Spring 5-24-2017

Using QuickSIN Speech Material to Measure Acceptable Noise Level for Adults with Hearing Loss

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In Fulfillment for the Degree of:

Doctoral of Audiology (Au.D.)

May 2017

Department of Communication Sciences and Disorders

Abstract

It is clinically useful to predict potential for hearing aid use success prior to the initial fitting of hearing aids. This information may be used to help with additional counseling for speech understanding in noisy listening environments and can also be used to describe the use of communication skills in combination with the dynamic functionality of hearing aids to guide patients that are hearing aid candidates towards success. The Quick Speech-In-Noise (QuickSIN) test and the Acceptable Noise Level (ANL) test have been recognized for their ability to predict hearing aid use success; however, the two measures use different stimuli and require administration of two tests. The purpose of this study was to evaluate the validity and reliability of using the QuickSIN speech material to measure the ANL for adult listeners with hearing loss. The present study found that the revised ANL test using the QuickSIN speech material resulted in equivalent ANLs compared to the original test. Test-retest reliability was high. It was concluded that the QuickSIN speech material could be used to measure ANL in clinic.

Introduction

Communication is an essential aspect of our daily lives. Our access to spoken language depends on our ability to hear. Therefore, it is important to identify and monitor the signs of hearing loss in order to effectively evaluate and select the most appropriate intervention options, and to provide access to key speech sounds to individuals experiencing the effects of hearing loss. Additionally, age-related hearing loss is progressively becoming a major public health concern as the elderly population continues to grow in the United States. The use of hearing aids is an appropriate intervention option designed to improve audibility; however, a majority of the elderly population that could benefit from hearing aids are not wearing them. Specifically, a study completed by McCormack and Fortnum (2013) examined why people fitted with hearing aids do not wear them. The statistics from this study revealed that 80% of adults between the ages of 55 and 74 years old who would benefit from a hearing aid do not wear them. The results from this study indicated that the most critical issues resulting in hearing aid non-use were the hearing aid not providing enough benefit, as well as comfort related to wearing the hearing aid.

Studies have evaluated a wide array of factors that were considered to have a potential influence on an individual's decision to proceed with the use of hearing aids. A literature review by Knudsen and colleagues (2010) summarized several factors that have been investigated regarding hearing aid uptake including source of motivation, attitudes towards hearing aids and hearing loss, expectations, personality, self-reported hearing, dexterity, health, hearing sensitivity, age, age at onset of hearing loss, duration of hearing loss, gender, educational level, socioeconomic status, living relations, matrimonial status, amount of social interaction, cost, type of clinic, general health attitude, speech reading, and pre-fitting counseling. These are some of the many factors that audiologists should consider when counseling patients regarding hearing aid use. Vuorialho (2006) discovered that the background noise amplified by the hearing aid was reported to be the reason for hearing aid non-use in 46.9% of the cases included in the study. These results demonstrate that a common challenge that individuals with hearing loss encounter is the inability to understand speech in the presence of background noise. Lack of hearing aid benefits and inability to communicate in noisy listening environments seem to be the primary reasons for the low prevalence of hearing aid use.

Background noise is a key factor that causes great difficulty for most listeners with hearing loss even with amplification from a hearing aid. A study by Kochkin (2000) focused on the reasons why hearing aids are purchased and not used. The second most common reason for hearing aid non-use was background noise. Specifically, the results from the survey showed that 25.3% of consumers reported that the hearing aids did not work in difficult listening situations, they amplified loud noises sometimes painfully, or background noise was annoying, distracting, or unacceptable. Kochkin indicated that improvements in non-linear hearing aid technology could possibly reduce aversiveness to sounds and increase speech intelligibility in noise. There have been many advancements in hearing aid technology, including directional microphones and noise reduction features, which allow for better signal processing algorithms. A study by Sarampalis, Kalluri, Edwards, and Hafter (2009) measured speech perception and listening effort utilizing different signal-to-noise ratios (SNRs) with and without digital noise reduction signal processing. The main finding from this study revealed that background noise has a negative effect on listeners by increasing listening effort and making speech intelligibility poorer. The authors suggested that the benefit of using a digital noise reduction algorithm is not in making speech more intelligible, but in reducing the cognitive effort involve in listening in noisy environments. Obtaining measurements of the patient's background noise tolerance is essential not only to anticipate hearing aid use success, but also has potential to influence the fitting of the hearing aid and selection of hearing aid features.

