8 and 12 year old children separately and all children combined.

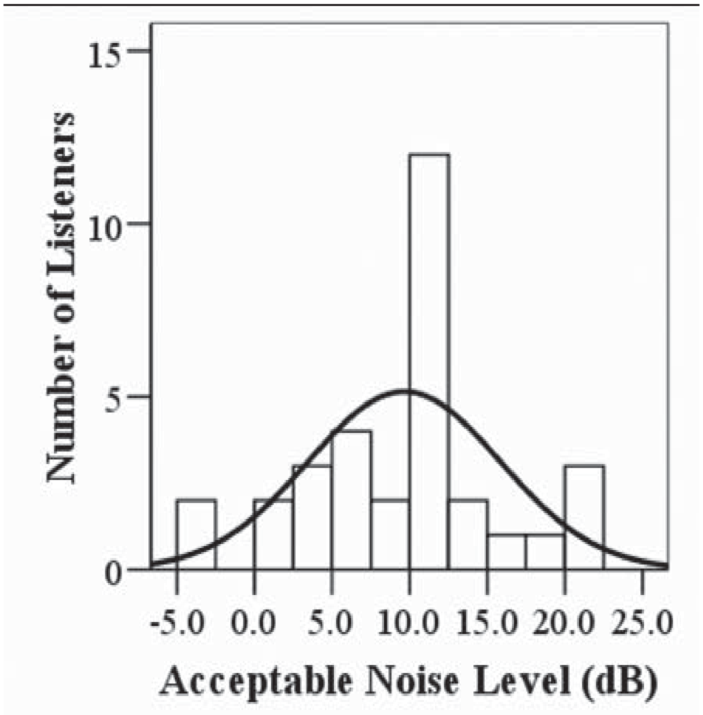
	ANL Mean (SD) (in dB)		Range	
Age	SSN	SBN	SSN	SBN
8 years (N = 16)	9.9 (5.5)	9.1 (6.3)	0.0 – 22.0	-2.7 – 21.7
12 years (N = 16)	12.1 (5.9)	10.2 (5.9)	-2.7 – 21.7	-2.7 – 21.3
8 & 12 years (N = 32)	11.0 (5.7)	9.7 (6.2)	-2.7 – 22.0	-2.7 – 21.7

ANL Reliability and Distribution in Children

Another purpose of the present study was to determine if ANLs were reliable and normally distributed in children with normal hearing. To determine the test-retest reliability of ANLs in children, a Single Measure Intraclass Correlation Coefficient based on the consistency definition was calculated for ANL measures using speech babble as the competing stimulus for all children (N = 32). The correlation coefficient was $r = 0.87$ ($p < 0.001$), indicating a high test-retest reliability of ANL for children 8 years and 12 years of age. Furthermore, Figure 1 shows that the ANLs for children with normal hearing are normally distributed (Note: The distribution includes ANLs obtained using speech babble background noise).

[1] The Audiec recording has been replaced with a commercially available recording by Cosmos Distributing, Inc. A copy of the ANL CD can be obtained online at www.cosmosdistributinginc.com or by contacting Robert McClocklin through email (info@cosmosdistributinginc.com), or by phone (1-866-764-7673).

Figure 1: Histogram displaying the frequency distribution of ANLs for the sample population (i.e., 32 children with normal hearing).



DISCUSSION

Results obtained from children ages 8 and 12 years with normal hearing indicated that ANLs are not dependent on type of noise distraction, gender, or age of the child. These results are in agreement with previous ANL investigations for listeners with normal hearing, which state that ANL is not dependent on type of noise distraction (Nabelek et al., 1991), gender (Nabelek et al., 2006; Rogers, Harkrider, et al., 2003), or age for young adults to elderly individuals (Nabelek et al., 1991; Nabelek et al., 2006). It should be noted that Freyaldenhoven et al. (2006) found statistical differences in ANLs obtained using different background noises ; however, they concluded that these differences were not clinically relevant (15.0 dB for speech spectrum noise and 12.9 dB for speech babble noise) and were probably due to different characteristics of the noise signals.

