

## PREDICTING HEARING AID ACCEPTANCE AND BEYOND

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The acceptable noise level (ANL) procedure was developed to quantify the maximum amount of background noise that listeners are willing to accept while listening to speech. The ANL is calculated as a difference between a listener's most comfortable listening level (MCL) for speech and the maximum acceptable noise level (BNL). Successful hearing aid use is related to an individual's ability to accept background noise. A formula was developed to calculate the probability of success with hearing aids as a function of individual ANL. Research has demonstrated that ANLs with and without hearing aids are highly correlated, and the ANL test can predict hearing-aid use with 85% accuracy. Several interesting issues have emerged from recent ANL investigations: 1) How should a patient be counseled regarding the ANL? 2) What factors contribute to the large inter-subject variability of ANL? 3) If successful hearing aid use relates to the ability to accept background noise, can this ability be enhanced by auditory training or pharmacological means? 4) Can hearing aids with advanced processing features, such as noise reduction, allow occasional or unsuccessful hearing aid users to become successful users?

**Keywords:** Acceptable Noise Level (ANL), Most Comfortable Level (MCL), Background Noise Level (BNL), hearing aids, successful hearing aid use.

### 1. Predicting hearing aid acceptance and beyond

Although I have not directly collaborated with Prof. Andrzej Rakowski on research projects, he provided considerable assistance in the completion of my doctoral dissertation on room acoustics at the Institute of Fundamental Technological Research in Poland. My doctoral project was the precursor to my later studies in the United States on the degrading effects of background noise and reverberation on speech perception by listeners with impaired hearing. Professor Rakowski was influential in my development as a researcher and on my approach to formulation of hypotheses, conducting studies, evaluation of data, and application of the results.

The significant connection of Prof. Rakowski to our studies regarding the prediction of hearing aid use was through Dr. Tomasz Letowski, who closely collaborated with Prof. Rakowski. My cooperation with Dr. Letowski resulted in the development of the acceptable noise level (ANL) procedure [1]. Dr. Letowski and I were trained as acousticians, which allows us to approach clinical problems quite differently than audiologists do. We first obtained a small grant from the American Association of Retired People, AARP, Andrus Foundation to investigate why some elderly people with hearing loss do not like their hearing aids or stop using them. A review of the literature available in the late 1980's indicated that background noise was the culprit of most complaints about hearing aids, but interestingly, speech perception in noise and improvement in speech understanding by amplification were not good indicators of success with hearing aids. Our own experience in listening to English as a second language drew our attention to willingness to listen to speech in the presence of background noise. I suppose each of us has experienced a noisy situation in which we stopped enjoying conversation or withdrew from the conversation. On the basis of such observations, we proposed to test people's willingness to listen to speech in the presence of background noise. As a measure of this willingness, we evaluated the amount of background noise in which a person is willing to accept while listening to recorded speech. In our first study, we called this willingness, "a tolerated speech to noise ratio, S/N," expressed in decibels. Subsequently, this willingness was termed, "Acceptable Noise Level" or simply ANL, when listening to speech expressed in decibels as a difference between an individual's most comfortable level (MCL) for speech and the maximum background noise level (BNL) that a listener is willing to accept when following the story without becoming tense or tired.

In the original study [1] with small groups of listeners (15/group), we determined that listeners who were good hearing aid users accepted significantly more background noise than those who struggled with the hearing aids or entirely rejected them. More recently, in a study sponsored by the National Institute on Deafness and other Communication Disorders, National Institutes of Health [2], with 191 listeners fitted with binaural hearing aids by audiologists independent of the study, we were able to establish a relationship between pattern of hearing aid use and the ANL. Listeners responded to a questionnaire inquiring about pattern of hearing aid use: 1) full-time, defined as used whenever hearing aids were needed, 2) part-time, used only occasionally, and 3) non-use, or total rejection of hearing aids. Because none of the auditory tests differentiated between part-time from non-users, listeners from these two groups were combined and called "unsuccessful" hearing aid users, while the full-time users were called "successful" hearing aid users. This dichomization of data allowed the use of logistic regression analysis to calculate the probability that an individual would become a successful hearing aid user. Listeners with low ANLs, no more than 7 dB, are acceptant of background noise and have approximately 90% probability of success with hearing aids. Listeners with high ANLs of 13 dB and more, have only a 10% probability of success with hearing aids. People with mid-range ANLs between 8 and 12 dB may be successful or unsuccessful. For listeners with ANL of 10 dB, the probability of success/unsuccess is 50%.

The accuracy of the prediction is 85%. In our recent study [3], responses to the Abbreviated Profile of Hearing Aid Benefit (APHAB) questionnaire developed by COX and ALEXANDER [4] were combined with the ANL in predicting hearing aid success. The accuracy of the prediction increased to 92%. The main contribution of the APHAB results was in resolving the ambiguity for predicting hearing-aid outcome in listeners with mid-range ANLs. The APHAB results indicated that the individuals who claimed to consistently have difficulties communicating in noise, reverberation, or following conversations were more likely to succeed with hearing aids than those who claimed to have these difficulties only occasionally.

