5-2017

Development of the Visual Acceptable Noise Level Test

Teresa Slade
University of Tennessee, Knoxville, tslade1@vols.utk.edu

Development of the Visual Acceptable Noise Level Test

Principle Investigator: Teresa Slade

Co-Investigators: Patrick Plyler, Ph.D., Katie Faulkner, Ph.D., & Mary Easterday, Au.D.

Department of Audiology & Speech Pathology, University of Tennessee Health Science Center

Chancellor's Honors Program Thesis

May 1, 2017

Introduction

Multiple factors have been studied to understand individuals' reasons to reject or to continue using hearing aids, including speech perception ability in both quiet settings and with background noise, as well as factors related to age and cognitive abilities (Besser, Zekveld, Kramer, Ronnberg, & Festen, 2012; Bentler, Niebuhr, Getta, & Anderson, 1993; Humes, Halling, & Coughlin, 1996; Schoof & Rosen, 2014; Besser, Koelewijn, Zekveld, Kramer, & Festen, 2013). Recent research has shown that unsuccessful hearing aid usage is related to background noise intolerance (Nabelek, Tucker, & Letowski, 1991; Lytle, 1994; Nabelek, Freyaldenhoven, Tampas, Burchfield, & Muenchen, 2006; Freyhaldenhoven, Plyler, Thelin, & Burchfield, 2006). The Acceptable Noise Level (ANL) test, developed in the early 2000s by University of Tennessee, Knoxville researchers, strives to test the level of background noise an individual is willing to tolerate (Nabelek et al., 2006). ANL scores are measured using both the individuals' Most Comfortable Level (MCL), defined as the volume level indicated by a decibel range that the individual deems most comfortable while listening to pre-recorded speech, and the Background Noise Level (BCL), defined as the level of background babble they are willing to tolerate as the pre-recorded speech plays (Nabelek et al., 1991). The ANL numerical value is derived by subtracting the BCL from the MCL (ANL = MCL – BCL). Thus, smaller ANL values indicate more willingness to accept background noise, while larger ANL values indicate less willingness to accept background noise (Nabelek et al., 1991). Notably, larger ANL values also indicate a greater likelihood that an individual will reject his or her hearing aids (Nabelek et al., 2006). The ANL test can be reliably used across different laboratories, even though ANL scores can vary up to 30 decibels between individuals (Gordon-Hickey et al., 2012; Nabelek, Tampas, & Burchfield, 2004).

Researchers have studied this variance of ANL values, related to differing acceptance levels of background noise. Surprisingly, ANL variability was not found to correlate with age, gender, or even background noise loudness levels for both normal and impaired listeners (Tampas, Harkrider, & Nabelek, 2004; Tampas & Harkrider, 2006; Freyaldenhoven, Plyler, Thelin, & Hedrick, 2007; Recker, McKinney, & Edwards, 2014). In her original 1991 paper, Dr. Nabalek theorized that noise acceptance could be inherent to an individual, resulting in large variance in ANL values (Nabalek, Tucker, & Letowski, 1991). This led to more recent scientific studies. Alworth, Plyler, and Madix (2007) studied personality differences and ANL values, using individuals delineated into Type A and Type B personalities. Results found that Type A's ANL values were significantly higher than Type B's, indicating that Type A personalities' tolerance of background noise was significantly lower than those with Type B (Alworth et al., 2007). Nichols and Gordon-Hickey (2012) also found that individuals with higher levels of self-control had smaller ANL values and accepted more background noise than those with lower levels of self-control. Thus, the relationship between personality and ANL values supported Dr. Nabelek's theory that noise acceptance may be inherent to an individual (Tampas & Harkrider, 2006; Nabelek et al., 2006).

