Aided Acceptable Noise Levels (ANL): A Comparison across Degree of Hearing Loss, Noise Reduction in Hearing Aid and Personality Type

Manuj Agarwal & P. Manjula*

Abstract

Acceptable Noise Level (ANL) is a measure of the willingness to accept the background noise while listening to speech and is defined as the difference between the most comfortable listening level (MCL) for running speech and the maximum background noise level (BNL) that a listener is willing to accept. The present study aimed to evaluate the relationship between the unaided and aided Acceptable Noise Levels, effect of degree of hearing loss , digital hearing aid with and without the noise reduction scheme, effect of presentation level and effect of personality type on Aided Acceptable Noise Levels. Three groups of participants based on the degree of hearing loss were assessed in unaided and two aided conditions. The two aided conditions included fitting of an appropriate digital hearing aid with noise-reduction feature turned-off and turned-on. To assess the effect of presentation level, only participants with the moderate degree were considered. The ANLs were obtained at three presentation levels, at 5 dB SL, mid-value of DR and 10 dB below the UCL. Eysenck Personality Questionnaire (EPQ) was administered to assess personality of the participant. The results indicated that: 1. ANLs obtained in the unaided and aided conditions were not significantly different. 2. The difference in ANLs across the severity of hearing loss was non-significant, indicating that ANLs are not affected by the peripheral hearing loss. 3. Digital noise-reduction feature significantly decreased the ANL by increasing the amount of tolerance to background noise. 4. When ANL was measured at different presentation levels of speech, there was a gradual increment in the ANL with increase in the presentation level. 5. On personality assessment, the higher extroverted personality obtained a lower ANL while the participant high on neuroticism obtained a higher ANL.

Key words: noise reduction, presentation levels, global ANL, personality questionnaire

Introduction

People with cochlear hearing loss frequently complain that their hearing aids are of limited benefit. Difficulty in understanding speech in the presence of noise is the most frequent complaint of adults who use hearing aids (Kochkin, 2002; Cord, Surr, Walden and Dyrlund, 2004). Nabelek, Tucker, and Letowski (1991) hypothesized that willingness to listen to speech in background noise may be more indicative of hearing aid use than speech perception scores obtained in the background noise. This hypothesis led to the development of a procedure called "Acceptable Noise Level" (ANL) which is a measure of the willingness to accept the background noise while listening to speech.

The ANL is defined as the difference between the most comfortable listening level (MCL) for running speech and the maximum background noise level (BNL) that a listener is willing to accept. The ANL measure assumes that speech understanding in noise may not be as important as is the willingness to listen in the presence of noise. It has been established that people who accept background noise have smaller ANLs and

* Professor in Audiology, AIISH, Mysore 570 006

tend to be “good” users of hearing aids (Nabelek, Freyaldenhoven, Tampas, Burchfield and Muenchen, 2006).

Nabelek, et al., (2006) assessed the usefulness of ANL as a predictor of hearing aid use. Results indicated that ANLs were related to hearing aid use. Specifically, full-time hearing aid users accepted more background noise than part-time users or non-users. Studies on ANL have investigated the effect of age, hearing sensitivity (Nabelek, Tucker and Letowski, 1991), gender (Rogers, Harkrider, Burchfield and Nabelek, 2003), type of background noise (Crowley and Nabelek, 1996), efferent activity of the medial olivocochlear bundle (MOCB) pathway (Harkrider and Smith, 2005), middle ear characteristics or speech perception in noise performance (Nabelek, Tampas and Burchfield, 2004).

Although the utility of ANL as a clinical tool to assess the success of hearing aid use has been established, most of the studies have used listeners with mild to moderate hearing loss. Freyaldenhoven, Plyler, Thelin and Hedrick (2007) investigated the effect of hearing sensitivity on ANL, by comparing global ANL to the pure-tone average (PTA) in listeners with hearing loss. The participants of the study had hearing loss of mild-moderately sloping to moderately severe- severe degree. The results obtained were insignificant indicating that global ANL is not related to hearing sensitivity. However, the participants were not classified into separate groups based on the degree of hearing loss. There is a dearth in literature on how the ANL value varies as a function of hearing loss from moderate to severe degree of loss.