The outcome of these ANL investigations [2] has introduced many questions and challenges in how the ANL is utilized. One immediate challenge is to popularize the test among audiologists for its use in clinical settings. The availability of a commercial recording of the test materials by COSMOS [5] facilitates the ANL's inclusion into the battery of audiological tests. Guidelines should be established on the use of the ANL results in counseling and planning of an audiologic rehabilitation program for patients. We recommend using the ANL information as a tool for audiologists to develop strategies for hearing aid fitting and rehabilitation programs. It is not clear, however, if patients should be informed about the ANL results and how they should be counseled. It is expected that this information may significantly influence a patient's attitude toward hearing aids and their outcome with amplification devices.

The ANL has been evaluated in the English language with listeners with normal and impaired hearing and in a small group of normal hearing listeners in the Korean language [6]. Investigation of the characteristics of ANL should be extended to other languages. The Korean study indicated greater acceptance of background noise by Korean than by comparable American listeners. Is it possible that acceptance of background noise is cultural dependent? Such dependency has previously been demonstrated in the investigation of pain tolerance [7].

Other issues related to the ANL are more basic. Listeners differed greatly in their acceptance of background noise when listening to speech. The distribution of the ANLs was normal for both listeners with impaired [2] and normal hearing [8]. The unpublished data for 220 listeners with normal hearing were compiled from our various studies in the Department of Audiology at the University of Tennessee. For both types of listeners, the range was between 2 and 28 dB with the most prevalent ANL occurring between 10 and 11 dB. There were several people with normal hearing willing to accept background noise at their MCL, (i.e., ANL = 0 dB). The upper range of the ANL was above 20 dB, which is puzzling because very low noise levels are almost non-existent in everyday life. For people with hearing loss, acceptance of background noise relates to success with hearing aids, the differences in the ANL among the population with normal hearing have no apparent consequences in everyday life. It has been shown that attitude toward background noise in everyday life was not related to measured ANL [9].

It has been demonstrated that the ANL is not related to gender, age, and hearing sensitivity [2]. The ANLs with and without hearing aids are highly correlated; the ANL is reliable and does not change over time [10]. Recent studies in our Department indicate

that differences in background noise acceptance are related to individual variations in the function of the central auditory nervous system as measured with auditory evoked potentials (AEPs). Investigations of young females with normal hearing by TAMPAS and HARKRIDER [11] indicated that female listeners with low ANLs exhibited smaller amplitudes and longer latencies in select AEP components relative to females with high ANLs. The neurophysiological characteristics of listeners with hearing impairment are currently being evaluated to compare to that of the young group with normal hearing.

In a conversation with Prof. Rakowski, he suggested incorporating a personality profile [12] into our battery of tests, which has been shown to be a centrally mediated process and inherent to individual and may influence ANL. A study which designated people as introvert or extravert [13] did not find any relationship with the ANL. Conversely, a recent student study [14] determining the Myers–Briggs personality type [15] in listeners with normal hearing indicated that listeners with a “Type A” personality had significantly higher ANLs than listeners with a “Type B” personality.

Results of our collective studies demonstrate that successful hearing aid use requires an individual to be acceptant of background noise. Some people are fortunate to be born with a willingness to listen in background noise and this ability seems to be retained throughout life and does not change should they acquire hearing loss. The challenge remains in how to address the hearing health care needs of those people with hearing impairment who do not possess the ability to accept background noise.

Hearing aids with directional microphones [16] and with digital noise reduction capabilities [17] allow less background noise to be delivered to the ears than conventional hearing aids; these hearing aids lowered mean group ANLs by approximately 3 dB. It is imperative that we investigate the possibilities of sophisticated hearing aids to convert part-time to full-time hearing aid users, and the capability of these hearing aids to prevent total rejection of hearing aids. Studies on the effect of assistive listening devices on the ANL also are needed for people who do not accept background noise.

A study of college students diagnosed with Attention Deficit/Hyperactivity Disorder indicated that the stimulant medication taken by these people reduced the mean ANL by 3 dB [18]. If lack of acceptance of background noise is mediated by the central auditory system, can these processes be altered by pharmacological means? Our research suggests that such a possibility exists, but is it cost effective to pursue that avenue? Probably the most appropriate and appealing method that is within the scope of audiologists for lowering the ANL and improving outcome with hearing aids is auditory training. Auditory training is the process of developing listening skills to improve the perception of sound. The potential of auditory training paradigms to affect ANL has not yet been completed by our group. JASTREBOFF and JASTREBOFF [19] developed an auditory training method, Tinnitus Retraining Therapy (TRT) attempting to alleviate the symptoms and/or completely eradicate tinnitus, a sometimes debilitating perception of sound in the ear in the absence of corresponding external sound. The researchers observed that many of their patients with hearing loss that were candidates for hearing aids changed their negative to a positive attitude toward amplification after completion of the therapy. The possibility of the ANL changing during this therapy has not been evaluated.

The rejection of hearing aids is expensive in terms of money, time, and motivation among prospective users. Previously it has not been possible to predict hearing aid use; however, results of our studies have allowed us to calculate the probability of successful hearing aid outcome based on an individual's willingness to accept background noise while listening to speech. Despite these important developments, there are many new issues that still await solutions.

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