Further research has attempted to examine the biological mechanisms behind varying ANL values. Harkrider and Smith (2005) indicated that acoustic reflex thresholds and otoacoustic emissions in normal hearing listeners had no significant relationship with ANL values. Other studies examined reactions of the central auditory nervous system when presented with auditory stimuli (Harkrider & Smith, 2005; Tampas et al., 2004). They found that individuals with larger ANL values have shorter latencies and larger amplitudes for auditory brainstem response activity, compared to those with lower ANL values (Tampas & Harkrider, 2006). Based on their results, Tampas and Harkrider theorized that central efferent or descending signals have greater amplitudes and that central afferent or ascending mechanisms are less active in individuals with lower ANL values (Tampas & Harkrider, 2006). A study examining central mediation and ANLs showed that individuals with low ANL values have less active neural excitatory mechanisms, suggesting neural excitation and toleration of background noise are negatively correlated (Shetty, Mahadev, & Veeresh, 2014). The researchers suggest the efferent mechanism involved is more efficient, in that the excitatory and inhibitory signals are more balanced when communicating relevant stimuli and suppressing irrelevant background noise (Shetty et al., 2014).

The identity of specific variables causing such wide ANL value ranges, like neural inhibitory processes and afferent and efferent channel measurements, needs to be further explored to better identify those with low background noise acceptance, develop future treatment plans, and potentially increase the rate of hearing aid usage (Tampas and Harkrider, 2005). Although the sources of ANL variability are still unknown, researchers have suggested testing speech perception values across sensory modalities to discover potential links (Zekveld, George, Kramer, Goverts, & Houtgast, 2007). The Text-Reception-Threshold Test (TRT) is an example of this kind of cross-modality examination, which was utilized in this study. The TRT, a visual equivalent of the Speech-Reception-Threshold (SRT) test, has been found to support various individual differences of measured TRT values and shows how audio-visual testing has been found useful in examining hearing aid users' processing abilities (Kramer, Zekveld & Houtgast, 2009; Zekveld et al., 2007; George et al., 2007). Both visual and auditory signals contribute to an individual's environmental understanding due to overlapping neural mechanisms in signal processing, especially when the need arises to compensate for deficits (Smith et al., 2009; Zekveld et al., 2007; Kramer, Zekveld & Houtgast, 2009; Humes & Christopherson, 1991).

Our University of Tennessee Health Science Center research team developed a visual Acceptable Noise Level (V-ANL) test to determine if it correlates with its auditory equivalent, the ANL. This visual test's goal is to measure the maximum amount of "visual noise" individuals are willing to accept using the auditory ANL test methods. The purpose of this study was to compare ANL and V-ANL values in normal hearing and seeing people, and we hypothesize that the ANL and V-ANL values will be positively correlated to each other. This cross-modality testing and potential correlation could pinpoint sources of different individuals' ANL scores, which we address more in the Discussion section. We hope to use this visual test to examine individuals' varying levels of background noise tolerance and apply it to future hearing aid screenings.

Methods

V-ANL Stimuli Development

To develop our V-ANL test, we used the software system MATLAB to create our visual degradation system, with the help of Dr. Jeff Reinbolt, Associate Professor in Mechanical, Aerospace, and Biomedical Engineering at University of Tennessee, Knoxville. We developed a systematic way to distort the original ANL newscaster video, employing a grainy static that is measured in percent degradation per pixel. This grainy distortion resembles television static and mimics the auditory ANL test's use of background noise to mask speech (see Figures 2-4). With this system of visual distortion, subjects can choose their maximum background "visual noise" comfort level (BCL) as the newscaster video is systematically and increasingly degraded. Each subject's BCL is the maximum percentage degradation that he or she would be willing to tolerate if watching everyday television. The V-ANL test presents these different static densities beginning from 0 percent degradation up to 80 percent, with each density percentage running onscreen for maximum of 20 seconds, and subjects can view and decide to either progress or go back. Subjects move forward through increased degradation levels until they reach their subjective BCL, or the point when they subjectively can no longer tolerate the onscreen degradation. These scores are then recorded and plotted. We expect to see a wide range of V-ANL scores, since auditory ANL scores range from about -2 to 29 dB for normal hearing listeners, with the most frequent score around 10 dB (Plyler, 2015).

