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Improving Acceptance of Background Noise with Sound Enrichment

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Abstract

Background Acceptance of background noise serves as a means to predict likelihood of hearing aid success. Individuals that are able to accept background noise are more likely to be successful with hearing aids.

Purpose The aim of the study was to assess the impact of sound enrichment on the acceptable noise level (ANL).

Study Sample Nineteen young adult participants served as listeners. Participants were randomly assigned to the experimental or control group.

Research Design An experimental design with random assignment to experimental or control group was used.

Data Collection and Analysis One group used sound enrichment procedures for 2 weeks, whereas the other group served as a control group. Sound enrichment procedures required that participants add low-level background sound to any quiet environment encountered during the study. Most comfortable listening level (MCL) and background noise level (BNL) were measured at three sessions, each 1 week apart (baseline, after 1 week of treatment, and after 2 weeks of treatment).

Results Analytical statistics revealed that ANL improved for the sound enrichment group but remained the same for the control group. For both groups, there was no significant change in MCL across sessions. However, for the experimental group, BNL improved (increased) over the 2-week period while using sound enrichment.

Conclusions Results of this study indicate that ANL can be improved with the use of sound enrichment procedures over a 2-week period. Future work should examine the use of sound enrichment procedures for older adults with hearing loss.

Key words
- acceptable noise level
- sound enrichment
- background noise
- background noise acceptance
- background noise level

Introduction

Hearing aid candidates often reject hearing aids because of difficulty listening in noise (McCormack and Fortnum[18]). Acceptable noise level (ANL) is an important prehearing aid fitting tool because it quantifies difficulty with background noise and serves as an indicator of an individual's *willingness* to listen to speech in the presence of background noise. Nabelek et al[23] concluded that individuals who were more accepting of background noise while listening to speech were more likely to be successful with hearing aids. In 2006, Nabelek and colleagues[21] reported that prefitting ANL measures successfully predict hearing aid success with 85% accuracy. However, this has not been replicated.

Identification of a listener's ANL requires the measurement of their most comfortable listening level (MCL) to speech and their background noise level (BNL). The BNL is the highest level of background noise acceptable to the listener while listening to speech for a long period of time. The ANL test (Cosmos Incorporated, currently available from Frye Electronics, Inc., Beaverton, OR) includes a primary speech stimulus of a male talker reading a story about a trip to Arizona (aka Arizona travelogue) and a competing background noise of 12 babble (Kalikow et al[16]). To measure ANL, the listener's MCL is

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evaluated with a running speech stimulus. Once the MCL is identified, the speech stimulus remains at the listener's MCL and the background noise of 12 babble is added to the signal. The listener is then instructed to identify their BNL in a three-step bracketing process, allowing the listener to hear signal-to-noise ratios that are above and below their ANL. The ANL is then calculated by subtracting the BNL from the MCL (ANL = MCL − BNL).

Nabelek et al[20] reported ANLs for normal hearing listeners (n = 221) that ranged from −2 to 38 dB, occurring most frequently between 10 and 11 dB. In addition, listeners with hearing impairment (n = 315) had similar ANLs, with a range of 0–27 dB, with most ANLs falling between 10 and 11 dB. The authors reported that the shape of ANL distribution was essentially normal and was similar across listener groups. In 2006, Nabelek et al[21] used logistic regression to determine three groups of ANL and a description of each group's likelihood of success with hearing aids, based on ANL. They reported an indirect relationship between ANL and hearing aid success rates. Individuals with low ANLs (≤6 dB) had a 92–99% success rate with their hearing aids; those with mid-range ANLs (7–13 dB) had a wide range of hearing aid success rates ranging from 10% to 80%; and those with high ANLs (≥14 dB) had a very low likelihood of hearing aid success with success ranging from 0% to 9%. However, recent work indicates that the predictive power of ANL may be lower than that suggested by Nabelek et al. More recently, Olsen and Brannstom[25] suggested that new ANL categorization should be developed and the predictive power of ANL should be re-evaluated using new categories (Olsen and Brannstom[25]).