Table 2 presents ANL data for children, young adults, and elderly individuals with normal hearing. Mean ANLs range from 9.7 to 15.9 dB for listeners with normal hearing age 8 to elderly individuals (i.e., about 80 years). When comparing mean ANLs for children to mean ANLs for young adults and elderly individuals, it appears that ANLs for children (M = 9.7 dB) and elderly individuals (M = 11.7 dB) are similar and ANLs between children (M = 9.7 dB) and young adults (M range = 10.9 to 15.9 dB) range from similar to different. The differences seen in mean ANLs in children and young adults with normal hearing may be due to differences in sampling. For example, table 2 shows that 2 of 3 sample populations of young adults with normal hearing had mean ANLs within about 3 dB of the mean ANLs in children. The difference in mean ANLs for children and young adults for the remaining study by Nabelek and colleagues (1991) was approximately 6 dB. This larger difference may have been due to random sampling, meaning that Nabelek et al. (1991) recruited a group of listeners with larger ANLs than the current study. Another possible explanation for the difference in ANLs in children and young adults with normal hearing is that some young adults may interpret ANL instructions with a stricter criterion than children or elderly individuals. Further studies should focus on how different age groups interpret the ANL instructions.

Table 2: Mean ANLs, standard deviations (SD), and ranges (in dB) for elderly individuals, young adults, and children with normal hearing. Speech babble was used as the competing stimuli for all investigations.

Investigations	Mean ANL (SD) (in dB)	Range
Nabelek et al (1991) N = 15 (elderly)	11.7 (7.6)	0.0 – 27.0
Nabelek et al (1991) N = 15 (young)	15.9 (8.5)	5.0 – 37.0
Rogers, Harkrider, et al (2003) N = 50 (young)	10.9 (7.1)	0.0 – 24.7
Freyaldenhoven et al (2006) N = 30 (young)	12.9 (5.2)	4.0 – 24.0
Present Study N = 32 (children)	9.7 (6.2)	-2.7-21.7

Another important finding of the current study was that reliable ANLs could be obtained in the pediatric population in approximately 2 – 4 minutes, which is comparable to the time it takes to obtain ANLs in adults. These results are in agreement with previous ANL studies that state ANLs are reliable both within a session and over time in adults with normal and impaired hearing (Freyaldenhoven et al., 2006; Nabelek, Tampas, et al., 2006). Future studies should investigate ANL reliability in children over time.

ANLs were normally distributed in children age 8 and 12 years. The normal distribution of ANLs obtained for children might have been expected (Figure 1) based on ANL distributions for adults with normal hearing. Figure 2 displays the distribution of ANL for 189 adults with normal hearing (Note: Figure 2 was prepared using a compilation of ANLs obtained from adults with normal hearing [Franklin, Burchfield, Nabelek, & Thelin, 2001; Franklin, Thelin, Nabelek, and Burchfield, 2006; Freyaldenhoven et al., 2006; Harkrider and Smith, 2005; Nabelek et al., 1991; Rogers, Harkrider, et al., 2003; Rogers, Nabelek, and Burchfield, 2003]). Figures 1 and 2 show that typical ANLs for children range from 6 – 12 dB with an overall mean of 9.7 dB, and typical ANLs for adults range from 7 – 17 dB with the overall mean at 11.6 dB. Additionally, the median ANL for children with normal hearing was 10.5 dB, and the median ANL for adults with normal hearing was 11.0 dB. This data supports the hypothesis that mean ANLs for the pediatric population are similar to mean ANLs for the adult population.

