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Effects of auditory and visual distracters on acceptable background noise level in hearing-impaired listeners

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Effects of Auditory and Visual Distracters on Acceptable Background Noise Level in Hearing-Impaired Listeners

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ABSTRACT

Acceptable Noise Level (ANL), is an established procedure for determining the amount of background noise a listener is willing to accept while listening to speech. ANL is established by having the listener select most amount of background noise they are willing to accept while listening to a speech stimulus presented at their most comfortable listening level (MCL). While ANLs have been established as good predictors of hearing aid use, little is known on how hearing aid users accept background noise while engaged in cognitively demanding tasks. Previous research in normal hearing listeners has demonstrated that listeners will allow the most background noise while engaged in a visual cognitive task. While it is apparent that cognitive distracters influence acceptable background noise levels in normal hearing listeners, it is unknown if this trend is present in hearing-impaired listeners. Therefore, the goal of this study is to investigate the effects of auditory and visual distracters on acceptable BNL. Acceptable BNL levels were obtained on thirteen hearing-impaired listeners in four conditions – baseline (no distraction), visual, auditory, and competing auditory-visual distraction. Results were similar to those reported with a normal hearing population, and indicated that hearing-impaired listeners were willing to accept the most background noise with visual distraction alone.

INTRODUCTION

It has been proposed that a resource allocation model can explain the cognitive capacity of an individual and its limitations while performing multiple tasks (Broadbent, 1958; Kahneman, 1973; Wickens, 1984). Resource allocation theory proposes that there is a finite amount of cognitive resources available to perform multiple simultaneous tasks. When an individual exerts most of the available cognitive resources on one task, performance on other simultaneous tasks will suffer. This concept is widely accepted in humans and computers that run parallel processing operating systems. When a hearing-impaired listener uses hearing aids to compensate for his hearing loss, the primary goal is to improve speech understanding. The simultaneous tasks that the hearing aid user has to navigate could include driving (a visual distraction), separating background noise from speech (an auditory distraction), another competing speaker, or performing some other form of mental tasks such as trying recall a prior event. It has been empirically reported by clinicians that hearing aid users complain of listening fatigue at the end of the day. Recent literature supports those clinical observations (Akelroyd, 2008; Arlinger et al., 2009; Frease et al., 2010; Pichora-Fuller, 2006; Pichora-Fuller and Singh, 2006; Rudner et al., 2012)

From an audiologic treatment perspective, a renewed interest has emerged in understanding how hearing aid users perform in a primary task while engaging in a cognitively demanding secondary task; and how much various signal processing schemes facilitate the primary task in demanding environments (Edwards, 2007, Lunner et al., 2009). Speech understanding in background noise has typically been used a primary task while various secondary tasks such as competing speech, simulated driving task, simulated video games, short-term memory tasks have been reported in the literature (Edwards, 2007; Rudner et al., 2012).

Acceptable Level of Noise in Different Listening Situations

Acceptable Noise Level (ANL) test was first introduced by Nabelek, Tucker, & Letowski (1991) as a way to assess and quantify the amount of background noise listeners were willing to accept. Difficulty listening in background noise is a common compliant among hearing aid users. The goal of the study was to establish a method of assessing toleration of background noise that would be a better predictor of hearing aid success. ANL is defined as the amount of background noise a listener is willing to accept while listening to a speech stimulus (Freyaldenhoven, et al., 2005). First the listener's most comfortable listening level (MCL) for the speech stimulus is obtained. Next, continuous background noise is presented while the listener attends to the speech stimulus. The level of the background noise is gradually increased or decreased until the listener selects the level they are willing accept. ANL is then calculated by subtracting the listener's background noise level (BNL) from their MCL (ANL = MCL – BNL).

Nabelek, et al. (1991) investigated ANLs, initially termed "tolerated signal-to-noise ratios (S/N)," in three groups of hearing-impaired listeners: full-time, part-time, and non-users. The full-time users wore their hearing aids whenever they needed them, part-time users wore their hearing aids occasionally, and non-users did not wear hearing aids. Five types of background noise were used: 12-talker babble, speech-spectrum noise, traffic noise, light music, and a pneumatic drill noise. Full-time users had smaller ANLs for all five types noise than part-time or non-users suggesting that they were willing to accept more background noise. There was no significant difference between the ANLs of the part-time users and the non-users.

The relationship between ANL and other factors have also been examined in the literature. The initial study by Nabelek et al. (1991) found no significant correlation between ANL and age, MCL, or pure tone average (average of hearing thresholds at .5, 1k, and 2k Hz). Rogers, Harkrider, Burchfield, and Nabelek (2003) investigated effects of gender on ANL and found that while male participants had higher MCL and allowed more levels of background noise, there was ultimately no significant difference between the ANLs of male and female participants. Several studies have investigated the impact of type of background noise on ANL and have shown no significant difference between multitalker babble and other types of background noise (Nabelek et al., 1991; Crowely & Nabelek, 1996). Nabelek, Tampas, and Burchfield (2004) compared ANLs obtained in the aided and unaided conditions and found no significant difference between the two groups suggesting that ANLs can be obtained reliably without hearing aids.

Follow-up studies have demonstrated ANLs to be a useful clinical tool in predicting hearing aid success. Nabelek, Freyaldenhoven, Tampas, Burchfield, & Muenchen (2006) investigated ANLs in full-time, part-time, and non hearing aid users. The researchers found again that ANL were significantly correlated with hours of hearing aid use; specifically, full-time users were willing to accept more background noise (small

ANLs) than part-time or non hearing aid users (large ANLs). When ANLs were used to predict hearing aid success they did so with 85% accuracy.