After data is taken, the relationships of our experimental test and its relatives are plotted to determine any linear relationship between the ANL and V-ANL test performance measures. Since Dr. Nabelek originally theorized that a subject's auditory background noise acceptance is unique to each person, we theorize that an individual's visual noise acceptance will also vary amongst participants. We hope to see varied enough scores to maintain that individual cognitive and perceptual factors contribute to these results. In the future, we hope to show a statistical relationship between the V-ANL and the auditory ANL test, which could lead to clinical use of both assessments. And with such varied ANL scores, we desire to pinpoint the sources of such individual differences using both auditory and visual testing methods.

Procedures

We decided that the implementation methodology of the V-ANL test should parallel the auditory ANL as closely as possible. The original auditory ANL test uses recorded speech and is an 8-minute monologue called *Arizona Travelogue* (from Cosmos, Inc.). The participant listens to the recorded monologue presented at 65 dB SPL, while the multi-talker babble noise is simultaneously introduced beginning at 45 dB SPL (signal-to-noise ratio of 20 dB). This combination is slightly different than the original ANL test (in which the speech is adjusted); we only adjusted noise levels and kept the speech level constant at 65 dB SPL. The instructions for adjusting the noise are as follows:

> *"You will listen to the same story with background noise of several people talking at the same time. After you have listened to this for a few moments, select the level of the background noise that you would be willing to accept or "put up with" without becoming tense and tired while following the story. First turn the noise up until it is too loud and then down until the story becomes very clear. Finally adjust the noise (up and down) to the level that you would put up with for a long time while following the story."*

Inside the sound booth, subjects use a computer mouse to indicate to the investigator they would like to adjust the noise level. With prompts from the subject, the investigator adjusts the noise in 4 dB increments until the subject finds the background noise level that is more than they are willing to accept. At that point, the subject directs noise adjustment downward (in 4 dB steps) to a level they can comfortably tolerate. Finally, the subject brings the noise upward in 2 dB increments to the highest level they are willing to tolerate. This final dB level is subtracted from 65 dB SPL to find the individual's ANL value. In previous ANL studies, the most common ANL value is between 6 and 12 dB, with 10 dB being the most frequent. We hope to find a similar range of values in our V-ANL results.

For our experimental V-ANL test, we use the same subjective method as the auditory ANL test. Our test consists of an 18-slide PowerPoint, in which the videos of the original ANL speech are presented in 20-second intervals, with each clip increasingly degraded (see Figures 2 through 4). The instructions for the test are as follows:

> *"You will see the same video with overlaid noise that looks like TV static. After you have watched for a few moments, select the level of the static that you would be willing to accept or "put up with" without becoming tense and tired while watching the story. First increase the static until it is intolerable and then down until the picture becomes clear to you. Finally adjust the static (up and down) to the level that you would put up with for a long time while following the story."*

Watching a small television screen inside the sound booth, subjects again use a computer mouse to prompt adjustments to visual noise levels. First, the subject adjusts the PowerPoint until the they find the level they deem is too much visual noise. Then, they indicate to decrease the noise levels until it is clear. Finally, they increase the visual noise until they settle on a level of static they could follow for a long time. Each slide has a corresponding level of percent degradation (beginning at 0.05 and going up in 0.05 increments, with 0.80 as the maximum level). Each subject's final chosen value is recorded as the V-ANL score. For example, if the subject chose their final value as 0.15, their V-ANL score would be 0.15, or 15 percent visual degradation.

After testing each subject, we subtracted their V-ANL scores from 100 percent to find the percent clarity tolerances.

Two other tests were used to explore each subject's visual and auditory discrimination abilities in noise. In the visual modality, the Text-Reception-Threshold (TRT) test measures a participant's ability to recognize written sentences that are partially obscured by vertical grating (Zekveld et al., 2007). For each trial, a meaningful sentence is obscured by a row of equally-spaced, vertical black bars, which is quantified according to the percentage of unmasked text. These sentences are presented randomly according to a schedule that is created before data collection begins, and each time the subjects read as much of the sentence as possible. The TRT score, calculated using four sets of sentences made of 13 trials each, is the mean percentage of unmasked text reported and encompasses how well the subject can identify each obscured sentence block. This value will be correlated with the subject's V-ANL score, to see if any relationship exists.