Also, the recent development of digital hearing aids opens up substantial new possibilities with respect to the use of advanced signal-processing techniques for noise reduction (Levitt, Neuman, Mills and Schwander, 1986). Mueller, Weber, Benjamin, and Hornsby (2006) studied the effect of digital noise reduction (DNR) on ANL on 22 adults fitted with 16-channel wide-dynamic range compression hearing aids with DNR processing. The results indicated a significant mean improvement for ANL (4.2 dB) for the DNR-on condition than DNR-off condition. However, it was not indicated that how this improvement with noise reduction algorithm varied as a function of degree of hearing loss and/or as a function of presentation level of the speech stimulus.

The effect of personality types on hearing aid benefit has been studied. Cox, Alexander, and Gray (1999) studied the relationship between the personality trait and self-reported hearing aid benefit in 83 individuals with mild to moderate sensorineural hearing loss. Participants completed the APHAB and measures of personality on the State-Trait Anxiety Inventory (STAI) (Spielberger, 1983), the MBTI (Myers and McCaulley, 1985), and a measure of locus of control (Levenson, 1981). The results indicated extroversion-introversion to be the best predictor of hearing aid benefit. However, there has been no literature available on the effect of personality type on ANL score. Since, ANL is indicated as an inherent characteristic of an individual, which does not change with age or acquired hearing loss (Nabelek, et al., 2006), it would be interesting to study its relation with the personality of an individual.

The present study aimed to evaluate the following:

1. The relationship between the unaided and aided Acceptable Noise Levels
2. The effect of degree of hearing loss on Aided Acceptable Noise Levels.
3. The effect of digital hearing aid with and without the noise reduction scheme on Aided Acceptable Noise Levels.
4. The effect of presentation level on Aided Acceptable Noise Levels in moderate degree of hearing loss.
5. The effect of personality type on Aided Acceptable Noise Levels.

Method

Participants

21 participants in the age range of 15 to 65 years (mean age being 49.78 years) were included in the study. They had a speech identification scores (SIS) of ≥ 75 %.The participants had hearing loss that was acquired post-lingually, symmetrical bilaterally and either sensori neural or mixed. They were native speakers of Kannada language. All of them were naïve hearing aid users. The participants did not have any significant neurological or cognitive listening deficits. Participants who got a lie score of ≤4 on the Eysenck Personality Questionnaire (EPQ) were included. Each participant was assigned in one of the three groups based on the degree of hearing loss. Each group had seven participants. The groups were-

- Group I - Participants with moderate degree of hearing loss (PTA between 41 dB HL and 55 dB HL).
- Group II - Participants with moderately-severe degree of hearing loss (PTA between 56 dB HL and 70 dB HL).
- Group III - Participants with severe degree of hearing loss (PTA between 71 dB HL and 90 dB HL).

Equipment and Test Material

1. A 15 channel digital BTE hearing aid, suitable for the hearing loss of the participants, with a noise reduction algorithm.
2. Personal Computer and Hi-Pro
3. A calibrated double channel diagnostic free-field audiometer
4. Speech material - Three recorded speech passages in Kannada.
5. Eysenck Personality Questionnaire (EPQ) (Eysenck and Eysenck, 1975).

Procedure

The conventional ANL procedure involved the listeners to first adjust the level of a story to their most comfortable listening level (MCL). Then, a background noise was added, and the listener had to adjust the noise to a level at which they would be willing to accept or "put up with" without becoming tense or tired while following the words of the story (called "background noise level, BNL"). The ANL was calculated by subtracting the BNL from MCL. In addition, the effect of presentation level on ANLs was also evaluated. For this, one of the three groups in the study was chosen. Since, the participants in Group I had the maximum dynamic range (DR) as compared to those in Group II and Group III, participants in Group I were utilized for this purpose.