While ANLs have been established as good predictors of hearing aid use and benefit, little is known on how hearing aid users accept background noise while engaged in cognitively demanding tasks. Previous work by Shastany (2013, unpublished doctoral dissertation) looked at the effects of auditory and/or visual cognitive distracters on acceptable BNL in normal hearing listeners and found that participants allowed the most background noise with visual distraction only. While it is apparent that cognitive distracters influence acceptable BNLs in normal hearing listeners, it is unknown if this trend is present in hearing-impaired listeners. The purpose of the present study is to investigate the effects of auditory and visual distracters on acceptable BNL in hearing-impaired listeners. It is hypothesized that hearing-impaired listeners will allow the most background noise in the visual distraction only condition. It is also hypothesized that hearing-impaired listeners will allow more noise with the combination of auditory and visual distraction.

RESEARCH QUESTIONS

1. Do acceptable BNLs measured in hearing-impaired subjects differ with auditory and/or visual distracters?
2. Do acceptable BNLs measured with auditory and/or visual distracters in hearing-impaired subjects differ from those measured in normal hearing subjects?

METHODS

Participants

Thirteen adult, hearing-impaired, native English speakers were recruited to participate in this study. Participants consisted of 11 males and 2 females with a mean age of 70.9 (age range 53-84). Participants also met the following criteria: current use of binaural amplification, symmetrical sensorineural hearing impairment with pure-tone thresholds that did not exceed 80 dB HL (see Figures 1 & 2), normal middle ear function (Type A tympanogram), and no known cognitive or memory deficits as established by completing the Mini Mental State Exam with a score ≥ 23.

Prior to testing, all participants were informed about the research and any risks or benefits. All subjects signed informed consent forms approved by the James Madison University Institutional Review Board (Protocol No. 13-0235). Participants were assigned code numbers and placed in one of four groups to determine test order counterbalancing for the order of presentation. Participants were compensated for their participation in the study with one box of hearing aid batteries.

Figure 1. Mean hearing thresholds (dB HL re: ANSI 1996) of participants from 250-8kHz. Right ear shown in red and left ear shown in blue. Error bars indicate 1 SD.

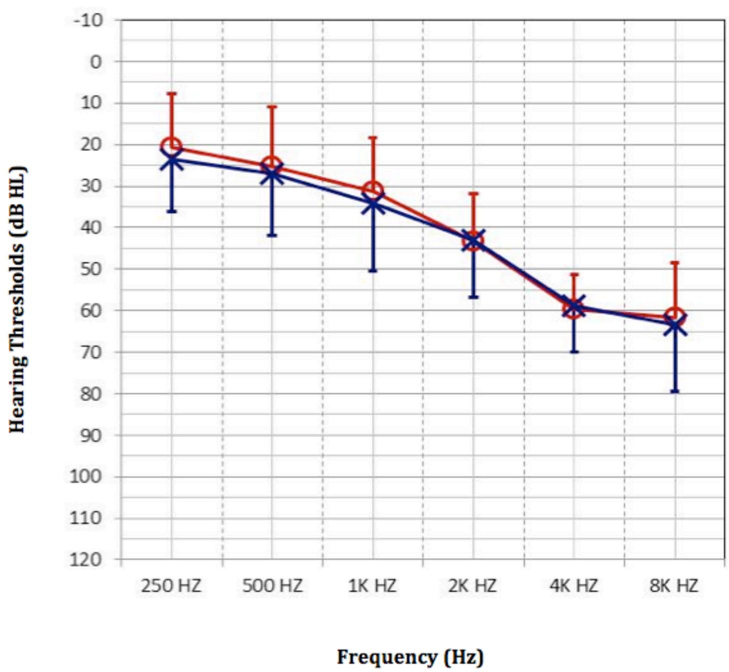
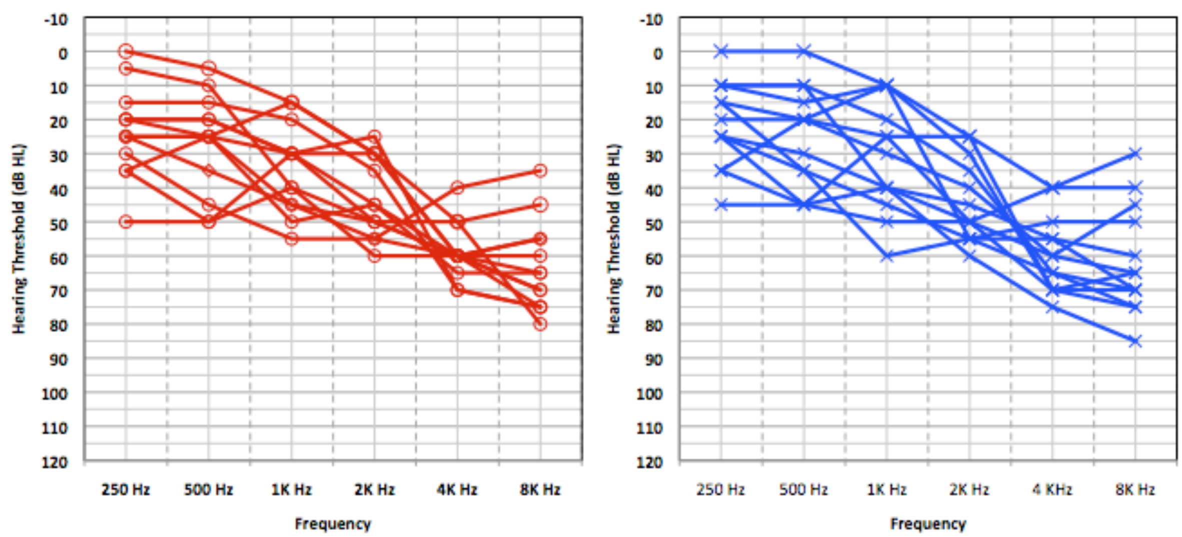


Figure 2. Hearing thresholds (dB HL re: ANSI 1996) of each participant for the right (red) and left (blue) ears.