In the auditory modality, the HINT (Hearing-In-Noise-Test) will be used to further explore each subject's auditory discrimination abilities in noise. In this test, each subject listens to two randomized word lists of 20 English sentences presented in noise, and they repeat back what they hear to the best of their ability. To ensure complete randomization, we created our sentence presentation schedule before testing began using a randomization website. For each subject, their sentences are presented at 66 dB, with 70 dB of competing noise also playing (signal-to-noise ratio of -4 dB). If the subject repeats the first sentence correctly, the noise is raised by 4 dB, so the task becomes more difficult; if the subject does not repeat the sentence correctly, the noise is lowered by 4 dB. After the fourth sentence presentation of each list, the step size for lowering and raising presentation levels becomes 2 dB, which allows for a more specific determination of the subject's Speech Reception Threshold (SRT). After the tenth sentence, the theoretical eleventh sentence representation's dB level is recorded, and the dB values for sentences 5 through 11 are averaged. This value becomes that sentence list's SRT. Each subject performs two trials, and after the average dB value is calculated for each sentence list, those two values are averaged. The final average is subtracted from 66 dB (the speech level), and that value becomes the subject's Speech Reception Threshold (SRT), or their speech discrimination ability in noise (Plyler, Bahng, & von Hapsburg, 2008).

Subjects

Our subjects were five volunteers over the age of 18, one man and four women. Before any tests were administered, we conducted pure tone hearing screenings to ensure normal hearing (measured at 20 decibels for 250, 500, 1000, 2000, 4000, and 8000 Hertz).

Results

We collected initial pilot data on our subjects using four total assessments. Their ANL, V-ANL, HINT, and TRT scores were recorded after passing a pure tone hearing screening (see Table 1). To better understand the initial data, we converted V-ANL scores into percent clarity tolerances, by subtracting each subject's chosen tolerance level from 100 percent. After plotting the ANL scores and V-ANL percent clarity scores, we found a slight positive linear relationship (see Figure 1). Thus, our pilot data suggest a possible trend, which should be explored in future studies with larger populations of both normal hearing and hearing impaired individuals.

Tables and Figures

Table 1

Subject #	*V-ANL (% Degradation)*	*V-ANL (% Clarity)*	*TRT (%)*	*HINT (SNR)*	*ANL (dB)*
1	0.15	0.85	43.8	-3.43	15
2	0.5	0.5	35.4	1.145	-1
3	0.2	0.8	43.2	-1.43	12
4	0.1	0.9	39.9	-0.86	24
5	0.2	0.8	40.5	-9.425	4
Average	**0.23**	**0.77**	**40.56**	**-2.8**	**10.8**