Predicting hearing aid use success through a clinical measurement has been an area of great interest since the development of the Acceptable Noise Level (ANL) test. The ANL is a clinical measure, developed by Nabelek and Burchfield (1991) which is designed to quantify the amount of background noise a listener is willing to accept while listening to speech simultaneously. The current speech material used to assess the ANL is a recording titled the Arizona Travelogue (Cosmos Inc.), which consists of standard running speech of a male speaker as the primary signal and 12-talker babble as the background noise. The ANL procedure determines the maximum level of background noise that an individual is willing to accept while listening to speech at his or her most comfortable loudness (MCL) level. Initially, the MCL is obtained by making adjustments to the primary speech signal. Then the patient continues to listen to the primary speech signal while the background noise is added. The patient is then instructed to adjust the noise level to the maximum background noise level (BNL) they would be willing to put up with for a long period of time while still being able follow and understand the primary speech signal. The BNL is subtracted from the MCL and the resulting score is the ANL.

The ANL is a useful clinical tool that can potentially be used to determine how much background noise an individual is willing to tolerate. The information obtained from a patient's ANL score enables audiologists to counsel their patients accordingly and develop appropriate recommendations based on their patient's ability to accept or tolerate background noise. Clinicians have the ability to use the ANL as a valuable counseling tool if they are able to recognize, understand, and acknowledge why patients are willing to put up with varying levels of background noise. Knowledge of this information helps guide the clinician to ensure that the patient understands realistic expectations regarding background noise situations, which leads to satisfaction and benefit from hearing aid use.

The ANL has gained popularity due to its potential to predict hearing aid use success. A study by Nabelek, Freyaldenhoven, Tampas, Burchfield, and Muenchen (2006) determined that individuals who accepted high levels of background noise (i.e., low ANLs) were likely to become successful hearing aid users and individuals who were not able to tolerate as much background noise (i.e., high ANLs) were likely to become unsuccessful hearing aid users. The overall results from this study revealed that unaided ANLs could predict a listener's hearing aid use success with 85% accuracy. Recent research has attempted to replicate this high degree of accuracy (Nabelek et al. 2006). Specifically, a study completed by Ho, Wu, Hsiao, and Zhang (2013) found that the prediction accuracy of the ANL for the probability of hearing aid use success was 78% to 80%. Some of the reasons for the lower prediction accuracy cited in this study include the sensitivity of the ANL to instruction translation and interpretation as found in a study by Ho, Wu, Hsiao, Stangl, and Lentz (2012). Additionally, the study mentioned that the ANL might also be sensitive to measurement procedures. This includes the transducer type, monaural or binaural testing condition, and how the participant was instructed to adjust the signal level throughout the test. For example, Nabelek et al. (2006) and Taylor (2008) both measured the ANL binaurally and participants used hand signals to guide the test giver to adjust the level of speech and noise. In contrast, Olsen and colleagues (2012), measured the ANL monaurally and participants used the audiometer attenuators to adjust the signal level.

There are multiple other factors that could impact ANL. It appears that speaker gender, listener gender, hearing sensitivity, type of background noise (4-talker babble, 12-talker babble, and static noise), ability to understand speech in noise, and hearing aid use can influence an individual's ANL score. Nabelek et al. (2006) examined the relations between hearing aid use and ANL, speech-in-noise scores, and listener characteristics (age, gender, and pure-tone average). A total of 191 listeners with hearing impairment participated in the study. The results from their study revealed that unaided ANLs were not dependent on age, gender, or pure-tone average of the listener, which suggests that the ANL may be an inherent characteristic of the individual that does not change with age or an acquired hearing loss. Another study by Rogers, Harkrider, Burchfield, and Nabelek (2003) investigated gender as a possible factor contributing to variability in ANL scores. The results from their study suggested that the ANL values were not different between males and females although males had higher MCLs and BNLs than females. A study completed by Plyler, Alworth, Rossini, and Mapes (2011) was designed in an effort to determine if the content and speaker gender of a running speech sample affected a participant's ANL. The results from this study found that neither the content of the sample nor the gender of the speaker significantly affected the most comfortable level or the acceptable noise level. A study by C. Franklin, White, and T. Franklin (2012) found that the loudness discomfort level (LDL) in individuals with normal hearing had not significantly affected the patient's ANL score. Overall, the results from these studies suggest that the ANL score may be an individual factor. Hearing sensitivity, listener or speaker gender and type of background noise have not been shown to significantly impact a participant's ANL score; however, these factors may explain slight differences observed between ANL scores.