Stimuli

A recording of a male talker reading the Arizona Travelogue (ANL CD, Frye Electronics) was used as the speech stimulus. Multi-talker babble, available as a second track on the ANL CD, was used for the background noise stimulus. The auditory stimuli were presented at 0˚ degrees azimuth from one speaker.

A stimulated driving application (Volkswagen Touareg Challenge 1.0.2 by Volkswagen) downloaded onto an iPad was used as the visual distracter. The task required the driver to navigate a car through a racecourse while steering, accelerating, and braking the vehicle. Steering of the vehicle was controlled by physically turning the iPad to the left or right, much like a steering wheel in a car. The driver controlled acceleration or braking by pressing the onscreen gas pedal or brake pedal with their thumb. Participants were instructed to keep the car on the road and not bump into any obstacles during the driving task.

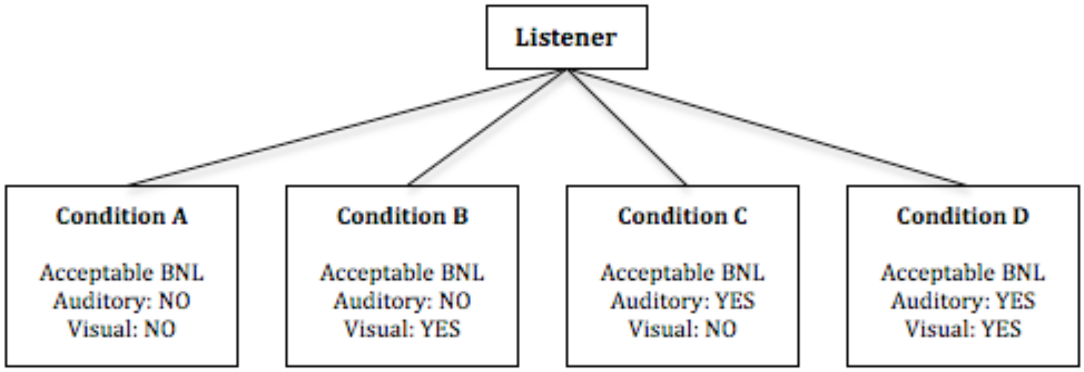
Procedures

All testing was completed without the use of the participant's hearing aids, as previous research has indicated no significant difference between ANLs obtained with or without amplification (Nabelek, et al., 2004). Testing was completed in a 3 x 2.8 x 2 meters double walled sound attenuating booth (Industrial Acoustics Company, Bronx, NY). A research assistant was seated in the booth with the participants to provide instructions.

Prior to testing, each participant's Most Comfortable Listening level (MCL) was established using the recording of the male talker reading the Arizona Travelogue. MCL was used as the presentation level of the auditory distracter in Conditions C and D. Additionally, each participant completed a practice condition, where they were encouraged to ask any questions regarding establishment of preferred background noise level. The practice condition was repeated as many times as necessary, until the participant felt comfortable with the task. Instructions for each task were provided in written form as well as verbally by the researcher and/or research assistant.

Following completion of the practice condition, testing began as determined by the assigned test group. A visual representation of the test conditions can be referred to below in Figure 3.

Figure 3. Summary of test conditions.



Instructions

The present study was a follow up to Shastany (2013) with hearing-impaired listeners. Accordingly, all the instructions from Shastany (2013) were used for consistency. Prior to completing any of the tasks, all participants completed a practice test. This practice test was both the ANL test and treatment condition C. The speech stimulus by the male talker was first introduced at 20 dB HL and increased in 2 dB steps. The participant was instructed to indicate to the researcher when the speech reached a level that was most comfortable for them to listen to for a prolonged period of time. The subject was encouraged to increase or decrease the level of the speech as many times as necessary to find a comfortable listening level. The subject indicated the MCL to the researcher by saying "stop." This MCL level was recorded by the researcher for future conditions. After the participant determined their MCL level, background noise was introduced at 20 dB HL. The noise was increased in 2 dB steps and the subject was asked to indicate when the background noise level reached the maximum level they were willing to tolerate by saying "stop." The written instructions for this practice test were as follows:

I am going to present ongoing speech by a male talker. The speech will slowly get louder. I want you to ***tell me when the speech is the most comfortable for you*** *as if you were listening to the radio. You may turn the loudness up and down as needed to help select the most comfortable level.*

Now I am going to present a background noise conversation of several people talking at the same time. The ***level of the background noise conversation will slowly increase and I want you to tell me when it is the most you are willing to accept or put-up-with****. You may turn the loudness of the background noise conversation up and down as needed to help you select the level you are most willing to accept.*

Task A required the subject to determine their tolerable BNL in the absence of a speech stimulus and no visual distraction. The background noise was the sole stimulus for this condition and was introduced at 40 dB HL. The noise level increased in 2 dB steps until the subject said "stop." The participant was encouraged to ask for the background noise to be increased or decreased as many times as necessary in order to determine their tolerable BNL. The written instructions for this condition were as follows:

Imagine you are engaged in a conversation. I am going to present a background noise conversation of several people talking. The level of the background noise will slowly increase. I want you to ***monitor the level of the background noise conversation and tell me when it is the most you are willing***

> ***to accept or put-up-with while imagining you are still engaged in a conversation****. You may turn the loudness of the background noise conversation up and down as needed to help you select the level you are most willing to accept.*

Condition B introduced a visual distracter, the iPad application, to the background noise presentation (See Figure 4). Prior to the start of this condition, the research assistant gave the iPad to the subject. The subject was instructed to pay attention to the game while monitoring the background noise level. Again, the background noise was introduced at 40 dB HL and increased in 2 dB steps. The subject was instructed to tell the researcher when the background noise level reached a maximum level they were willing to tolerate by saying "stop." The subject was encouraged to increase or decrease the level to help determine their tolerable BNL level as many times as necessary by saying "up" or "down." At the conclusion of this task, the research assistant collected and reset the iPad for future conditions. The written instructions for this condition were as follows:

> *You are going to play a game on the iPad. I am going to present a background noise conversation of several people talking. Imagine you are engaged in conversation.* ***Your task is to play the game while monitoring the level of the background noise.*** *The background noise conversation of several people will get louder.* ***Tell me when it reaches a level that you are most willing to accept or put-up-with while imagining you are still engaged in that conversation****. You may turn the loudness of the background noise conversation up and down as needed to help you select the level you are most willing to accept.*

Figure 4. Screenshot of the visual distraction task in conditions B and D. The participants were able to control the speed of the vehicle by pressing the bottom right side and brake by pressing on the bottom left corner. Rotating the iPad simulating a steering wheel turned the vehicle accordingly.

Test condition C was the actual ANL test. This condition introduced the running speech by the male talker at the level the participant had determined to be their MCL during the practice task. After the participant was listening to the speech stimulus for several seconds, the background noise was introduced at 40 dB HL. The noise was increased in 2 dB steps and the subject was asked to indicate when the background noise level reached the maximum level they were willing to tolerate by saying “stop.” The written instructions for this condition were as follows:

> ***There will be ongoing speech by a male talker.*** *The speech will be at the level you decided was most comfortable for you to listen to during the Practice Task.*

A background noise conversation of several people talking will be presented and will slowly get louder. ***Tell me when the noise reaches a level that you are most willing to accept or put-up-with while still listening to speech by the male talker.*** *You may turn the loudness of the background noise conversation up and down as needed to help you select the level you are most willing to accept.*

You will be asked to give a short summary of the ongoing speech by the male talker at the end.

In the final condition, D, the subject was required to determine their BNL to a speech stimulus with visual distraction. Prior to the start of this condition, the research assistant gave the iPad to the participant. The participant was instructed to pay attention to the game while monitoring the background noise level. This condition introduced the speech stimulus by the male talker at the subject's previously established MCL. After the participant was listening to the speech stimulus for several seconds, the background noise was introduced at 40 dB HL. The noise was increased in 2 dB steps and the subject was asked to indicate when the background noise level reached the maximum level they were willing to tolerate by saying "stop" while playing the iPad application. At the conclusion of this task, the research assistant collected and reset the iPad for future conditions. The written instructions for this condition were as follows:

There will be ongoing speech by a male talker. The speech will be at the level you decided was most comfortable for you to listen to during the Practice Task. I am going to present a background noise conversation of several people *talking and you are going to be playing a game on the iPad.* ***Your task is to focus on playing the game while monitoring the level of the noise.*** *The background noise conversation will slowly get louder and* ***I want you to tell me when the noise has reached a level you are willing to accept or put-up-with****. You may turn the loudness of the background noise conversation up and down as needed to help you select the level you are most willing to accept.*

You will be asked to give a short summary of the ongoing speech by the male talker at the end.

After the four tasks were completed in the order determined by the Latin-square design, the subject's UCL was obtained in two final conditions. The first UCL condition was measured to background noise only as this is a true clinical measure of the subject's UCL. The background noise was introduced to the subject at 40 dB HL and increased in 2 dB steps until the subject said "stop." The written instructions for this condition were as follows:

Your task is to listen to the background noise. This noise will slowly get louder. I want you to listen to the noise and ***tell me when the noise reaches a loud level that is uncomfortable for you to tolerate****.*

Data Analysis

A repeated measures ANOVA was performed using the mean background noise scores to investigate the effects of auditory and visual distraction. An alpha level of 0.05 was used to test significance.

RESULTS

The mean acceptable background noise level for each group was calculated. The mean acceptable background noise level for condition A, the baseline condition, was 58. When the listeners were tested with a visual distracter (Condition B), the acceptable BNL level increased to 66.3. Condition C, the actual ANL test condition, introduced the auditory distracter with a resulting acceptable BNL of 56.6. The final condition (Condition D) combined both the auditory and visual distracters with a mean acceptable BNL of 62.

It was hypothesized that with both auditory and visual distracters, the listeners would allow less background noise. However, the results indicated that for Condition D, listeners actually allowed more background noise than either the baseline condition or auditory distracter only condition.