Figure 1

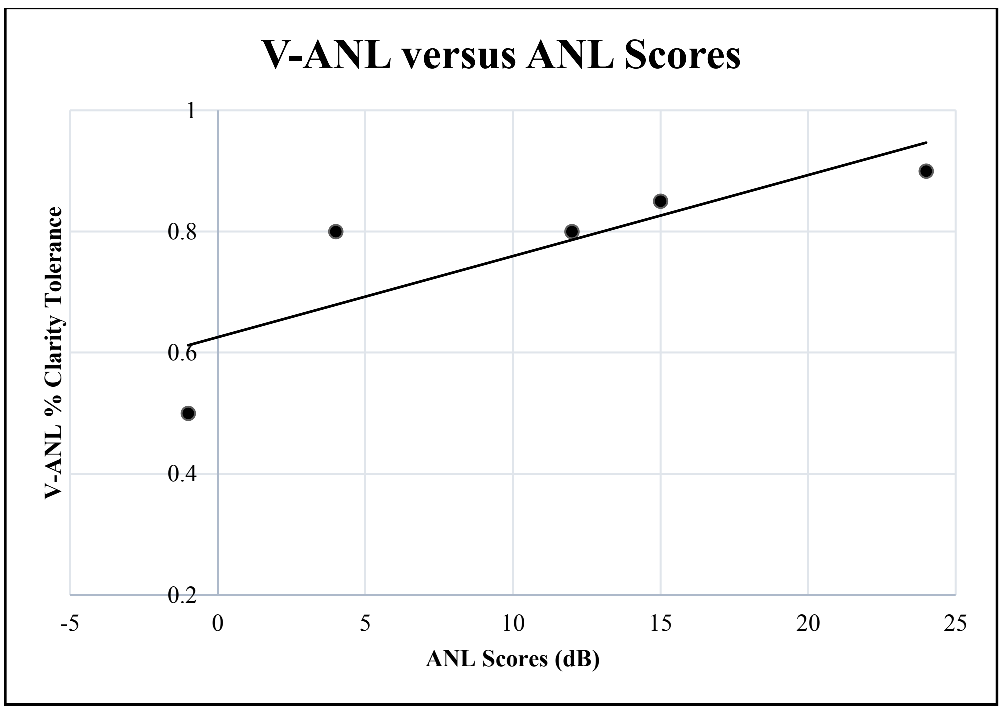

Figure 2 (0 % Degradation/100 % Clarity)

Figure 3 (5% Degradation/95% Clarity)

Figure 4 (10% Degradation/90% Clarity)

Discussion

A positive linear relationship between ANL and V-ANL percent clarity scores suggests that individuals who tolerate more background noise also tolerate more visual noise. Even though our sample size was small, we observed a significant linear trend, indicating that individuals' noise acceptance levels within the two modalities are related. This goes against one of our initial ideas that significant differences in modality tolerance levels would be observed, suggesting compensatory strategies.

In future tests, we would like to correlate each subjects' performance measures on the TRT and HINT tests and their performance measures from the V-ANL and ANL tests. The TRT, as previously explained, is a visual speech-in-noise measure forcing subjects to put context and language abilities together as they distinguish distorted sentences. The HINT (Hearing-in-Noise-Test) is used to evaluate speech understanding in noise and considered the auditory equivalent of the TRT test (Plyler, Bahng, & von Hapsburg, 2008). The performance measures of these two tests will be taken for each subject and the results plotted against both the V-ANL and ANL tests, so the visual tests (TRT versus V-ANL) and the auditory tests (HINT versus ANL) are compared against each other and any relationship examined. Thus, we can explore each patient's auditory and visual abilities and determine if a global relationship exists for general noise acceptance, or if acceptance is more modality-specific.

Our proposed mechanism for individuals' acceptance of background noise, both auditory and visual, is the cognitive concept of inhibition. Inhibition deals with the ability to regulate the perception of stimuli and to tune out irrelevant sensory information, or selective attention. However, speculation still exists as to inhibition's exact function in regulating multiple sensory signals, especially in the acceptance of noise. Many inhibition studies have focused on loss-of-function cases, where central inhibition is obviously absent, such in individuals with Attention Deficit Hyperactivity Disorder, suicidal thoughts, and schizophrenia (Pliska, Liotti, & Woldorff, 2000; Liotti, Pliszka, Higgins, Perez, & Semrud-Clikeman, 2010; Schachar et al., 2007; Richard-Devantoy et al., 2012; Westerhausen, Kompus, & Hugdahl, 2011). Neurologic studies of the brain indicate that during cognitive inhibitory processes, the synaptic neural membrane threshold increases its tolerance of incoming neurotransmitters, slowing the overall firing rate (Shetty et al., 2014). Theories have been developed to explain the mechanisms behind inhibiting irrelevant information, primarily dealing with the relationship between inhibition and attention, which the "cognitive control" theory poses have similar goals and maintenance processes (Hübner, Steinhauser, & Lehle, 2010; Miller & Cohen, 2001; Goghari & MacDonald, 2009). A critical aspect of inhibition, attention was first described in terms of Broadbent's model, developed in a well-known 1957 paper, in which Y-shaped branches funnel into a single cognitive channel. While early theories argued whether selection of relevant information occurs early or late in the attention processes, now a dual-stage two-phase model has been presented (Kahneman & Treisman, 1984; Broadbent, 1958; Johnston & Dark, 1982; Neisser, 1976; Deutsch & Deutsch, 1963; Duncan, 1980; Moray, 1959; Shiffrin & Schneider, 1977; Hübner, Steinhauser, & Lehle, 2010). Selective attention prohibits excessive stimuli from entering an already-crowded channel so only certain information is processed, which could involve inhibitory processes (Broadbent, 1962; Aron, 2007; Goghari & MacDonald, 2009). This focus on attention for explaining ANL variance and the inhibitory processes behind it correlates with Dr. Nabelek's original 1991 paper, in which she stated that "ANL might be used to measure changes in the willingness to accept…background noise on individuals who are sensitive to background noise such as those with attention disorders" (Nabelek et al., 1991). Thus, in cases concerning overall cognitive control, inhibition could contribute to the suppression of irrelevant incoming stimuli and should be considered when exploring the mechanisms of background noise acceptance (Aron, 2007; Goghari & MacDonald, 2009).