To re-evaluate and fine-tune the ANL model, we need to gain a better understanding of the factors that influence ANL. For years, researchers have worked to identify factors that impact a listener's ANL with the hope that we could better distinguish the likelihood of hearing aid success for the mid-range ANL group. To date, many variables have been ruled out as potential factors affecting ANL (e.g., age, gender, and loudness tolerance) (Nabelek et al[23]; Rogers et al[27]; Franklin et al[7]). Many researchers have reported no association between ANL and pure tone average (PTA) (Nabelek et al[23]; Crowley and Nabelek[5]; Harkrider and Smith[11]; Gordon-Hickey and Moore[9]); however, Brannstrom and Olsen[3] reported that low-frequency thresholds affect ANL, indicating that individuals with better low-frequency hearing have higher ANLs. In addition, Nichols and Gordon-Hickey[24] reported a relationship between ANL and the psychological variable of self-control. Listeners with high levels of self-control were found to have lower ANLs, and vice versa.

For ANL, test–retest correlation coefficients of within-session BNL trials are strong, indicating strong intrasubject reliability (e.g., Freyaldenhoven et al[8]; Gordon-Hickey and Moore[9]). In addition, intrasubject reliability of ANL has been established for listeners over 3-week, 3-month, and 1-year periods (Nabelek et al[22]; Freyaldenhoven et al[8]; Hay and Bryan[13]). The stability of ANL supports Nabelek's contention that ANL is an inherent trait (Nabelek et al[22]). If ANL is inherent, we may be unable to improve hearing aid success rates for those who reject their hearing aids because of problems with background noise.

Pitchaimuthu et al[26] explored the use of a systematic desensitization training to improve ANL. They required that listeners participate in 10 days of auditory training, with each session lasting 20–30 minutes. The training involved a difficult listening environment with reduction of the signal-to-noise ratio throughout the listening exercise. The signal-to-noise ratio was decreased until listeners reported that any increase in the background noise would make them uncomfortable, feel tense or tired, or until the participant was unable to understand the speech. For listeners with high ANLs, the authors found a significant improvement in ANL post-training. For listeners with mid- or low ANLs, no significant differences were found in ANL from baseline.

Methods of aural rehabilitation, such as tinnitus retraining therapy, may improve ANL in some listeners (Huang and Chang[15]). Tinnitus retraining therapy includes both directive counseling and sound enrichment via ear-level sound generators. Formby et al[6] explored the impact of sound enrichment via ear-level sound generators and sound deprivation on a listener's loudness perception. They measured baseline loudness growth via the contour test of loudness (Cox et al[4]) and loudness discomfort levels. Listeners then completed 4 weeks of treatment (i.e., sound enrichment or sound deprivation). Sound enrichment was accomplished via the use of ear-level noise generators that provided a low-level broadband noise. Sound deprivation was provided with the use of ear plugs. Participants were instructed to use the ear-level noise generator or ear plugs 23 hours per day for 4 weeks. Findings demonstrated a recalibration of auditory system gain for both measures of loudness via the contour test and for loudness discomfort levels. Earplug users rated sounds as louder than at the time of baseline assessment, indicating more sensitivity to sound. Ear-level sound generator users were less sensitive to sound and found sounds to be softer than they did at the time of baseline evaluation. A limitation to the use of ear-level noise generators is that the patient must wear the devices at all times.

Another method, progressive tinnitus management (PTM), implements sound enrichment in an easy-to-use method that does not require ear-level noise generators and provides patients with the flexibility to select appropriate sounds for a particular environment (Henry et al[14]). PTM prescribes low-level sound be added to any quiet environment encountered by the patient. Patients implementing PTM are instructed to enrich quiet environments with environmental sound, interesting sound, or uninteresting sound. Patients are counseled to use different sounds in different environments. For example, interesting sound (e.g., music) could be used when knitting or doing other quiet activities, whereas uninteresting sound (e.g., white noise) may be more useful for activities requiring concentration or for sleep. Patients implementing PTM are instructed to use sound enrichment in any quiet environment that they encounter. The purpose of the present study was to evaluate the use of the instructional sound enrichment technique as a potential method to improve a listener's acceptance of background noise. The sound enrichment technique used was similar to that of the methods described in the PTM protocol. For our study, we recruited individuals who described difficulty with background noise and had an ANL of 7 or greater (mid-range or high ANL). This group was of interest as these individuals have the lowest likelihood at hearing aid success.

Methods

Participants

Fifty-four young adults between the ages of 19 and 34 years volunteered to participate. All volunteers reported difficulty listening in a noisy environment. The volunteers had not participated in previous ANL studies and had never had their ANL evaluated. All study volunteers read and signed a Statement of Informed Consent approved by the Institutional Review Board at the University of South Alabama.