The data were collected in the following five stages:

Stage 1. Establishing the unaided ANL (ANL_1).
Stage 2. Programming the hearing aid.
Stage 3. Establishing the aided ANL with noise reduction scheme turned off (ANL_2).
Stage 4. Establishing the aided ANL with noise reduction scheme turned on (ANL_3).
Stage 5. Assessment of the personality through Eysenck Personality Questionnaire

Stage 1. Establishing the unaided ANL (ANL_1).

The participant was made to sit comfortably on a chair in front of the loudspeaker in the test room. The speech stimulus (recorded passage in Kannada) was initially presented through the loudspeaker at the level of speech reception threshold (SRT), determined at the time of audiological assessment. Gradually, the presentation level was adjusted in 5 dB steps upto the level of MCL and then in 2 dB steps until the participant's MCL was established reliably. The step was repeated two times, and the average of the two levels was taken as the MCL. This level was noted down as MCL.

For establishing the MCL the following instructions were given: "You will listen to a story through the loudspeaker placed in front of you. The loudness of the story will be varied. First, the loudness will be turned up until it is too loud and then down until it is too soft. You have to indicate the level at which the loudness of the story is most comfortable for you".

At this stage, a speech noise was introduced at 30 dB HL and its level raised to a point, in 5 dB steps, at which the participant was willing to accept the noise without becoming tired or tensed while listening to and following the words in the speech. This maximum level of speech noise at which he/she could accept the noise without becoming tired was considered as the BNL. For the purpose of establishing BNL, the instructions used were "You will listen to the story with a background noise. After you have listened to it for a few moments indicate the level of background noise that is the most you would be willing to accept or 'put-up-with' without becoming tense or tired while following the story. First, the noise will be turned up until it is too loud and then down until the story becomes very clear. Finally, indicate the maximum noise level that you would be willing to 'put-up-with' for a long time while following the story". This level, called the BNL, was noted down. The ANL_1 (in dB) was calculated as difference between MCL (dB HL) and BNL (dB HL) for each participant.

For the participants in Group I, the participant's dynamic range was also determined, by establishing the SRT and UCL for speech. The difference between UCL and SRT determined the dynamic range (DR). The instructions used for establishing the DR was "You will be listening to a story through the loudspeaker placed in front of you. Initially the loudness of speech will be more and gradually the loudness will reduce. You have to indicate the softest level at which you are just able to follow the story. Then, the loudness of the story will be gradually increased. You have to indicate the level at which you are not able to tolerate the loudness of the speech stimulus". This procedure was repeated two times, and the average level was taken as DR. The dynamic range (DR) was measured for each participant in Group I. For this purpose, the softest level at which the participant was just able to follow the story was determined. For the purpose of the study, this level was noted down as SRT. Then, the level was gradually increased to a level at which the participant reported of discomfort. This level was noted down as UCL. ANL was obtained at three presentation levels of speech, i.e., at 5 dB SL, at mid value of DR and at 10 dB below UCL. The ANL_1 was calculated as difference between Presentation Level (dB HL) and BNL (dB HL). Thus, for the participants in Group I, three ANLs were obtained at three presentation levels, which were referred as ANL_{1a}, ANL_{1b} and ANL_{1c} respectively. This was in addition to the ANL_1 that was measured, as described earlier.

Stage 2. Programming the hearing aid

The hearing aid was connected to the programming hardware (Hi-Pro) through a cable and detected by the programming software. The hearing thresholds of the better ear of the participants were then fed into the programming software and target gain curves were obtained using the proprietary prescription formula of the hearing aid. The hearing aid gain was set to the default target gain and fine-tuned according to participant's preference. The hearing aid chosen for the study had three programs. Program 1 of the hearing instrument had the noise reduction algorithm (dNC) turned off. In Program 2, the noise reduction algorithm (dNC) was turned on. The dNC had two degrees of noise reduction - light, and moderate. 'Moderate dNC' was selected for the purpose of the study. Only Program 1 and Program 2 were used in the study. These settings were saved in the hearing aid for each participant.

Stage 3. Establishing the aided ANL with noise reduction scheme turned off (ANL_2).