In addition to the ANL, the Quick Speech-in-Noise (QuickSIN) test (Etymotic Research Inc., 1993) is a popular clinical test currently used to assess an individual's performance while listening to speech in the presence of background noise. Speech recognition performance scores obtained by utilizing the QuickSIN speech material provides audiologists with additional insight into how the individual's hearing loss impacts their ability to understand speech in real-world listening situations, and guides in the selection of amplification strategy for the individual with hearing loss. The QuickSIN speech material consists of a female speaker as the primary signal. The primary speech signal is presented as sentences with pauses. The background noise consists of 4-talker babble (1 male and 3 females). There are specific tracks on the QuickSIN speech material that separate the speech signal from the background noise. This provides clinicians with the ability to administer the ANL procedure using this background noise due to the ability to manipulate the primary speech signal and the background noise separately. Many clinics already have the QuickSIN speech material; therefore, this feature makes it easier for clinicians to measure the patient's QuickSIN and ANL without the purchase of an additional recording or CD.

Test	ANL (Arizona Travelogue)	QuickSIN speech material
Babble Noise	12-talker babble	4-talker babble (1 male and 3 females
Primary Speech Signal	Male - standard running speech	Female – sentences with pause
Context	Continuous monologue	Sentences with no context

Table 1: Differences between the Arizona Travelogue and QuickSIN speech material.

There are various differences between the original ANL speech material, the Arizona Travelogue, and the QuickSIN speech material as portrayed in Table 1. The difference in the background noise material is an important factor to examine. One important factor is the difference in the number of background talkers. It has been hypothesized that an increase in the number of background talkers increases the potential for more energetic masking, whereas a decrease in the number of background talkers increases the potential for more informational masking.

Energetic masking is referred to as noise that can physically interfere with the speech signal (Lidestam, Holgersson, & Moradi, 2014). In contrast, informational masking is referred to as noise that can perceptually interfere with the speech signal. The background noise of the QuickSIN speech material has greater potential for informational masking due to lower number of background talkers and the potential for the listener to detect meaningful words if the listener tunes in to the competing signal (Mueller, Bentler, & Rickets, 2014). The Arizona Travelogue speech material consists of a greater amount of background talkers (12-talker babble), which has less potential for informational masking due to the inability of the patient to recognize individual words from the multi-talker babble. It may be the case that some listeners are willing to tolerate less noise if it has a high potential for informational masking. The differences between energetic and informational masking observed in the Arizona Travelogue and the QuickSIN could result in different ANL values for an individual listener for each of these types of speech materials.

Although information obtained from these clinical assessments provides information about various aspects of the individual's hearing loss, it is not time efficient to administer all speech test measures in a clinical setting. Therefore, it is important to examine the possibility of using the same QuickSIN speech material to assess an individual's ANL, as well as their speech recognition performance in a sequential manner, in order to obtain more information about the functional impact of the individual's hearing loss in a timely manner. Using one recorded speech material to obtain two measures eliminates the extra time of setting up and calibrating an additional recording. The use of the QuickSIN speech material to obtain both the individual's ANL and their speech performance scores allows us to learn more about the individual's functional auditory skills in a timely manner. The information retrieved from utilizing the QuickSIN speech material to measure the ANL provides audiologists with the ability to make appropriate hearing aid adjustments and discuss additional communication strategies with the patient. The purpose of this study is to determine if the use of the speech material from the QuickSIN test can produce an equivalent result of ANL compared to the original method for adult listeners with hearing loss. Additionally, the purpose of the present study is to evaluate the reliability of using the QuickSIN speech material to measure the ANL for adult listeners with hearing loss.

It was hypothesized that the Revised QuickSIN ANL would be a valid and reliable measure and would show similar results to the Original Arizona ANL. Additionally, it was hypothesized that utilizing the QuickSIN speech material to acquire both the QuickSIN performance score and the ANL would save both the clinician and the patient time. It was also predicted that the value of the ANL measured using the QuickSIN would be slightly higher than that using the Arizona Travelogue, reflecting the greater potential for informational masking of the QuickSIN background noise.