The data was analyzed using a repeated measures ANOVA with the BNL of each condition (A, B, C, D) as within-subject factors and total number of errors during simulated driving task (high, low) as between-subject factors. The subjects were divided into two groups based on number of errors (high= >5; low= <5) with nine subjects in the low error group and four in the high error group. The results of the repeated measures ANOVA revealed a significant main effect test condition [$F(3,36)=9.391$, $p<.001$], indicating that the mean acceptable background noise level was different for the four test conditions (no distraction, visual, auditory, and visual + auditory distraction). There was a significant main effect of visual distraction [F (1,12)=24.397, p<.001]. No significant interaction between total number of errors, acceptable background noise level, auditory distraction or visual distraction was observed.

Post hoc pairwise comparisons between each test condition using Bonferroni correction revealed a significant difference between the mean scores of the following pairs: B-A and B-C. There was no significant difference between the pairs A-C, A-D, B-D, or C-D.

Table 1. Summary of repeated measures ANOVA comparing auditory and visual distraction.

Effects	***df***	***F***	**Significance**
Auditory distraction	(1,12)	3.04	.107
Visual distraction	(1,12)	24.39	.000*
Auditory distraction ✕ Visual distraction	(1,12)	1.42	.255

*. Results are significant at the .05 level.

Table 2. Pairwise comparisons using Bonferroni corrections between each significant test condition.

(I)	**(J)**	**Mean Difference (I-J)**	**± 1 Std. Error**	**Sig. [b]**	**95% Confidence Interval for Difference**	
					Lower Bound	**Upper Bound**
A	B	-8.30*	1.95	.007	-14.48	-2.13
B	C	9.69*	1.10	.000	6.20	13.17
C	D	-5.38	1.73	.054	-10.84	0.07

* The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Paired-samples T-test was performed to compare the baseline acceptable background noise level (Condition A) and reported uncomfortable listening level (UCL) conditions. There was a significance difference in the scores for acceptable BNL (M=58, SD=6.58) and UCL (M=75.3, SD=9.50) conditions; $t(12)= 7.902$, $p < 0.001$.

Summary of results

In summary, statistical analysis indicates that thirteen hearing-impaired listeners were willing to accept more background noise with visual distraction only.

DISCUSSION

The purpose of this study was to determine the amount of background noise that hearing-impaired listeners would accept in the presence of auditory and/or visual distracters. This study was conducted as a follow-up study to Shastany, 2013 (unpublished doctoral dissertation), which investigated tolerable background noise levels in normal hearing listeners.

Normal Hearing vs. Hearing Impaired Listeners

The results of this study followed the same pattern for visual distraction as reported by Shastany (2013) (See Figure 5). In the current study the subject group consisted of thirteen older hearing-impaired listeners (mean age = 70.9 yrs). Consistent with the participants hearing loss, the overall acceptable levels of BNL were higher when compared to the previous study with normal hearing listeners (See Figure 6). Both studies showed a significant main effect of visual distraction suggesting that normal hearing and hearing-impaired listeners are influenced in similar ways by a visual cognitive distracter. Shastany (2013) reported a significant main effect of auditory distraction in normal hearing listeners. This same trend was not observed in hearing-impaired listeners. One explanation for this trend is that older hearing-impaired listeners may not be as efficient in allocating cognitive resources as younger normal hearing subjects. Research has established that elderly adults do not perform as well as young adults on working memory tasks suggesting that some aspects of cognitive processing may become impaired with age (Wingfield, Stein, Lahar, & Aberdeen, 1988; Salthouse, 1994;

Meyerson, Emery, White, & Hale, 2003). Hayes, Kelly, and Smith (2013) investigated the effects of aging and working memory on selective attention and found that older adults were less efficient in selective recall than younger adults. Additionally, studies have show that older adults have poorer multitasking abilities and are highly susceptible to distraction (Healy, Campbell, Hasher, 2008; Clapp, Rubens, Sabharwal, Gazzaley, 2011). Therefore, there is a strong possibility that when both stimuli were presented in the same modality that the hearing-impaired listeners background noise preference was effected by their ability to differentiate the two stimuli and process them separately.

Figure 5. Box plots showing acceptable BNL (dB HL) for each condition in **normal hearing listeners** (Shastany, 2013). Each box represents the median score, 25th percentile, and 75th percentile. The whiskers represent maximum and minimum scores.