Figure 2: Histogram displaying the frequency distribution of ANLs for the 189 adults with normal hearing. The listeners ranged in age from young adults (e.g., 18 years) to elderly adults (e.g., 70 years).*

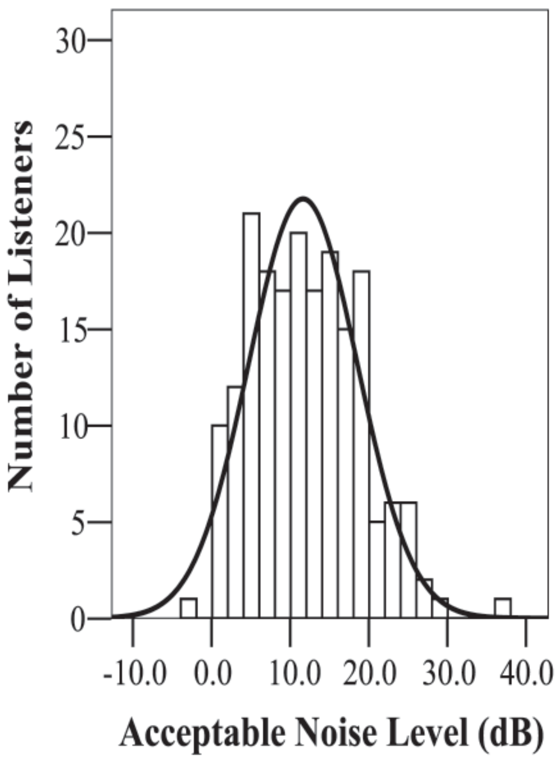


*Figure developed with permission from Nabelek, Burchfield, Tampas, and Freyaldenhoven (2004) with only data from adults with normal hearing.

CONCLUSIONS AND CLINICAL IMPLICATIONS

Nabelek et al. (1991) and Nabelek et al. (2006) showed that acceptance of background noise is not dependent on hearing status, type of noise distraction, or age in adults with normal or impaired hearing. Rogers, Harkrider, et al. (2003) and Nabelek et al. (2006) further showed that acceptance of noise is not related to gender in adults with normal or impaired hearing. Additionally, Nabelek, Tampas, et al. (2004) showed that ANL distributions for listeners with normal and impaired hearing are similar. Most importantly, Nabelek et al. (2006) demonstrated that using hearing aid users' unaided ANL value, listeners' probability of success with hearing aids can be determined with 85% accuracy. In the present study, ANLs were examined in male and female children with normal hearing. Results demonstrated that ANLs are not related to age (at least for children ages 8 and 12 years old), gender, or type of noise distraction. Results further demonstrated that ANLs are reliable within a session, normally distributed, and obtained quickly and easily for listeners 8 and 12 years of age. These results indicate that the measured ANL characteristics in the pediatric population appear to behave similar to ANL characteristics measured in the adult population. Therefore, it is possible that ANL may be used as a prediction of hearing aid success in the pediatric population. Further investigations should study the predictive ability of ANLs in children with hearing impairment. The ANL distribution in a large sample of school-aged children with normal hearing should also be investigated.

This study demonstrated that ANLs could be effectively measured in children with normal hearing. Since ANLs have the potential to identify successful versus unsuccessful adult hearing aid users (Nabelek et al., 2006), ANLs should be obtained on children with hearing impairment who both use and reject hearing aids. This may give clinicians one more indication as to whether a child is likely to succeed with or reject hearing aids. Furthermore, ANLs may also help clinicians justify which device is most appropriate for a child (e.g., hearing aids with noise reduction, frequency modulated system, etc.).

APPENDIX A: ANL Instructions for Children

Instructions for establishing MCL:

I'm going to play a story for you to listen to through the loudspeaker in front of you. The story is going to be very soft at first. I want you to use these buttons (pointing) to **turn the story up until it is at your perfect listening level**. For example, if this was a television, and these buttons were your remote control – I want you to turn the story up until you think it's at a perfect level for you. Remember if it gets too loud, you can turn it down a little by pushing the softer button. When it gets just right, give me a thumbs-up. Then I'll tell you what else we are going to do.

Instructions for establishing BNL:

Now I'm going to put some noise through the same speaker. The lady that was telling you the story is going to stay at the same loudness level that she was before the noise was introduced. The noise is going to be very soft – like the lady's voice when I first turned it on. I want you to **turn it up until you think, "I could 'put up with' that noise for a long time if I had to, but if it is any louder then it would probably get on my nerves.**" It is important that you can also still follow the story that the lady is telling you through the speaker.

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