There are other tests that assess an individual's ability to inhibit irrelevant stimuli, which we would like to be part of future studies involving multimodality inhibition testing. The auditory Stroop test and the Color and Word Stroop test measure how well subjects can tune out irrelevant stimuli to accomplish a certain task, from listening to speech in noise to suppressing automatic reading responses in order to name a word's print color. For the Color and Word Stroop Test, participants first read a full page of word colors in regular print, and then a full page of color words printed in that corresponding color. Finally, they will read a page of color words printed in conflicting colors. Participants are timed and scored based on accuracy percentages. This test measures the participant's ability to separate word and color naming stimuli and to suppress the automatic cognitive process of reading.

In the auditory Stroop test, participants must separate auditory stimuli and the characteristics of the presented voice. Participants hear the words ''high'' and ''low'' spoken in either a high pitch (360 Hz) or a low pitch (180 Hz), a difference equal to one octave. The participants are to indicate the pitch of the word they hear (and ignore the actual word presented) by responding ''high'' or ''low'' as quickly and as accurately as possible. Auditory stimuli are delivered and responses are recorded via wireless headset microphones, and their latency and accuracy responses are recorded. These Stroop test performance measures would be correlated with ANL and V-ANL results, to determine if any relationship between exists.

Using these tests, we hope to explore possible links between ANL and V-ANL factors influencing the sensory perception and processing, and to see if acceptance of background noise (in different modalities) is related to inhibitory cognitive abilities. We want to investigate if inhibition is a global multimodal ability, or if differing modality acceptances compensate for potential weaknesses. Ideally, to preserve the multimodal component of the studies, we would test future subjects with all six assessments: the HINT, TRT, ANL, V-ANL, and both auditory and visual Stroop tests. Our goal would be to determine if cognitive/inhibitory abilities correlate with ANL and V-ANL scores. This could help pinpoint factors relating to general background noise acceptance and to individuals' ANL and V-ANL score variance. This knowledge could help us identify individuals who would otherwise reject hearing aids due to low noise tolerance, allowing introduction of potential remediation strategies. We hope to continue exploring the ANL and V-ANL relationship, as well as each test's underlying physiological mechanisms, and hope to ultimately pinpoint the source of these multimodal phenomena.

References

Alworth, L., Plyler, P., & Madix, S. (2007). Effect of personality type on the acceptance of noise. Poster presentation, American Academy of Audiology Convention. Denver, Colorado.

Aron, A.R. (2007). The neural basis of inhibition in cognitive control. *The Neuroscientist, 13(3)*, 214-228.

Bentler, R., Niebuhr, J., Getta, C., & Anderson, C. (1993). Longitudinal study of hearing aid effectiveness. II: Subjective measures. *Journal of Speech and Hearing Research, 36*, 820-831.

Besser, J., Zekveld., A.A., Kramer, S.E., Ronnberg, J., & Festen, J.M. (2012). New measures of masked text recognition in relation to speech-in-noise perception and their associations with age and cognitive abilities. *Journal of Speech, Language, and Hearing Research, 55*, 194-209.