Methods

Participants

A total of 46 participants between the ages of 18 and 89 years completed the present study (male: 22; female: 24). The mean age of the participants was 57.54 years (SD = 18.47). The mean years of education was 16.58 years (SD = 3.01). All participants had sensorineural hearing loss, ranging from mild to profound in both ears. Refer to Figure 1 for the mean thresholds for all participants. Thirty-two of the 46 participants with hearing loss were hearing aid users. Fourteen of the 46 participants were potential hearing aid candidates based on their audiograms. The potential hearing aid candidates had never purchased and had never been fitted with hearing aids. All participants completed the Original ANL test using the Arizona Travelogue and the Revised ANL using the QuickSIN speech material. A retest of the Revised ANL using the QuickSIN speech material was completed at the end of the session to evaluate reliability. Hearing aid users completed all tests unaided in the soundfield in the Hearing Aid and Spatial Hearing Research (HASHR) lab at the Illinois State University campus.

Procedures

Both Revised ANL and the Original ANL were measured following the step-by-step procedures recommended by the official ANL CD (Cosmos, Inc.).The most comfortable level (MCL) measure was repeated at least three times using the QuickSIN speech material and the Arizona Travelogue speech material. The values of the second and the third MCL were averaged to obtain the final MCL. Once the MCL was established, the background noise was added to the same channel through the loudspeaker to measure the background noise level (BNL). Similar to the MCL, the BNL measure was repeated at least three times. The ANL was calculated by subtracting the BNL from the MCL. The order of the two methods to measure ANL was randomized and balanced between all participants. The same procedures to measure QuickSIN ANL were repeated at the end of the session for the purpose of the test-retest reliability.

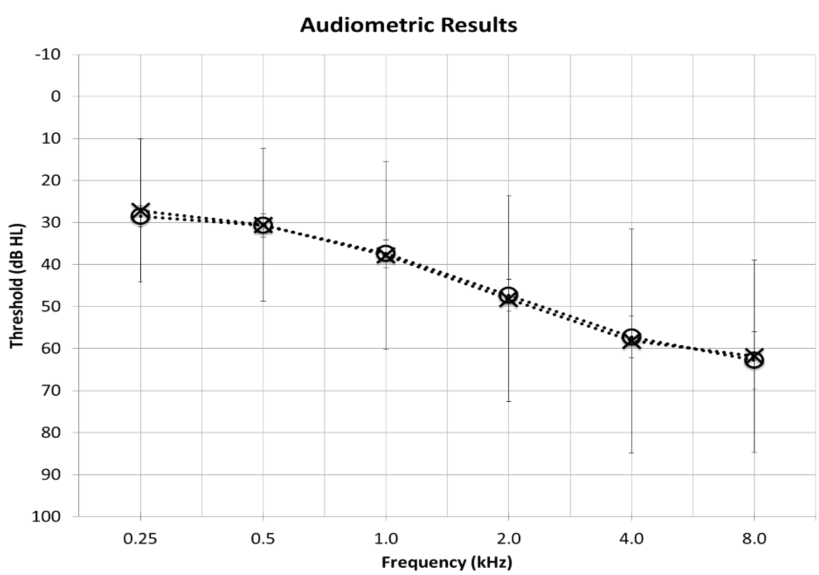

Figure 1. Mean thresholds for the left (X) and right (O) ears in dB HL for all participants. The error bars indicate standard deviations.

Results

The average Revised QuickSIN ANL was 8.76 dB (SD = 4.35 dB) whereas the Original Arizona Travelogue ANL was 5.63 dB (SD = 4.59 dB) for the same group of participants. See Figure 2 for the average ANL for both the Revised QuickSIN ANL and the Original Arizona Travelogue ANL. The results from the paired t-test indicated that there was a significant difference between these two ANLs using the two different materials ($t(45) = 5.82$, $p < .0001$). An equivalence test called the two one-sided (TOST) test was used to validate the equivalence of the two means. The TOST is based on the classical t-test that is used to test the hypothesis of equality between two means. The results from the t-test indicated that the two mean values were not equivalent; therefore, the TOST was used to demonstrate that they are equivalent within a practical, preset limit. Conceptually, this is the opposite of the two-sample t-test procedure. The equivalence test (TOST) indicated that the two stimuli resulted in equivalent ANLs when the lower and upper bounds were set at ± 5 dB ($t(90) = 2.01$, $p = .024$; $t(90) = -8.72$; $p < .0001$, respectively). The test-retest reliability was high for using the QuickSIN speech material to obtain ANL ($r = 0.81$, $p < .0001$).