Nineteen of the volunteers met all qualification criteria and agreed to serve as participants. Ten participants served as part of the experimental group and had a mean age of 24.6 years. Nine participants served in the control group and had a mean age of 20.89 years. All participants had normal hearing (pure-tone thresholds <25 dB HL at 0.5, 1, 2, and 8 k Hz) (ANSI S3.6-2004), had normal uncomfortable loudness levels (UCLs) (>85 dB HL at 500, 2000, and to speech), had ANLs of 7 or greater, were native speakers of American English, and had no history of otologic or neurological disorders. Participants qualifying for the experimental portion of the study were compensated for their time and transportation. The volunteers who did not qualify for this study were excluded because of hearing loss, a history of otologic or neurologic disorders, were not native speakers of American English, had plans for loud sound exposure during the following 2 weeks (e.g., firearms or concert), or had a low ANL (<7 dB).

Materials

All testing was completed in a sound-treated room meeting American National Standards Institute specifications for maximum allowable ambient noise levels for audiometric rooms (ANSI[1]). All measures were completed with an Otometrics Astera audiometer, calibrated in accordance with ANSI[2] specifications for a type 2 audiometer. Audiologic evaluation was completed via TDH 50P earphones (Telephonics, Huntsville, AL) mounted in supra-aural cushions. The experimental stimuli were from the commercially available ANL compact disc (Cosmos Incorporated; currently available through Frye Electronics, Inc.), which includes a recording of the Arizona Travelogue (male talker) and 12 babble from the Speech Perception In Noise test (Kalikow et al[16]). Experimental stimuli were present through an Insignia speaker located at 0 degrees azimuth, 1.5 m from the participant.

Procedures

Pre-experimental tasks included obtaining consent, completing a case history form, and an audiometric evaluation. For the audiometric evaluation, auditory thresholds were recorded from 250 to 8000 Hz and UCLs were measured to speech. Experimental procedures included measurement of MCL and BNL at three separate sessions, each 1 week apart. Experimental procedures additionally included instructions for sound enrichment (i.e., experimental group) or sound static procedures (i.e., control group) for the 2 weeks of the experiment.

For MCL and BNL measures, the published ANL instructions were followed (Nabelek et al[20] & Cosmos Incorporated instructions provided with the test compact disc). MCL and BNL were assessed using a three-step bracketing procedure which allowed the listener to hear levels above and below their MCL and BNL. All participants received written and verbal instructions before beginning experimental tasks. The written instructions are provided in previous publications (e.g., Cosmos Incorporated ANL Test CD Jacket, Nabelek et al[20] & Gordon-Hickey and Moore[10]). Participants were instructed to signal the investigator to adjust the signal level up (thumbs up), down (thumbs down), or stop adjustments (flat palm). Three trials were completed for MCL and for BNL. These trials were recorded. Means were computed for calculation of ANL.

For MCL measurement, the participant was instructed to increase the level of the story until it was too loud (i.e., louder than most comfortable). The level of the discourse was presented at 30-dB HL and increased in 5-dB steps until the participant signaled that it was louder than preferred. The participant was then instructed to decrease the level of the primary discourse until it was too soft (i.e., softer than most comfortable). The discourse was then decreased in 5-dB steps until the participant signaled that it was too soft. Last, the participant was instructed to "turn the level of the discourse up to your MCL." This final adjustment was made in 2-dB steps until the MCL was identified.

To find the BNL, the primary discourse was presented at the listener's MCL and 12 babble was introduced at 30-dB HL. The listener was instructed that their hand signals would now control the BNL. The listener was then instructed to turn the level of the background noise up until they could no longer hear the story. The loudness level of the 12 babble was increased in 5-dB steps until the participant signaled that the story could not be heard. The listener was then instructed to adjust the background noise so that the story was very clear. The level of the discourse was then decreased in 5-dB steps until the participant indicated that the discourse was clear. Last, the listener was then instructed to adjust the background noise "to the most noise that you would be willing to put-up-with and still follow the story for a long period of time without becoming tense or tired." This final adjustment was made in 2-dB steps until the BNL was identified. Three trials of MCL and BNL were completed at each session.