Besser, J., Koelewijn, T., Zekveld, A.A., Kramer, S.E., & Festen, J.M. (2013). How linguistic closure and verbal working memory relate to speech recognition in noise—A review. *Trends in Amplification, 17(22)*, 75-93.

Broadbent, D.E. (1957). A mechanical model for human attention and immediate memory. *Psychological Review, 64(3)*, 205-215

Broadbent, D. E. (1958). *Perception and communication.* London, England: Pergamon Press.

Broadbent, D.E. (1962). Attention and perception of speech. *Scientific American, 206,* 143-148.

Deutsch, J. A., & Deutsch, D. (1963). Attention: Some theoretical considerations. *Psychological Review, 70,* 80–90.

Duncan, J. (1980). The locus of interference in the perception of simultaneous stimuli. *Psychological Review, 87,* 272–300.

Franklin, C.A., Jr., Thelin, J.W., Nabelek, A.K., & Burchfield, S.B. (2006). The effect of speech presentation level on acceptance of background noise in listeners with normal hearing. *Journal of the American Academy of Audiology, 17*, 141-146.

Freyaldenhoven, M.C., Plyler, P.N., Thelin, J.W., & Burchfield, S.B. (2006). Acceptance of noise for monaural and binaural hearing aid fittings. *Journal of the American Academy of Audiology, 17*, 659–666.

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 Hearing Research, 50*, 878-885.

George, E.L.J., Zekveld, A.A., Kramer, S.E., Goverts, S.T., Festen, J.M., & Houtgast, T. (2007). Auditory and nonauditory factors affecting speech in noise by older listeners. *Journal of the Acoustical Society of America, 121(4),* 2362-2375.

Goghari, V.M., & MacDonald, A.W., III. (2009). The neural basis of cognitive control: Response selection and inhibition. *Brain and Cognition, 71*, 72-89.

Gordon-Hickey, S., Adams, E., Moore, R., Gaal, A., Berry, K., & Brock, S. (2012). Intertester reliability of the acceptable noise level. *Journal of the American Academy of Audiology, 23(7)*, 534–541.

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.

Hübner, R., Steinhauser, M, & Lehle, C. (2010). A dual-stage two-phase model of selective attention. *Psychological Review, 117(3)*, 759-784.

Humes, L. E. & Christopherson, L. (1991). Speech identification difficulties of hearing-impaired elderly persons: The contributions of auditory processing deficits. *Journal of Speech and Hearing Research, 34,* 686–693.

Humes, L., Halling, D., & Coughlin, M. (1996). Reliability and stability of various hearing aid outcome measures in a group of elderly hearing aid wearers. *Journal of Speech Language and Hearing Research, 39*, 923-935.

Johnston, W. A., & Dark, V. J. (1982). In defense of intraperceptual theories of attention. *Journal of Experimental Psychology: Human Perception and Performance, 8,* 407–421.

Kahneman, D., & Treisman, A. (1984). Changing views of attention and automaticity. In R. Parasuraman (Ed.), *Varieties of attention* (pp. 29– 61). London, England: Academic Press.

Kramer, S.E., Zekveld, A.A., & Houtgast, T. (2009). Measuring cognitive factors in speech comprehension: The value of using the Text Reception Threshold test as a visual equivalent of the SRT test. *Scandinavian Journal of Psychology, 50,* 507-515.

Liotti, M., Pliszka, S.R., Higgins, K., Perez, R., III., & Semrud-Clikeman, M. (2010). Evidence for specificity of ERP abnormalities during response inhibition in ADHD children: A comparison with reading disorder children without ADHD. *Brain and Cognition, 72*, 228-237.

Lytle, S. (1994). A comparison of amplification efficacy and toleration of background noise in hearing impaired elderly persons. Unpublished master's thesis, University of Tennessee, Knoxville.

Miller, E. K., & Cohen, J. D. (2001). An integrative theory of prefrontal cortex function. Annual *Review of Neuroscience, 24*, 167–202.