Only one ear, the ear with better PTA, of the participant was aided. The hearing aid was fitted in the ear with better pure tone average while it was ensured that the participation of the unaided ear was ruled out, when indicated. The hearing aid was set at Program 1. The participant was made to listen to a story passage. A different story was used to avoid any practice effect. MCL and BNL were determined in this condition following the procedure described earlier, and the ANL was calculated. This ANL was labeled as $ANL_{2.}$

For the participants in Group I, their SRT_2 and UCL_2 were established to obtain the dynamic range with the hearing aid called DR_2. The ANL was obtained at 3 presentation levels of speech, i.e., at 5 dB SL, mid value of DR_2 and 10 dB below UCL_2. The ANL_2 was calculated as difference between presentation level (dB HL) and BNL (dB HL). Thus, for the participants in Group I, ANLs were obtained at three presentation levels, which were referred to as ANL_{2a}, ANL_{2b} and ANL_{2c} respectively.

Stage 4. Establishing the aided ANL with noise reduction scheme turned on (ANL_3).

To activate the noise reduction scheme in the hearing aid, Program 2 was used. This program had all the settings similar to Program 1 except for the addition of dNC noise reduction scheme at moderate level. With this program setting, the entire procedure described in Stage 3 was repeated and ANL was obtained. This was labeled as ANL_3. For the participants in Group I, three ANLs were obtained at three presentation levels, which were referred as ANL_{3a}, ANL_{3b} and ANL_{3c} respectively.

Stage 5. Assessment of the personality through Eysenck Personality Questionnaire (EPQ).

The *Eysenck Personality Questionnaire (*EPQ) (Eysenck and Eysenck, 1975) was administered to each participant. He/she was instructed to read each statement and if it described him or her, or, if he or she was in agreement with the statement then to draw a circle around ‘Yes’. If the statement did not describe the participant, then a circle was drawn around ‘No’. The participant was also informed that there were no right or wrong answers and were required to give honest answers.

Scoring was done after the administration of EPQ. Each response was checked with the scoring key. Scoring was done with the help of a clinical psychologist. If the participant’s response agreed with the key, a score of 1 was given, if not a score of 0 was given. Separate scores were derived for Extroversion (E) and Neuroticism (N). Lie scale (L) was also checked and the number of responses agreeing with the key was totaled. Thus, there were three scores - E, N and L. If the L score was found to be high (5 or >5), the data were deleted and the participant was not considered for further study. In the present study, two participants had to be deleted based on this criterion.

Results and discussion

The analysis of the data was done separately for Group I, Group II and Group III.

Group I (moderate degree of hearing loss)

In the unaided condition, the mean ANL in group with moderate hearing loss was 8.85 dB with a standard deviation of 2.03 dB. In the first aided condition when the noise reduction was turned-off (A1), the mean ANL was also 8.85 dB with a standard deviation of 1.57 dB. In the second aided condition when the noise-reduction was turned-on (A2), the mean ANL was 7.71 dB with a standard deviation of 1.79 dB. It was also noticed that, the MCL values in all the conditions were higher than the BNL values.

Group II (moderately-severe degree of hearing loss)

In the unaided condition, the mean ANL in the group with the moderately-severe hearing loss was 9.42 dB with a standard deviation of 2.93 dB. In the first aided condition (A1), the mean ANL was 9.71 dB with a standard deviation of 2.43 dB. In the second aided condition (A2), the mean ANL was 8.85 dB with a standard deviation of 1.95 dB. The MCL values in all the conditions were higher than the BNL values.

Group III (severe degree of hearing loss)

In the unaided condition for the group with severe hearing loss, the mean ANL was 8.28 dB with a standard deviation of 2.98 dB. In the first aided condition (A1), the mean ANL was 8.57 dB with a standard deviation of 3.20 dB. In the second aided condition (A2), the mean ANL was 7.71 dB with a standard deviation of 2.69 dB. The MCL values in all the conditions were higher than the BNL values.