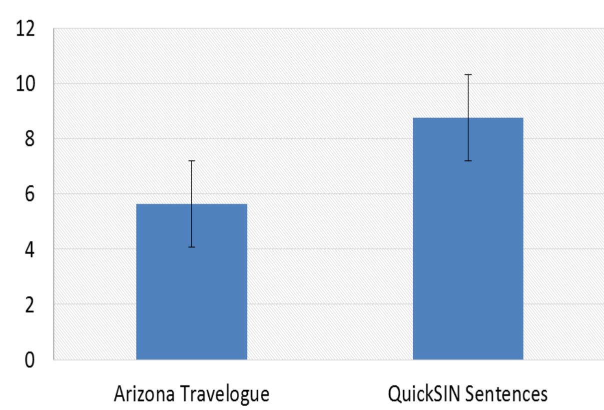

Figure 2. Average acceptable noise levels (ANL) in dB HL for each stimulus for all participants. Error bars indicate standard error.

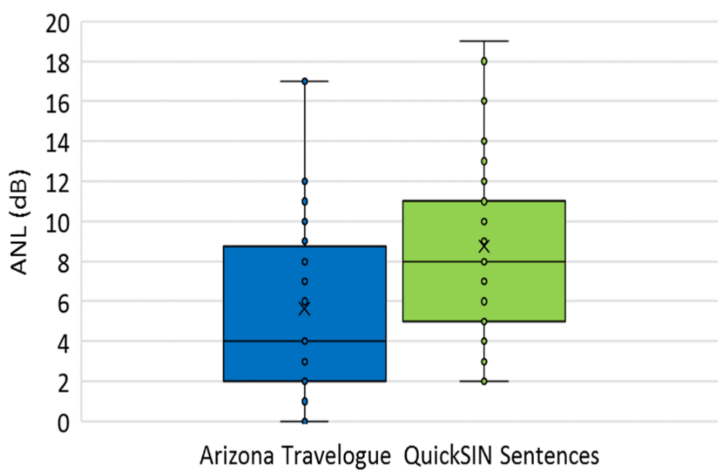

Figure 3. The ANL scores plotted as a function of stimulus. The box represents the middle 50% of the data. The lower and upper outer lines that encase the box represent the 25th and 75th percentiles. Solid horizontal lines indicate the median. The whiskers represent the maximum and minimum values for each stimulus. The circles represent individual data. The "X" indicates the mean.

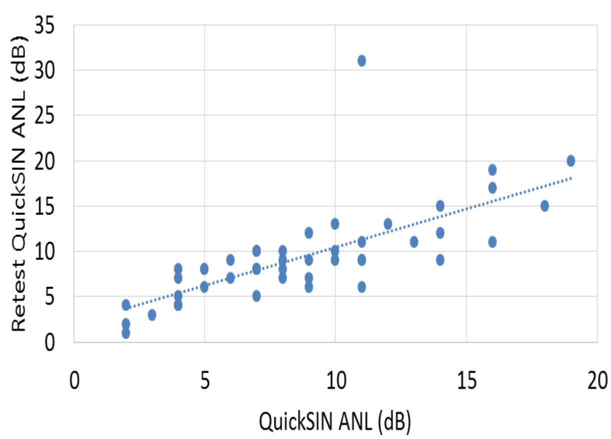

Figure 4. The relationship between test and retest QuickSIN ANLs (dB) with the fitted regression line.