After the MCL and BNL were assessed, ANL was calculated as mean MCL–mean BNL = ANL. Volunteers meeting all qualification requirements were then asked if they would be willing to participate in the study for the following 2 weeks. All qualified participants agreed to participate. Participants were then randomly assigned to the experimental or control group.

For participants in the experimental group, sound enrichment techniques were discussed and a handout was provided. The instructions to each participant were quite simple: Do not allow yourself to be in a quiet setting, always add sound to the environment. It was suggested that any type of sound could be used to augment a quiet space. For example, open a window; turn on a fan, music, or television; or use a device such as a tabletop sound generator or a sound app on their cell phone. Furthermore, we suggested that participants read or study in a coffee shop or other environment with background noise present. Participants were instructed that the sounds used could be soft or at a moderate (i.e., comfortable) level. Examples were provided and discussion was encouraged. Before leaving the first appointment, all participants agreed that they understood and would implement sound enrichment procedures immediately. For participants in the control group, they were encouraged to live life as they would normally (i.e., sound static procedure). Participants were not provided the specific goals of the study. At the end of session 1, the participant and examiner identified and agreed to two additional appointment times.

After session 1, the experimenter contacted each participant 2–3 days later via email or phone to inquire as to how they were doing with sound enrichment (experimental) or sound static (control) procedures and learn if they had questions. In the case that the participant had questions or needed help, specific scenarios and possible solutions were discussed.

Session 2 was scheduled 1 week after session 1. At session 2, participants in the experimental group were asked to describe their use of sound enrichment and asked if they had any questions or concerns. Participants were asked to describe how they were able to incorporate sound into their daily life, to describe any difficult scenarios, and to provide an estimate of the amount of time per day they were in a sound-rich environment (i.e., existing background or other noise- and sound-enriched environments). The experimenter helped troubleshoot any difficult scenarios (e.g., use of sound during sleep or study). All participants were asked if they were recently exposed to loud sounds (e.g., concert, fireworks, and firearms use). All participants denied exposure to loud sounds over the past week. Three trials of MCL and BNL were completed in the same manner as in session 1. The experimenter was blinded to the MCL and BNL measures at the previous appointment. At the end of session 2, the participant was reminded to continue to follow either the sound enrichment or sound static procedures. The examiner and participant then confirmed the appointment for session 3. After session 2, the experimenter contacted each participant 2–3 days later via email or phone to touch base and learn if the participants had any questions or concerns.

Session 3 included a repetition of all measures completed at session 1 (i.e., pure-tone audiometric assessment from 250 to 8000 Hz and UCLs to speech) as well as measurement of MCL and BNL (i.e., three trials each). In addition, experimental participants were interviewed regarding their use of sound enrichment. All participants were again asked if they had been exposed to loud sounds over the past week. As in session 2, all participants denied exposure to loud sounds over the past week. At the conclusion of session 3, the participants in the control group were given a full description and of sound enrichment techniques so that they could implement sound enrichment if they wished to do so. The first testing session lasted approximately 60–90 minutes with the second and third sessions lasting 30–45 minutes. One experimenter completed all measures at all three appointments for every participant.

Results

The reliability and repeatability of MCL and BNL trials were evaluated before averaging trials for calculation of ANL. Mean, standard deviation (SD), range of ANL test differences, coefficient of repeatability (CR), and correlation coefficients for MCL are presented in ►**Table 1** and for BNL in ►**Table 2**. Since test–retest reliability and repeatability for MCL and BNL were strong, mean MCL and mean BNL were calculated for each test session for computation of ANL. Mean MCL, BNL, and ANL for the experimental group are presented in ►**Table 3** and for the control group in ►**Table 4**.

To insure that at the outset of the study, the two groups were similar for MCL, BNL, and ANL, three one-way analyses of variance (ANOVAs) were completed for measures completed at the initial appointment. No significant differences were found between the groups for MCL [$F_{(1, 17)} = 0.548$, $p > 0.05$], BNL [$F_{(1, 17)} = 1.149$, $p > 0.05$], or ANL [$F_{(1, 17)} = 0.833$, $p > 0.05$].