The effect of digital hearing aid, with and without the noise reduction feature, on aided Acceptable Noise Levels and its relationship with the unaided ANLs

To evaluate interactions between the ANLs obtained in the unaided and different aided conditions across the severity of the hearing impairment, mixed analysis of variance (ANOVA) was done. There was no significant interaction effect of the ANL among the three conditions across the severity of hearing impairment [$F (4, 36) = 0.202, p > 0.05$]. Thus, the results indicated that the ANLs obtained for all the three groups varying in severity of hearing impairment were not significantly different. However, there was a significant main effect for different unaided and aided conditions [$F (2, 36) = 5.66, p< 0.01$]. To evaluate the significant differences in the unaided (UA) and different aided (A1 & A2) conditions, pair-wise comparison using post-hoc Bonferroni test was done. The Table 1 depicts the results of post-hoc Bonferroni analysis for the UA, A1 and A2 conditions.

Table 1: Results of post-hoc Bonferroni analysis for the unaided (UA) and aided (A1 & A2) conditions.

Conditions	Significance level
UA∗A1	p>0.05
UA∗A2	p<0.05
A1∗A2	p<0.05

Pair-wise comparisons of the UA, A1 and A2 conditions revealed a non-significant difference (p> 0.05) between the ANLs obtained in the unaided and A1 conditions, i.e., the ANL obtained in the unaided condition and in the aided condition with noise-reduction algorithm turned-off were not significantly different. This implied that the hearing aid did not make any significant difference in the ANLs measured in the UA and A1 conditions. However, the ANLs obtained in the A2 condition were significantly different (p < 0.05) from the ANLs obtained in the unaided and A1 conditions, i.e., when the noise-reduction algorithm was turned-on, the ANL values obtained were significantly different from those obtained in the unaided and the aided condition with noise-reduction turned-off conditions. Thus, the activating the noise-reduction feature in a hearing aid significantly affected the ANL score. The ANL values were always lower in the aided condition when the noise-reduction was turned-off.

The results of the present study are in agreement with those reported earlier (Nabelek, Tucker and Letowski, 1991; Nabelek, Freyaldenhoven, Thelin, Burchfield and Muenchen, 2006; Mueller, Weber and Hornsby, 2006). The participants with average thresholds in the range of mild to moderate were included in the previous studies. In the present study, the hearing loss of the participants ranged from moderate to severe degree and it was found that the ANLs were not significantly different from moderate hearing loss to severe hearing loss groups.

Harkrider and Smith (2005) investigated the individual differences in the efferent activity in medial olivocochlear bundle (MOCB) and acoustic reflex (AR) pathways to account for inter-subject variability in ANL and phoneme recognition in noise (PRN). They indicated that the amount of background noise the participants were willing to accept in monotic and dichotic listening conditions were directly related, suggesting that non-peripheral factors, beyond the level of the superior olivary complex where binaural processing first occurs, mediate ANL. Thus, in the present study even when the degree of hearing loss was varying across the groups, the ANL obtained for the participants was not dependent on the severity of hearing loss, indicating a central mediation of ANL.

The results of pair-wise comparison indicated a significant difference between the ANLs obtained in both UA or A1 conditions and the A2 condition. Also, no significant difference between UA and A1 condition was noticed. The results are in agreement with the findings of Nabelek, Tampas and Burchfield (2004) that compared the speech perception in background noise (SPIN) with the acceptance of background noise in the unaided and the aided conditions. The results indicated that ANLs were independent of hearing aid amplification. In their study, the ANLs and SPIN scores were found to be unrelated as there was a significant improvement in the SPIN scores with amplification.

In the present study, when the noise-reduction algorithm was turned-on, the mean MCL value was found to be same as in the first aided condition, i.e., 61.4 dB, which indicates no effect of noise reduction algorithm on the MCL for speech. The mean BNL values for the moderate group in the UA, A1 and A2 conditions were 63.1 dB, 52.5 dB and 53.7 dB respectively. Thus, a reduction in the BNL was observed with the use of the hearing aid. However, when the noise-reduction is turned-on, the BNL was further increased by 1.2 dB, which is reflected as a lower ANL in the A2 condition than in A1 condition. A similar trend was seen in Group II and Group III. It should be noted that in a study by Nabelek, Tampas, and Burchfield (2004), the full-time and part-time groups had similar MCLs and the main contributor for the difference in ANL was the BNL. In contrast, in the present study, the groups were formed on basis of the degree of hearing loss and though both the MCLs and BNLs were found to vary, the ANLs were found to be similar in each group.