The results from Figure 2 demonstrate that the average ANL scores between the original Arizona Travelogue speech material and the QuickSIN speech material differed by approximately 3 dB. This demonstrates that the ANL scores between the two speech materials were comparable. The box plots in Figure 3 illustrate that the range of ANL scores for all the participants were between 0 and 17 dB for the original Arizona Travelogue speech material and were between 2 and 19 dB for the QuickSIN speech material. The range of ANL scores across both materials was similar. The results from the scatter plot displayed in Figure 4 demonstrate that the initial ANL scores obtained utilizing the QuickSIN speech material at the beginning of each session were similar to the retest of the ANL scores using QuickSIN speech material at the end of the session. The outlier observed in Figure 4 was due to a fatigued participant. Each session was approximately 2.5 hours in length and the retest of the QuickSIN ANL was during the last 15 minutes of the session. The participant showed lack of concentration on the task due to fatigue. The participant was reinstructed and encouraged multiple times; however, this did not seem to change their responses to the BNL.

Discussion

The results from the present study agree with our original hypothesis regarding the use of the QuickSIN speech material to administer and retrieve a patient's ANL score. Specifically, the ANL obtained from the QuickSIN speech material is a valid and reliable measure and can be used in clinic to determine a patient's background noise tolerance. It was also proposed that the ability for clinicians to utilize the same QuickSIN speech material to acquire both the QuickSIN performance score and the ANL would save both the clinician and the patient time. Therefore, the time was recorded for 27 of the 46 participants in this study for the Revised QuickSIN ANL.

The results revealed that the average time taken to administer the Revised QuickSIN ANL was 6 minutes and 30 seconds. Based on the typical session completed for this study, it is estimated that the total time to administer both the QuickSIN performance and the QuickSIN ANL would be less than 15 minutes. This allows for additional time that clinicians can use to expand on the patient's listening needs in various environments and counsel patients based on the results from these two measures. Additionally, the purchase of only one recorded speech material is less costly for the clinician.

The results from our Revised QuickSIN ANL were more similar to the results from the study by Nabelek et al. (2006). A frequency distribution was utilized to demonstrate the range of ANL scores in the study by Nabelek and colleagues with the most prevalent ANLs occurring between 10 and 11 dB. The mean Revised QuickSIN ANL was 8.76 dB in our study, which is more similar to the Nabelek study than the results from the Original Arizona Travelogue ANL. The mean Original Arizona Travelogue ANL from our study was only 5.63 dB, which is considerably lower than the mean Revised QuickSIN ANL of 8.76 dB. The results demonstrate that the ANL score obtained by using the QuickSIN speech material is comparable to the ANL using the original Arizona Travelogue speech material.

The reasons why the ANLs measured with the original Arizona Travelogue speech material in this study were slightly lower than that reported by Nabelek and colleagues (2006) and Ho and colleagues (2013) are not entirely clear. Both studies mentioned that the procedures may impact the difference observed in ANL scores across studies. However, the procedures used in this study were replicated from the study completed by Nabelek and colleagues (2006); therefore, the clinical applications mentioned in the Nabelek study can be used for the interpretation of the results from the present study. Specifically, the same soundfield setup was used in our study to acquire the patient's ANL where the speech and noise stimuli were both delivered by a loudspeaker located in front of the listener (0 degrees azimuth) in an audiometric booth. The study by Ho and colleagues (2013) also replicated the same set up to administer the ANL to their participants and also indicated that the ANL could be affected by the transducer type and the monaural or binaural testing condition. Some reasons for the difference in ANL scores obtained in our study can be due to a different cohort of listeners. Specifically, the mean age of the participants in the Nabelek and colleagues (2006) study was 72 years old for the full-time hearing aid users, whereas the mean age of participants in our study was 57 years old. Additionally, the number of participants in our study was considerably lower than the Nabelek and colleagues (2006) and Ho and colleagues (2013) studies. There were a total of 191 participants in the Nabelek (2006) study and a total of 80 individuals with hearing loss participated in the Ho (2013) study. There were 46 participants included in our study, which creates a smaller sample size than in the Nabelek (2006) and Ho (2013) studies. Future research in this area should consider larger sample sizes to replicate the results in the previous studies.