To evaluate the impact of sound enrichment on ANL, a between-group repeated-measures ANOVA was completed. A main effect of the session was found [$F_{(2, 34)} = 6.771$, $p < 0.01$]. In addition, an interaction was found for the

Table 1 Mean Difference, SD, and Ranges of Test Differences between Consecutive Trials, CR, and Pearson Product–Moment Correlation Coefficients for MCL Trials

	Session 1, Trials 1 and 2	Session 1, Trials 2 and 3	Session 1, Trials 1–3	Session 2, Trials 1 and 2	Session 2, Trials 2 and 3	Session 2, Trials 1–3	Session 3, Trials 1 and 2	Session 3, Trials 2 and 3	Session 3, Trials 1–3
Mean difference	−0.90	−0.05	−0.95	−1.16	0.16	−1.00	−0.53	−0.21	−0.74
SD	3.0	2.1	2.3	1.8	2.1	1.7	1.7	1.3	2.1
Range	−8.0 to 2.0	−4.0 to 4.0	0 to −6.0	−4.0 to 2.0	0 to 4.0	−4.0 to 2.0	−4.0 to 2.0	−2.0 to 2.0	−6.0 to 2.0
CR	6.3	4.4	4.8	3.8	4.4	3.6	3.6	2.7	4.4
Correlation coefficient	0.93	0.97	0.96	0.97	0.96	0.97	0.96	0.98	0.94

Note: All correlations are significant ($p < 0.01$). CRs were calculated using 2.1 as the multiplier because of the degree of freedom of 18.

Table 2 Mean Difference, SD, and Range of Test Differences between Consecutive Trials, CR, and Pearson Product–Moment Correlation Coefficients for BNL Trials

	Session 1, Trials 1 and 2	Session 1, Trials 2 and 3	Session 1, Trials 1–3	Session 2, Trials 1 and 2	Session 2, Trials 2 and 3	Session 2, Trials 1–3	Session 3, Trials 1 and 2	Session 3, Trials 2 and 3	Session 3, Trials 1–3
Mean difference	−0.1	−0.3	−0.3	−0.8	−0.2	−1.1	−1.1	−0.4	−1.5
SD	1.7	2.3	2.5	1.8	2.0	1.2	2.6	1.5	2.9
Range	−4.0 to 3.0	−3.0 to 4.0	−6.0 to 6.0	−5.0 to 0	−4.0 to 4.0	−6.0 to 4.0	−6.0 to 2.0	−3.0 to 0	−8.0 to 2.0
CR	3.6	4.8	5.3	3.8	4.2	2.5	5.5	3.2	6.1
Correlation coefficient	0.99	0.97	0.97	0.98	0.98	0.98	0.97	0.99	0.96

Note: All correlations are significant ($p < 0.01$). CRs were calculated using 2.1 as the multiplier because of the degree of freedom of 18.

Table 3 Mean (SD) MCL, BNL, and ANL in dB for the Experimental Group (n = 10)

	Session 1	Session 2	Session 3
MCL	47.11 (6.99)	48.11 (7.01)	48.22 (6.76)
BNL	31.67 (12.29)	32.67 (11.21)	33.00 (10.92)
ANL	15.78 (6.36)	15.56 (5.03)	15.33 (5.59)

Table 4 Mean (SD) MCL, BNL, and ANL in dB for the Control Group (n = 9)

	Session 1	Session 2	Session 3
MCL	47.11 (6.99)	48.11 (7.01)	48.22 (6.76)
BNL	31.67 (12.29)	32.67 (11.21)	33.00 (10.92)
ANL	15.78 (6.36)	15.56 (5.03)	15.33 (5.59)

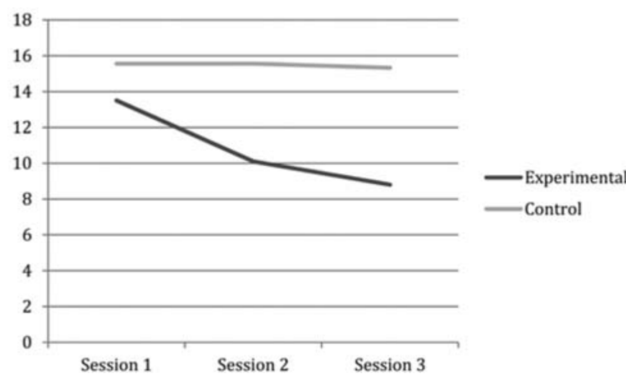

Fig. 1 Mean ANL across test sessions by group (experimental and control).