Within the group, the ANLs in the A2 condition were significantly different from the ANL obtained in the UA and A1 conditions. This indicates a significant effect of noise-reduction algorithm on the ANLs and specifically on the BNLs, as the MCLs were unaffected with the noise-reduction algorithm. The results of the present study are in consensus with the results of the study by Mueller Weber, and Hornsby (2006), in which a significant mean improvement of 4.2 dB was observed on ANLs with the noise-reduction turned-on. However, in the present study, the mean improvement in ANL with noise reduction algorithm turned-on was 1.1 dB in Group I, 0.9 dB in Group II and 0.8 dB in Group III, which was significant. The discrepancy between the mean improvement in the study by Mueller Weber and Hornsby (2006) and the present study could be accounted for by the differences in the hearing instrument used and the lesser number of participants in each group in the present study. It has been reported that the listeners often demonstrate a strong tendency for subjective preference for digital noise reduction (DNR) algorithms (Boymans and Dreschler, 2000), and actual improvement in speech perception is reportedly unreliable.

Effect of presentation level on Aided Acceptable Noise Levels in moderate degree of hearing loss

Table 2 gives the mean and standard deviation (SD) of the ANL values obtained at the three presentations levels in the unaided and two aided conditions. The results indicated that the ANL score increased as the level of presentation increased.

Table 2: Mean and standard deviation (SD) of ANLs obtained at three presentation levels, in unaided (UA) and aided (A1 & A2) conditions.

	Mean (dB)	Std. Deviation
UA ANL1	8.86	2.61
UA ANL2	10.00	1.73
UAANL3	11.71	1.38
A1 ANL1	8.28	1.70
A1 ANL2	10.71	2.98
A1 ANL3	11.86	1.95
A2 ANL1	7.71	2.50
A2 ANL2	9.00	2.89
A2 ANL3	9.28	2.43

The Global ANLs were also calculated by taking the sum of ANLs obtained at three presentation levels and averaging it. Table 3 shows the mean and standard deviation for the Global ANLs across the unaided and the two aided conditions.

Table 3: Mean, standard deviation and range of the Global ANL in the unaided (UA) and aided (A1 and A2) conditions

Condition	Global ANL, dB			
	Mean	SD	Minimum	Maximum
UA	10.19	1.44	8.86	11.71
A1	10.28	1.82	8.29	11.86
A2	8.67	.837	7.71	9.29

The results indicate that the mean Global ANL was 10.19 dB in the unaided condition (UA), 10.28 dB in the first aided condition (A1) and 8.66 dB in the second aided condition (A2). To determine the effect of presentation level on ANL under different conditions, two-way repeated measures ANOVA was carried out.

The results are in agreement with the study by Freyaldenhoven, Plyler, Thelin and Hedrick (2007) determining the effect of presentation level on ANLs. They measured the effects of speech presentation level on the acceptance of noise in listeners with normal and impaired hearing to determine whether these effects were related to the hearing sensitivity of the listener. The results demonstrated that global ANLs and ANL growth were not significantly different for listeners with normal and impaired hearing. Further, neither of the ANL measures was related to pure-tone average (PTA; i.e., average of 0.5, 1, 2, and 4 kHz) for listeners with impaired hearing. In addition, conventional ANLs were significantly correlated with both global ANLs and ANL growth for all listeners.

Freyaldenhoven, Plyler, Thelin and Muenchen (2008) evaluated the effects of speech presentation level on the hearing aid users. The participants formed different groups based on the hearing aid use were tested at eight presentation levels in the aided condition. Results indicated similar findings as reported by Freyaldenhoven, Plyler, Thelin and Hedrick (2007). However in their study too, no direct comparison was made between the unaided and aided conditions, as a function of speech presentation level. This discrepancy in results in the present study and the previous research can be explained in terms of measurement of ANL. It is possible that since the ANLs were measured at different presentation levels and not at MCLs. This would have affected the performance when the participants were aided. When the participant is aided, the dynamic range is increased and thus the perception of loudness of speech and the background noise at the three presentation levels would be different from the loudness perceived in the unaided conditions at three presentation levels.