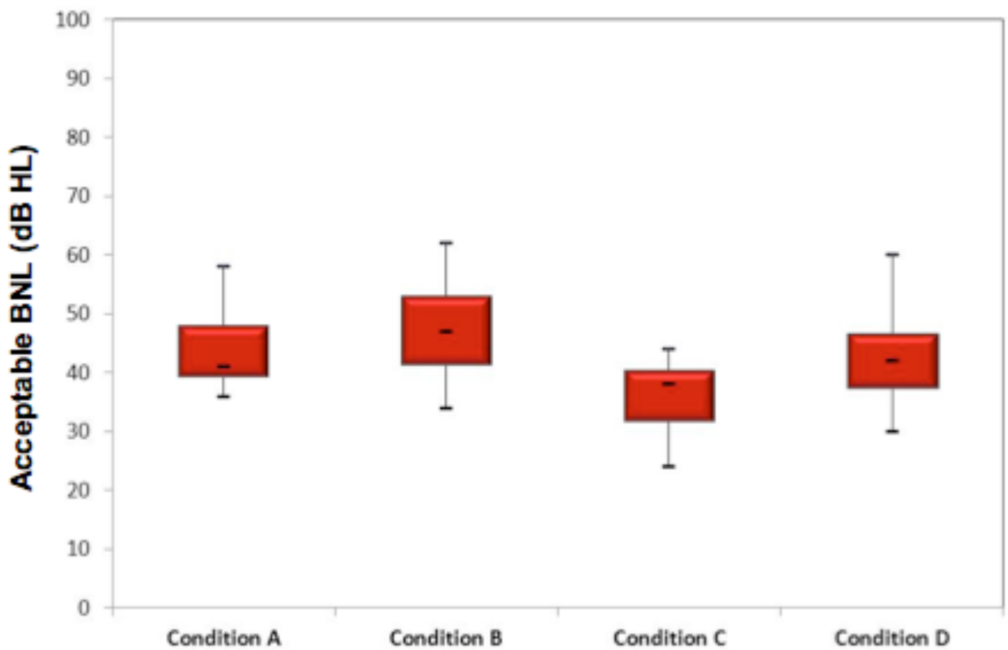


Figure 6. Box plots showing acceptable BNL (dB HL) for each condition in **hearing-impaired listeners**. Each box represents the median score, 25th percentile, and 75th percentile. The whiskers represent maximum and minimum scores.

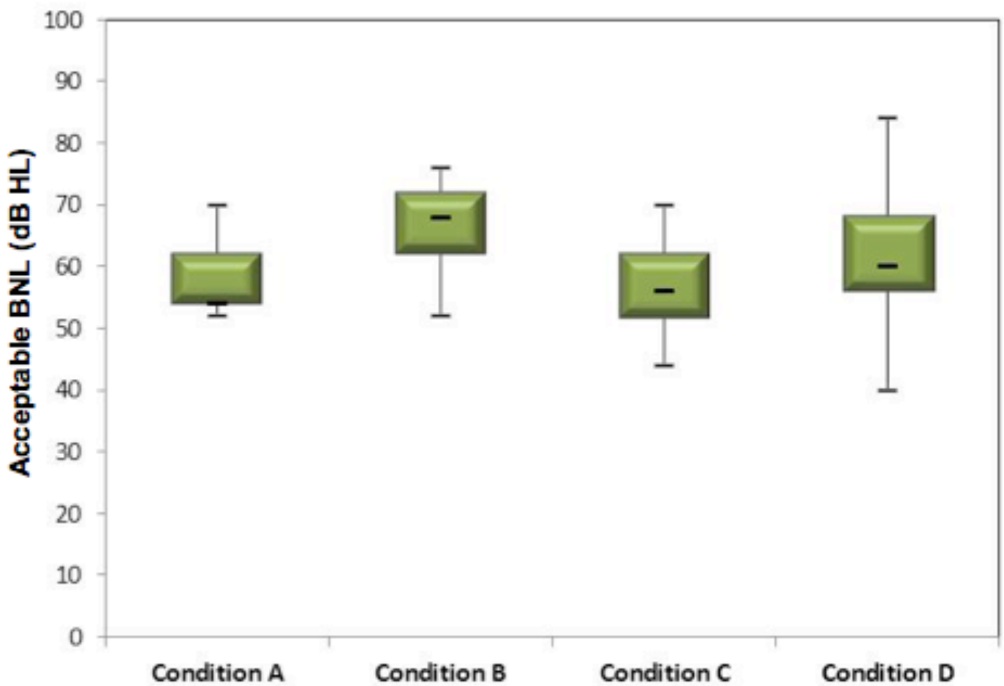
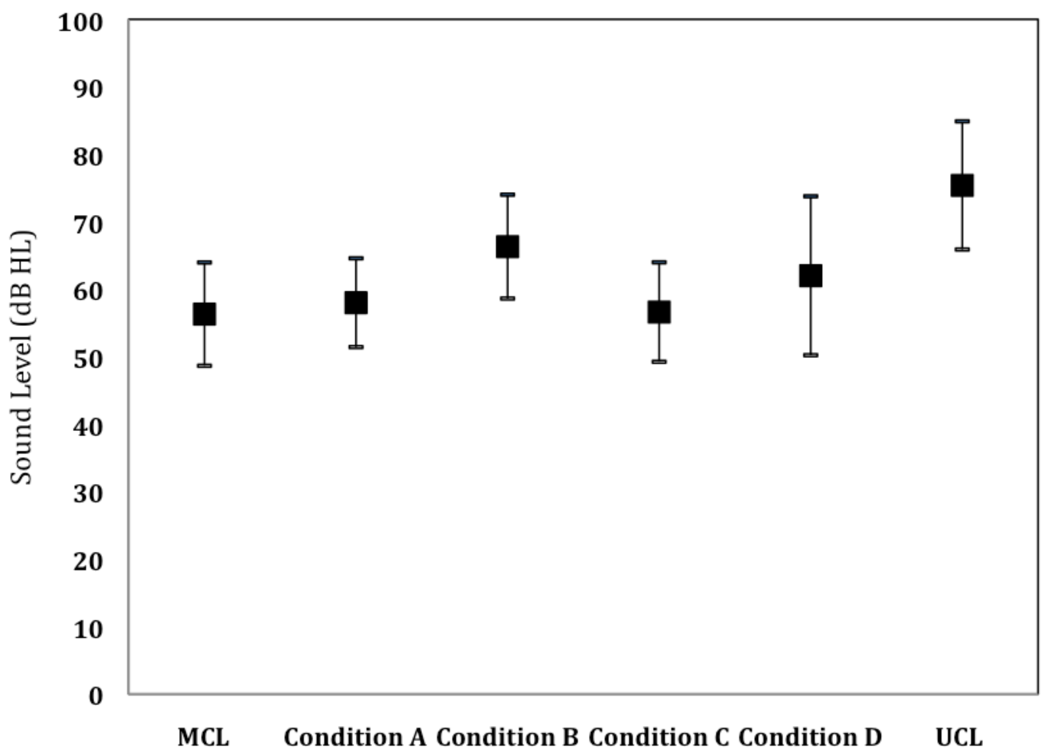