session and group [$F_{(2, 34)} = 4.773$, $p < 0.05$]. To evaluate the interaction of the session and group, post hoc analysis was completed. First, group differences were evaluated with two repeated-measures ANOVAs, with session serving as the independent variable. For the experimental group, the ANOVA revealed a significant difference for session [$F_{(2, 18)} = 8.886$, $p < 0.01$]. Pairwise comparison revealed that ANL was significantly different between sessions 1 and 2 ($p < 0.05$) and sessions 1 and 3 ($p < 0.05$), but was not significantly different between sessions 2 and 3 ($p > 0.05$). For the control group, the ANOVA revealed no significant difference for ANL across sessions [$F_{(2, 16)} = 0.145$, $p > 0.05$]. The second set of post hoc testing was completed to evaluate group difference at each of the three sessions. As previously stated, for session 1, there was no significant difference found for ANL [$F_{(1, 17)} = 0.833$, $p > 0.05$]. For session 2, a significant main effect was found for ANL [$F_{(1, 17)} = 5.595$, $p < 0.05$], demonstrating a significantly lower ANL for the experimental group than the control group. For session 3, a significant main effect was found for ANL [$F_{(1, 17)} = 8.024$, $p < 0.01$], with the experimental group having a lower mean ANL than the control group. ►**Figure 1** displays ANL across test sessions for each group.

Eight of the ten participants in the sound enrichment group demonstrated an improvement in ANL over the 2-week period, whereas two participants did not show an improvement. For those with an improvement in ANL, the average improvement was 7 dB (with a range of 3–13 dB improvement). For the whole experimental group, the average improvement was 5 dB (range of −2 dB worsened to 13 dB improved). For the control group, seven participants showed no change in ANL (i.e., 0, −1, or +1 dB change), whereas two showed a mild improvement (i.e., one participant improved by 2 dB and the other by 4 dB). For the control group, the average change in ANL was 1 dB (range of −1 dB worsened to 4 dB improved). To consider the magnitude of change in ANL, we calculated the percentage change in ANL relative to the initial ANL, with 0-dB ANL as the gold standard. For example, a participant with an initial ANL of 10 dB and a final ANL of 6 dB had a 40% decrease in ANL. For the experimental group, the average percentage change in ANL was 21% (range of 13% worsened to 100% improved). For the control group, the average percentage change in ANL was 1.4% (range of 11% worsened to 13% improved). To summarize, 80% of the experimental group had improved ANLs after treatment compared with 22% of the control group. The magnitude of improvement was much greater for the experimental group (5 dB or 21% improved) than the control group (1 dB or 1.4% improved).

To determine the factors that affected ANL, analytical statistics were completed for MCL and BNL measures. For MCL, a repeated-measures ANOVA revealed no significant differences in MCL across test sessions for both groups [$F_{(2, 34)} = 2.165$,

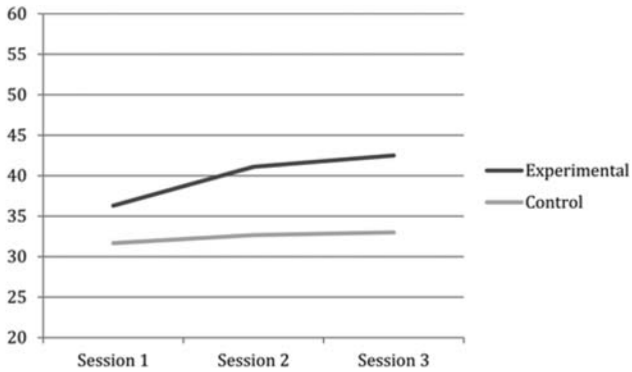

Fig. 2 Mean BNL in dB across test sessions by group (experimental and control).