Effect of personality type on Aided Acceptable Noise Levels

To investigate the effect the personality type on the ANL value, Pearson's correlation analysis was carried out. The personality scores were obtained as Extroversion score and Neuroticism score and compared with ANLs separately. Table 4 gives the results of correlation analysis between ANL (in different conditions) and Extroversion score.

Table 4:Pearson's correlation between ANL and Extroversion score.

Condition	N	Pearson Correlation	Level of significance
UA ANL	21	-0.288	p>0.05
A1 ANL	21	-0.118	p>0.05
A2 ANL	21	-0.288	p>0.05

The results indicate negative correlation between the ANLs and the Extroversion score ($p>0.05$). Thus, for all the conditions, the participants with higher ANL scores achieved a lower score on Extroversion scale and vice versa. However, this correlation was non-significant. It is thus possible that, an individual scoring higher on extroversion is likely to tolerate more amounts of background noise and thus obtains a lower ANL.

The Table 5 gives the results of correlation analysis between ANL (in different conditions) and Neuroticism score. The results indicate a positive correlation between the ANLs and the Neuroticism score ($p>0.05$).

Table 5:Results of correlation analysis between ANL and Neuroticism score.

Condition (N=21)	Pearson Correlation	Level of significance
UA ANL	0.196	p>0.05
A1 ANL	0.122	p>0.05
A2 ANL	0.101	p>0.05

For all the test conditions, the participants with higher ANL scores achieved a higher score on Neuroticism scale and vice versa. However, this correlation was also non-significant. According to Costa and McCrae (1997), individuals scoring low on Neuroticism are more relaxed and calm, and are better able to cope with stressful situations in their lives. Thus, participants who scored low on neuroticism were capable of tolerating more amount of background noise which was reflected as a low ANL score. The back ground noise represents a stressful condition for an individual with hearing impairment.

The results on the effect of personality, thus, indicate that the acceptance of background noise be an individual is related to his personality also. The relationship was however, non-significant, which may be because of the limited number of participants in the study. Cox, Alexander and Gray (1999) investigated the relationship between the personality trait and self-reported hearing aid benefit in individuals with mild to moderate sensori-neural hearing loss. The results indicated extroversion-introversion to be the best predictor of hearing aid benefit. More extroverted individuals reported greater hearing aid benefit on these three sub-scales of the APHAB than the more introverted individuals. In addition, individuals who reported greater anxiety also reported more problems in communication as measured on the aided condition of the 'Ease of Communication' sub-scale of the APHAB.

Summary of the findings of the present study:

The present study investigated the effect of digital hearing aid, with and without noise reduction, on the aided Acceptable Noise Levels and the relationship between the unaided and aided ANLs. The effect of degree of hearing loss, presentation level of speech stimuli, and the effect of personality type on the aided Acceptable Noise Levels (ANLs) were also investigated. The findings of the study indicate:

1. ANLs obtained in the unaided and aided conditions are not significantly different.
2. ANLs across the severity of hearing loss were found to be non-significant, indicating that ANLs are not affected by the peripheral hearing loss.

3. Digital noise-reduction feature significantly decreased the ANL by increasing the amount of tolerance for background noise. However, as the hearing loss increased, this decrement in ANL reduced.
4. When ANL was measured at different presentation levels of speech rather than MCL, there was a gradual increment in the ANL with increase in the presentation level.
5. The personality of the participant influenced the ANLs. Individuals with higher extroverted personality type obtained a lower ANL while those with high neuroticism obtained a higher ANL. However, this correlation was not significant.

References

Boymans, M. & Dreschler, W.A. (2000). Field trials using a digital hearing aid with active noise reduction and dual-microphone directionality. *Audiology,* 39 (5), 260-8.