Moray, N. (1959). Attention in dichotic listening: Affective cues and the influence of instructions. *Quarterly Journal of Experimental Psychology, 11,* 56–60.

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

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 and Hearing Research, 47*, 1001–1011.

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*(9), 626-639.

Neisser, U. (1976). *Cognition and reality: Principles and implications of cognitive psychology.* San Francisco, CA: Freeman.

Nichols, A. & Gordon-Hickey, S. (2012). The relationship between locus of control, self-control, and acceptable noise levels. *International Journal of Audiology, 51*, 353-359.

Pliszka, S.R., Liotti, M., & Woldorff, M.G. (2000). Inhibitory control in children with Attention-Deficit/Hyperactivity Disorder: Event-related potentials identify the processing component and timing of an impaired right-frontal response-inhibition mechanism. *Society of Biological Psychiatry, 48,* 238-246.

Plyler, P.N., Bahng, J., & von Hapsburg, D. (2008). The acceptance of background noise in adult cochlear implant users. *Journal of Speech, Language, and Hearing Research, 51*, 502-515.

Plyler, P.N. (2015, June). 20Q: Acceptable Noise Level Test - The basics and beyond. *AudiologyOnline*, Article 14403. Retrieved from http://www.audiologyonline.com.

Plyler, P.N. (2015, July). 20Q: Acceptable Noise Level Test - supporting research and clinical insights. *AudiologyOnline*, Article 14692. Retrieved from http://www.audiologyonline.com.

Recker, K., McKinney, M., & Edwards, B. (2014). Loudness as a cue for acceptable noise levels. *Journal of the American Academy of Audiology, 25,* 605-623.

Richard-Devantoy, S., Gorwood, P., Annweiler, C., Olié, J.P., Le Gall, D., & Beauchet, O. (2012). Suicidal behaviours in affective disorders: A deficit of cognitive inhibition? *Canadian Journal of Psychiatry, 57(4*), 254-262.

Schachar, R., Logan, G.D., Robaey, P., Chen, S., Ickowicz, A., & Barr, C. (2007). Restraint and cancellation: multiple inhibition deficits in Attention Deficit Hyperactivity Disorder. *Journal of Abnormal Child Psychology, 35*, 229-238.

Schoof, T. & Rosen, S. (2014). The role of auditory and cognitive factors in understanding speech in noise by normal-hearing older listeners. *Frontiers in Neuroscience, 6,* 1-14. Online.

Shetty, H.N., Mahadev, S., & Veeresh, D. (2014). The relationship between acceptable noise level and electrophysiologic auditory brainstem and cortical signal to noise ratios. *Audiology Research, 4(93)*, 1-4. Online.

Shiffrin, R. M., & Schneider, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. *Psychological Review, 84,* 127–190.

Smith, D.V., Davis, B., Niu, K., Healy, E.W., Bonilha, L., Fridriksson, J., Morgan, P.S., & Rorden, C. (2009). Spatial attention evokes similar activation patterns for visual and auditory stimuli. *Journal of Cognitive Neuroscience, 22(2)*, 347-361.

Tampas, J. W., Harkrider, A. W., & Nabelek, A. K. (2004). Physiologic correlates of background noise acceptance. *Journal of the Acoustical Society of America, 115,* 2500–2501.

Tampas, J.W. & Harkrider, A.W. (2006). Auditory evoked potentials in females with high and low acceptance of background noise when listening to speech. *Journal of the Acoustical Society of America, 119*, 1548–1561.

Westerhausen, R., Kompus, K., & Hugdahl, K. (2011). Impaired cognitive inhibition in schizophrenia: A meta-analysis of Stroop interference effect. *Schizophrenia Research, 133(1-3)*, 172-181.

Zekveld, A.A., George, E.L.J., Kramer, S.E., Goverts, S.T., & Houtgast, T. (2007). A development of the Text Reception Threshold test: A visual analogue of the Speech Reception Threshold test. *Journal of Speech, Language, and Hearing Research, 50*, 576-584.