$p > 0.05$]. For BNL, a repeated-measures ANOVA revealed a significant main effect for session [$F_{(2, 34)} = 16.507$, $p < 0.01$] and a significant interaction of session and group [$F_{(2, 34)} = 6.940$, $p < 0.01$]. The significant interaction of session and group for BNL was evaluated with post hoc testing. First, two separate ANOVAs were completed for each group across test sessions. For the experimental group, BNL was significantly different across test sessions [$F_{(1.244, 11.193)} = 23.248$, $p < 0.01$]. Pairwise comparisons revealed that BNL differed significantly across all test sessions (<0.05). For the control group, the repeated-measures ANOVA revealed no significant difference across the test session for BNL [$F_{(2, 16)} = 0.990$, $p > 0.05$]. ►**Figure 2** displays the mean BNL for each test session by group. Second, group differences were evaluated by test session. No significant difference was found for BNL at session 1 [$F_{(1, 17)} = 1.149$, $p > 0.05$] or session 2 [$F_{(1, 17)} = 4.349$, $p > 0.05$]; however, significant differences were found for BNL in session 3 [$F_{(1, 17)} = 5.580$, $p < 0.05$]. At session 3, the mean BNL was significantly better (higher) for the experimental group than for the control group.

Last, to evaluate potential differences in auditory thresholds and UCLs across test sessions, a series of analytical statistics was completed. No significant difference was found for UCL to speech from session 1 to session 3 for the right [$F_{(1, 17)} = 1.848$, $p > 0.05$] and left ears [$F_{(1, 17)} = 0.064$, $p > 0.05$]. To evaluate any potential changes in auditory sensitivity due to sound enrichment, four repeated-measures ANOVAs were completed with group serving as a between-subjects factor. No main effects were found for auditory sensitivity or for group. The interaction was also not significant for each of these ANOVAs. For right-ear PTA at baseline [$F_{(1, 17)} = 0.004$, $p > 0.05$], right-ear PTA posttreatment [$F_{(1, 17)} = 0.238$, $p > 0.05$], left-ear PTA at baseline [$F_{(1, 17)} = 0.383$, $p > 0.05$], and left-ear PTA posttreatment [$F_{(1, 17)} = 0.025$, $p > 0.05$].

Participants in the sound enrichment group (n = 10) reported that sound enrichment techniques were easy to implement (100%). Participants reported using sound enrichment techniques for 16–22 hours per day. Many participants reported that quiet activities such as reading or studying posed the most difficulty when trying to use sound enrichment techniques. In addition, participants described sleep time as a difficult environment to enrich with sound. The experimenters counseled these participants regarding uninteresting sound (e.g., rushing water and white noise) for use when reading and/or sleeping.

Discussion

The purpose of the present study was to evaluate the influence of sound enrichment on background noise acceptance to learn if we can improve a listener's ANL or to confirm that ANL is an inherent trait that cannot be adjusted or changed. Participants in this study all reported difficulty listening in a noisy environment, had normal hearing thresholds, and had an ANL that was categorized as having low likelihood of hearing aid success (i.e., mid [7–14 dB] or high [>14 dB]). The experimental group participated in 2 weeks of sound enrichment, whereas the control group did not.

Findings of the present study indicate that ANL can be improved through the use of sound enrichment. From baseline assessment to session 3, the experimental group demonstrated no significant difference in MCL, with a statistically significant increase in BNL (6.2 dB increase). The change in BNL resulted in a decrease in ANL (4.7 dB decrease) from baseline to session 3. Thus, after sound enrichment treatment, listeners were more accepting of background noise while listening to speech. MCL, BNL, and ANL were stable for the control group, with no statistically significant changes in these measures over the timeframe of the study. Listeners implementing sound enrichment demonstrated a significant shift in ANL between weeks 1 and 2 (3.4 dB decrease). Although not statistically significant, the difference was slightly improved between weeks 2 and 3 (1.3 dB decrease). This pattern indicates that the critical time period for recalibration of acceptance of background noise through sound enrichment therapy may be as short as 1 week. This is promising for audiologists seeking to improve a listener's potential success with hearing aids as sound enrichment treatment can be implemented in a manner that is practical, simple, and inexpensive. Patients are not required to purchase special equipment or software but are asked to use everyday tools to supplement their sound environment.

If our findings translate to the target population of older adult candidates using hearing aids, then we may be able to improve their ANL within one to 2 weeks after assessment. Ultimately, we hope that this will lead to improved hearing aid success rates; however, to date, there are no studies that have reported improvements in ANL equating to improvements in hearing aid success. Sound enrichment is an easy-to-implement strategy for individuals with normal hearing and for those with mild hearing impairment. However, environmental sound enrichment has limitations as augmenting the sound environment with low-level background sound will prove challenging for those with moderate to severe hearing impairment. If future work demonstrates that improvements in ANL via environmental sound enrichment translate to increased hearing aid success rates, then investigators should evaluate other methods to provide sound enrichment for individuals with greater amounts of hearing loss.