Cord, M.T., Surr, R.K., Walden, B.E. & Dyrlund, O. (2004). Relationship between laboratory measures of directional advantage and everyday success with directional microphone hearing aids. *Journal of the American Academy of Audiology,* 15, 353–364.

Costa, P.T. & McCrae, R.R. (1997). Longitudinal stability in adult personality. In: Hogan, R., Johnson, J. & Briggs, S. (Eds), *Handbook of Personality Psychology* (pp. 269-290). San Diego, CA: Academic Press.

Cox, R.M., Alexander, G.C. & Gray, G. (1999). Measuring satisfaction with amplification in daily life: the SADL scale. *Ear and Hearing*, 20 (4), 306-320.

Crowley, H.J. & Nabelek, I.V. (1996). Estimation of client-assessed hearing aid performance based upon unaided variables. *Journal of Speech and Hearing Research*, 39, 19-27.

Eysenck, H.J. & Eysenck, S.G.B. (1975). *The eysenck personality* questionnaire. London: Sevenoaks, Hodder & Stroughton.

Freyaldenhoven, M.C., Nabelek, A.K. & Tampas, J.W. (2008). Relationship between acceptable noise level and the abbreviated profile of hearing aid benefit. *Journal of Speech Language Hearing Research*, 51, 136-46.

Freyaldenhoven, M.C., Plyler, P.N., Thelin, J.W. & Hedrick, M.S. (2007). The effects of speech presentation level on acceptance of noise in listeners with normal and impaired hearing. *Journal of Speech, Language and Hearing Research*, 50 (4), 878-85.

Harkrider, A.W. & Smith, B. (2005). Acceptable noise level, phoneme recognition in noise, and auditory efferent measures. *Journal of the American Academy of Audiology 16*, 530-545.

Kochkin, S. (2002). Consumers rate improvements sought in hearing instruments. *The Hearing Review*, 9, 18–20.

Levenson, H. (1981). Differentiating among internality, powerful others, and chance. In: Lefcourt H.M., (Ed.), *Research with the Locus of Construct (Vol. 1)*: *Assessment Methods* (pp. 15-63). New York: Academic Press.

Levitt, H., Neuman, A.C., Mills, R. & Schwander, T. (1986). A digital master hearing aid. *Journal of Rehabilitation Research and Development*, 23(1), 79-87.

Mueller, H.G., Weber, J., & Hornsby, B. (2006). The effects of digital noise reduction on acceptance of background noise. *Trends in Amplification*, *10*(2), 83-93.

Mueller, H.G., Weber, J., Benjamin W.Y., & Hornsby, B. (2006). The Effects of Digital Noise Reduction on the Acceptance of Background Noise. *Trends in Amplification*, 10, 83-93.

Myers, I.B. & McCaulley, M.H. (1985). *Manual: A guide to the development and use of the myers-briggs type indicator (2nd ed.).* Palo Alto, CA: Consulting Psychologists Press.

Nabelek, A.K., Freyaldenhoven, M.C., Tampas, J.W., Burchfield, S.B. & Muenchen, R.A. (2006). Acceptable noise level as a predictor of hearing aid use. *Journal of the American Academy of Audiology*, 17, 626–639.

Nabelek, A.K., Tampas, J.W. & Burchfield, S.B. (2004). Comparison of speech perception in background noise with acceptance of background noise in aided and unaided conditions. *Journal of Speech Language and Hearing Research,* 47, 1001-1011.

Nabelek, A.K., Tucker, F.M., & Letowski, T.R. (1991). Toleration of background noises: relationships with patterns of hearing aid use by elderly persons. *Journal of Speech and Hearing Research,* 34, 679–685.

Rogers, D.S., Harkrider, A.W., Burchfield, S.B. & Nabelek, A.K. (2003). The influence of listeners' gender on the acceptance of background noise. *Journal of the American Academy of Audiology,* 14, 374-385.

Spielberger, C.D. (1983). *State-trait anxiety inventory*. Palo Alto, CA: Consulting Psychologists Press.