Figure 7. Mean scores for each condition (±1 SD) in **hearing-impaired listeners.**



BNL in hearing-impaired listeners

In the present study the average BNL for condition C was higher than the BNL level reported by Nabelek, et al. (2006) for full-time hearing aid users. Average MCLs were slightly lower than those reported by Nabelek, et al. (2006) for full-time hearing aid users but were comparable for part-time users. Both studies used the same speech stimulus (Arizona Travelogue, male talker) and a similar background noise (multitalker babble). One possible explanation for the observed higher background noise levels is a difference in how the background noise level was selected. In the Nabelek, et al. (2006) study, participants were provided with a control to signal the researcher to turn the volume up or down. In the current study, the researcher adjusted the level of the background noise and the participant verbally reported, “stop”, “up”, or “down.” It is possible that the participants were slower to report their preferred background noise level verbally, thus allowing the background noise level to continue to be increased. Additionally, the hearing-impaired listeners were not grouped by hours of hearing aid use. While all participants were current hearing aid users, they were not differentiated based on full-time or part-time use. Therefore it is likely that both full-time and part-time users were represented in the current study.

Acceptable Noise Levels for Auditory Competing Task

Repeated measures ANOVA was used and found a significant difference between the mean background noise level of each test condition. Mean background noise levels were noted to decrease slightly (1.4 dB) from Condition A to Condition C, however this difference was not significant. In Condition A, the listener was asked to imagine they were engaged in a conversation. In Condition C, the actual ANL condition, a speech stimulus was introduced. This suggests that hearing-impaired listeners may be able to accurately estimate the level to background noise they are willing to accept in the absence of an auditory stimulus.

Acceptable Noise Levels for Visual Task

In Condition B with only visual distraction, listeners allowed the most background noise. One explanation for these findings is that the visual driving task was more distracting than either the auditory only or combined auditory and visual distraction conditions. While the idea that one task can be more distracting than two tasks may be contrary to expectations, there is evidence within the research to support this trend. Laing and Lee (2009) found that participants in a stimulated driving task made more driving errors with visual distraction than in the combined visual and cognitive distraction condition. The researchers concluded that visual distraction dominates the driver's cognitive resources and that the introduction of the auditory cognitive distracter actually reduces the demands of the visual distracter on the system. Additional research has suggested that driving performance is significantly more impaired with visual distraction alone (Kaber et al., 2011; Muhrer & Vollrath, 2011).

Furthermore, electrophysiological research in humans has suggested that selective attention to an auditory or visual stimulus can modulate peripheral cochlear sensitivity through top-down processing. Smith, Aouad, & Keil, (2012) looked a distortion product otoacoutic emission (DPOAE) levels in auditory-attending (counting tones) and auditory-ignoring/visual distraction (watching a movie with subtitles) conditions. They found that average DPOAE levels were higher in the auditory-ignoring/visual distraction condition suggesting that cognitive tasks have a significant impact on outer hair cell function. Additional research using animal models has demonstrated that cochlear sensitivity significantly decreases when attending to a visual stimulus (Delano, Elgueda, Hamame, & Robles, 2007). This suggests that peripheral cochlear sensitivity can be modulated by selective attention and therefore may be an influencing factor in the level of background noise a listener is willing to accept.

Acceptable Noise Levels in Combined Auditory and Visual Distractions

Data analysis revealed that listeners were willing to accept more background noise than the baseline condition when auditory and visual distracters were combined. This was unexpected as it was hypothesized that combination of distracters would result in less toleration of background noise. This finding is consistent with Shastany (2013) and stimulated driving research, which shows that the combination of auditory and visual distraction actually results in less driver errors (Laing & Lee, 2009; Kaber et al., 2011; Muhrer & Vollrath, 2011).

Error Rates on Visual Task

The total number of errors (i.e. deviations from the course) made during the driving task were recorded. Participants were divided into high and low error rate groups based on the total number of errors made during the driving task. Those in the high error group allowed for significantly more background noise with the combination of auditory and visual distraction than the low error group (See Figure 8). This suggests that those in the high error group were more distracted by the driving task thus allowing the background noise level to continue to be increased. Error rates present one possible way of looking at how much attention participants were giving to the driving task.

Additionally, they may also represent the participant's ability to nudge their internal criteria when selecting an acceptable BNL. For example if a participant chose to drive cautiously and have fewer mistakes they may not be as distracted and therefore choose a lower BNL.

Figure 8. Relationship between number of errors (low, high) and acceptable background noise level.