It was also predicted that the Revised QuickSIN ANL would result in higher ANL scores due to the greater potential for informational masking from the QuickSIN speech material. As mentioned previously, the background noise of the QuickSIN speech material consists of less background talkers, which increases the potential for informational masking. On the contrary, the background noise of the Arizona Travelogue consists of more background talkers which decreases the potential for informational masking. Therefore, the higher mean ANL score observed from the Revised QuickSIN ANL could be due to greater interference from informational masking. In addition, Mueller et al. (2014) stated that the informational masking from the QuickSIN speech material increases the potential for the listener to detect meaningful words if the listener tunes in to the competing signal. A few participants in our study commented that the female background talkers in the QuickSIN speech material were annoying and often made it difficult to understand the primary signal. Some participants mentioned that the distraction and ability to pick out main phrases from the background talkers interfered with their focus on the primary signal. These comments demonstrate the effect of more informational masking from the QuickSIN speech material as predicted by previous studies. Therefore, the slight differences observed between the Revised QuickSIN ANL and the Original Arizona Travelogue in the present study could be due to the potential effect of informational masking.

Conclusion

The results from the present study indicated that the Revised ANL using the QuickSIN speech material was essentially the same compared to the ANL using the original Arizona Travelogue speech material. The use of the QuickSIN speech material to obtain both the individual's ANL and their speech performance scores allows us to learn more about the individual's functional auditory skills in a timely manner. The information retrieved from utilizing the QuickSIN speech material to measure the ANL provides audiologists with the ability to make appropriate hearing aid adjustments and discuss additional communication strategies with the patient. Overall, the results of the present study suggested that the adapted Revised ANL test using the QuickSIN speech material is valid and reliable and can be used in the clinical setting.

References

Cosmos, Inc. Acceptable Noise Level Test A.N.L. Kelowna, B.C: Cosmos, Inc.

Etymotic Research. (2001). QuickSIN Speech-in-Noise Test Manual. Elk Grove Village, IL: Etymotic Research.

Franklin, C.A., White, L.J., & Franklin, T.C. (2012). Relationship between loudness tolerance and the acceptance of background noise for young adults with normal hearing. *Perceptual & Motor Skills, 114*(3), 717-722.

Ho H., Wu Y., Hsiao S., Stangl E., Lentz E. (2012). The equivalence of acceptable noise level (ANL) with English, Mandarin, and non-semantic speech: A study across the U.S. and Taiwan. *International Journal of Audiology, 52*, 83-91.

Ho, H., Wu, Y., Hsiao, S., & Zhang, X. (2013). Acceptable noise level (ANL) and real-world hearing-aid success in Taiwanese listeners. *International Journal of Audiology*, *52*(11), 762-770.

Knudsen, L., Öberg, M., Nielsen, C., Naylor, G., & Kramer, S. (2010). Factors influencing help seeking, hearing aid uptake, hearing aid use and satisfaction with hearing aids: A review of the literature. *Trends in Amplification*, *14*(3), 127-154.

Kochkin, S. (2000). MarkeTrak V: 'why my hearing aids are in the drawer': the consumers' perspective. *Hearing Journal*, *53*(2), 34-42.

Lidestam, B.A., Holgersson, J.A., Moradi, S.A. (2014). Comparison of informational vs. energetic masking effects on speechreading performance. *Frontiers in Psychology*, *5*.

McCormack, A., & Fortnum, H. (2013). Why do people fitted with hearing aids not wear them? *International Journal of Audiology, 52*(5), 360-368.

Mueller, H. G., Ricketts, T., & Bentler, R. A. (2014). Modern hearing aids. San Diego, CA: Plural Publishing.

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

Olsen, S., Lantz, J., Nielsen, L., & Brännström, K. (2012). Acceptable noise level (ANL) with Danish and non-semantic speech materials in adult hearing-aid users. *International Journal of Audiology, 51*, 678-688.

Plyler, P.N., Alworth, L.N., Rossini, T.P., & Mapes, K.E. (2011). Effects of speech signal content and speaker gender on acceptance of noise in listeners with normal hearing. *International Journal of Audiology, 50*(4), 243-248.

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

Sarampalis, A., Kalluri, S., Edwards, B., & Hafter, E. (2009). Objective measures of listening effort: Effects of background noise and noise reduction. *Journal of Speech, Language & Hearing Research*, *52*(5), 1230-1240.

Taylor B. (2008). The acceptable noise level test as a predictor of real-world hearing-aid benefit. *Hearing Journal*, *61*(9), 39-42.

Vuorialho, A. (2006) Costs and effectiveness of hearing aid rehabilitation in the elderly. Faculty of Medicine, Department of Otorhinolaryngology, University of Oulu, 1-66.