Findings of the present study indicate that ANL is not an inherent (i.e., permanent) trait and that it can be improved through the use of sound enrichment. This differs from Nabelek's hypothesis that ANL is inherent and stable to a given individual (Nabelek[19]). Nabelek's hypothesis was based on physiologic data presented by Harkrider and Tampas[12] indicating different central auditory processing for individuals with low ANLs compared with those with high ANLs. These data indicated that individuals with low ANLs may have different responses to auditory stimuli from the level of the inferior colliculus and above. However, more recent findings indicate that psychological variables, such as self-control and auditory experience, play a role in how listeners set their ANLs. Nichols and Gordon-Hickey[24] reported that individuals with high levels of self-control accepted more background noise (low ANLs) than those with low levels of self-control. They suggested that listeners who are able to improve their overall self-control may be able to improve their ability to cope with background noise. Wu et al[28] indicated that ANL is complex and many variables play a role in establishing ANL. They described psychological variables and the individual's own weighting of the importance of acoustic features as having a role in how listeners determine their ANLs. For our study, we asked for volunteers who had difficulty with background noise. It is possible that these individuals were more psychologically ready or open to treatment than an average person. This begs the question: Were our findings based on a psychological factor such as self-control or a placebo effect rather than the use of sound enrichment techniques? Evidence from the present study does not allow us to discern which factor caused the shift or recalibration of ANL.

Findings of the present study are based on young adults with normal hearing sensitivity. Because ANL is a central task, young listeners may be more likely to demonstrate a shift or change in ANL because of active neural plasticity. Because older adults demonstrate reduced neural plasticity, this treatment protocol may not be effective or may not be as effective for this population. In addition, individuals with hearing loss may not respond as positively to sound enrichment as do listeners with normal hearing. The level of sound required for listeners with hearing loss to enrich their environment may be intrusive or frustrating and not practical because of the level of sound needed for audibility. For these reasons, future studies should assess older adult listeners with and without hearing loss to learn if sound enrichment is effective for the target audience. In addition, the present study used 2 weeks of sound enrichment training with no follow-up for 1 month or several months later. For this reason, we do not know if a longer treatment time period would have a greater impact on ANL or if the effect stabilizes after a period of time. Furthermore, we do not know if the recalibration or improvement in ANL remained after sound enrichment ceased or if the ANL adjusted back to baseline. Future work should include longer treatment timelines and posttreatment follow-up to learn if treatment effects are increased and/or maintained over time. Future work should also aim to evaluate attributes of sound enrichment used by each participant to learn if these elements increase or decrease a change in ANL (i.e., sounds used and frequency of use of sound). Use of dosimeters and/or detailed participant journals may provide clues for refining sound enrichment recommendations for patients with background noise difficulties. Last, future studies should test a larger sample size of the target audience.

Sound enrichment treatment lasting 4 weeks has been shown to effectively improve (i.e., increase) UCLs (Formby et al[6]). However, in the present study, we found no change in UCLs. The present study differed from Formby et al's study by participant type, method of sound enrichment, and length of treatment. Formby et al's[6] included listeners with normal hearing (no complaint of background noise) and used ear-level sound generators for 23 hours per day, and the treatment lasted 4 weeks. Our study included participants who complained of background noise issues/problems, used the instructional sound enrichment technique (i.e., did not require ear-level devices), and was 2 weeks in length. Future work should evaluate whether or not the instructional sound enrichment strategy affects UCLs, given a longer treatment timeline.

In conclusion, ANL may be improved for young listeners with normal hearing sensitivity through a 2-week treatment with sound enrichment. Good hearing hygiene is often viewed as protecting hearing from loud sounds. In the future, audiologists may also encourage patients to allow or seek out low- to moderate-level background noise in typical listening environments rather than avoidance of these sounds. Although ANL may be a seemingly inherent trait, at least some portions of background noise acceptance can be altered or modified by sound-related behaviors.

Abbreviations

ANL	acceptable noise level
ANOVA	analysis of variance
BNL	background noise level
CR	coefficient of repeatability
MCL	most comfortable listening level
HL	hearing level
PTA	pure tone average
PTM	Progressive Tinnitus Management
SD	standard deviation
UCL	uncomfortable loudness level

Conflict of Interest
None declared.

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