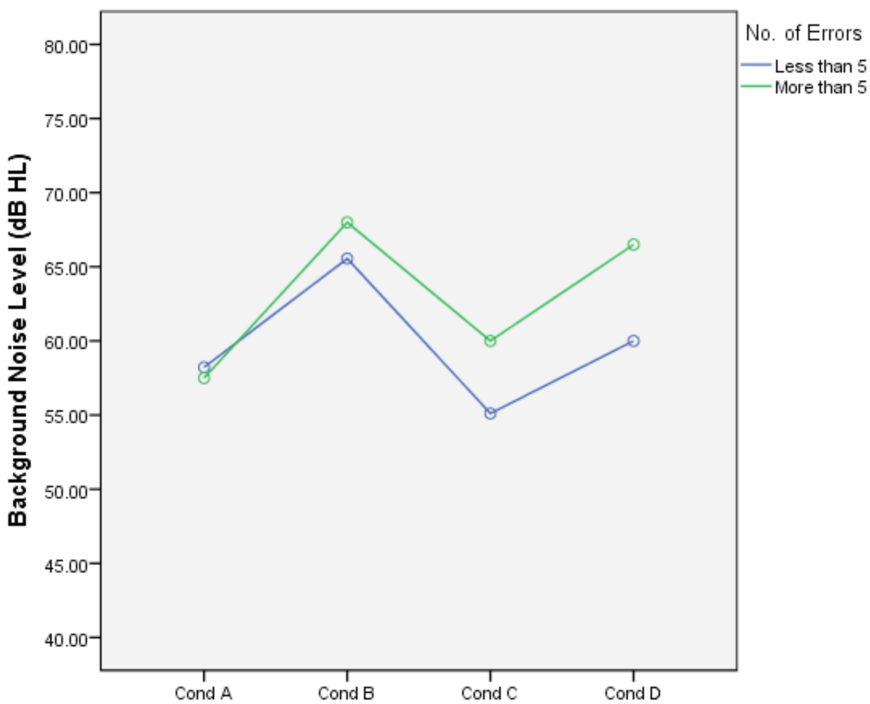
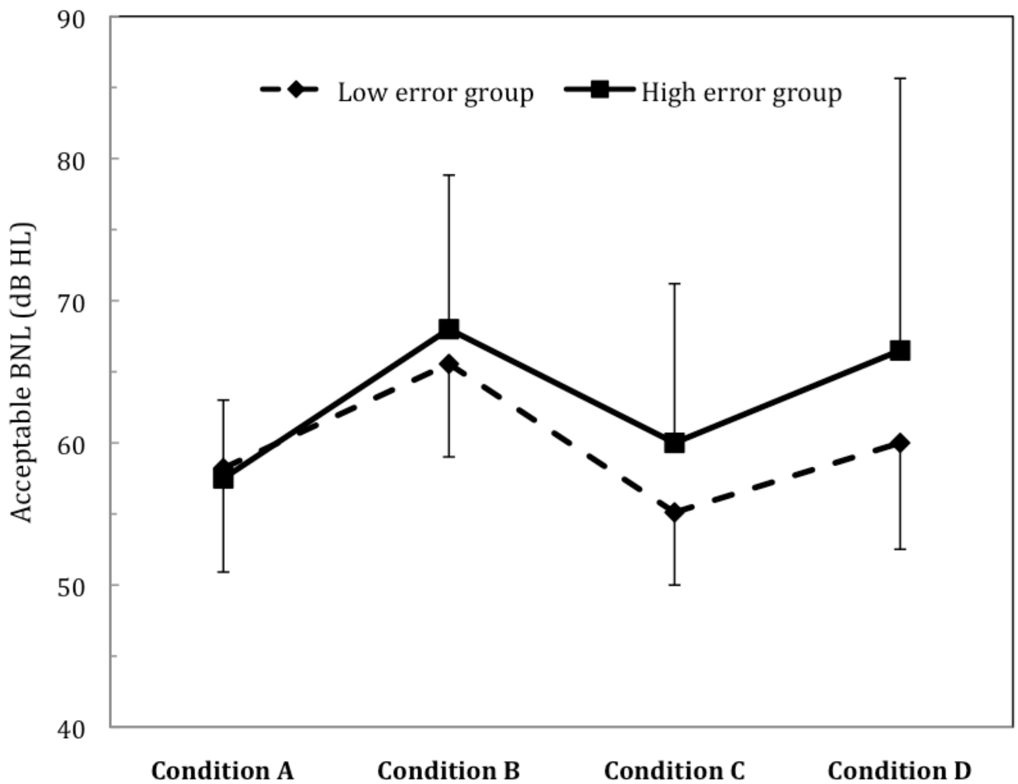


Figure 9. Mean background noise level (±1 SD) for the low and high error groups.



Comparison of UCL to the baseline condition:

Each participant's uncomfortable listening level was established to unsure that they were not reporting UCL when measuring acceptable BNL. A paired samples T-test comparing the baseline condition to the listeners UCL was performed. Analysis revealed a significant difference between scores suggesting that the listeners followed directions when asked to select an acceptable background noise level.

Implications:

The findings of this study have direct implications to tinnitus management therapies and noise reduction processing in hearing aids. Based on the findings of this study it may be beneficial to add a visual component to tinnitus retraining therapies. It has been shown that visual distraction can dominate cognitive resources leading to increased distraction. Approaches to tinnitus management from a cognitive-behavioral perspective may offer new strategies to reduce tinnitus perception.

Noise reduction strategies in hearing aids have focused on reducing as background noise as possible without distorting speech. However, aggressively reducing noise in all listening situations may not be necessary if hearing-impaired listeners are willing to accept more background noise when engaged in other activities.

Limitations and Future Directions:

Several limitations of the current study should be considered. First the number of participants was small (n=13). Therefore, it is possible that the results obtained are not representative of the larger population. Future research should focus on obtaining data with a larger number of participants. The present study did not group participants by hearing aid use; however, research on ANLs has demonstrated significant differences between full-time and part-time hearing aid users. Finally only one type of visual distracter was used in this study. It is possible that the iPad driving game could have been more distracting in older adults who are unfamiliar with this type of technology. Other methods of visual distraction such as watching a video or performing a driving task with a joy-stick could be explored in future studies.

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