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Listening fatigue and response time in normal hearing listeners

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Listening Fatigue and Response

Time in Normal Hearing Listeners

A Project Presented to

The Faculty of the Undergraduate Department of

Communication Sciences and Disorders

James Madison University

In Partial Fulfillment of the Requirements

for the Degree of Bachelor of Science

By Rachel Pittard

May 2015

Accepted by the faculty of the Department of Communication Sciences and Disorders, James Madison University, in partial fulfillment of the requirements for the Degree of Bachelor of Science.
To be presented at the Honors Symposium on April 24th.

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Acknowledgements

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Introduction

Individuals with hearing loss undergo exertion with the change in the auditory environment they are exposed to throughout the day. This fatigue causes individuals with hearing loss to expend more effort in order to achieve the level of speech understanding that a normal hearing individual would under the same environmental circumstances (Gosselin and Gagné, 2011). Because of this, hearing aid users experience listening fatigue by the end of the day, especially in the presence of background noise (Rabbitt, 1991). This listening fatigue affects school aged kids and their ability to perform and succeed on grade level in the classroom. Older adults are also heavily affected as their speech understanding naturally reduces with age.

Increasing audibility for individuals with hearing loss is addressed through digital hearing aids, which aid in reducing individual's auditory and cognitive strain. The digital noise reduction (DNR) feature adds gain to signals identified as sounds and reduces signals identified as noise, allowing the affected individual to more easily distinguish speech in the presence of background noise, ultimately reducing the effect of listening fatigue experienced by the individual. Research suggests that DNR may be capable of reducing the effects of listening fatigue through evidence that shows a faster response time in individuals with DNR than in individuals without this feature (Sarampalis et al, 2009). In response to this, subjective questionnaires have been rated showing the same amount of listening fatigue despite being an aided or unaided listener. Thus the goal of this study and future studies is to understand DNR and its level of success in reduced listening efforts and fatigue.

The purpose of this study is to measure response time in normal hearing individuals in order to determine if listening fatigue is reflected as a change in response time.

Methods

This study was conducted at James Madison University in the Hearing Aid Research Laboratory (IRB protocol # 15-0050). Individuals 18 years or older were invited to participate by word of mouth. The inclusion criteria for participation includes: normal hearing listeners with thresholds less than 20 dB from 250 to 8000 Hz, no traces of ear pathologies or ADHD, and no current intake of strong medications, caffeine, or alcohol prior to the study. Each participant began with a free audiologic screening to eliminate the possibility of any hearing loss or ear pathologies. This audiologic screening included an otoscopy, tympanometry, and a pure tone screening of 250-8000 Hz at 20 dB HL. The subjects received free hearing screening through participation in this study.

After the participants hearing screening they began the study, which consisted of three components: a pre-test, a fatigue inducing condition, and a post-test. Both the pre and post-test had two measures, a response time test and a self-reported listening effort questionnaire.

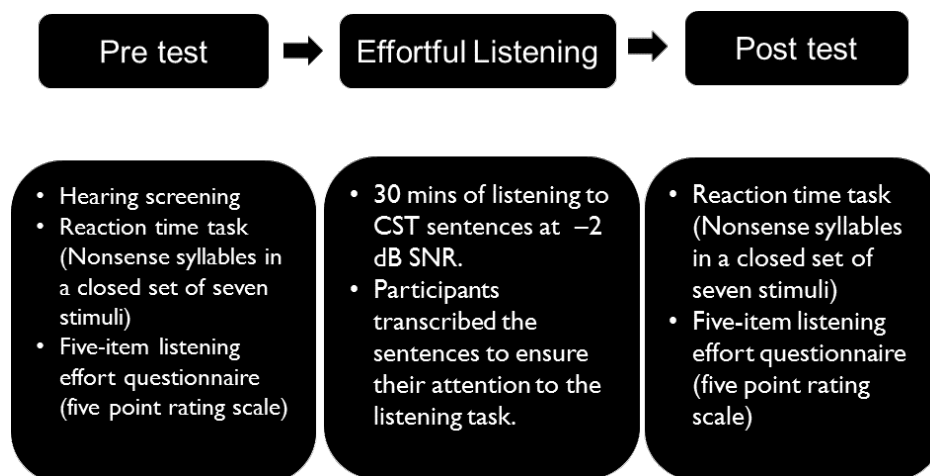


Figure 1. This figure explains the three components of this study.

The study was conducted in a double walled sound booth in the Hearing Aid Research Laboratory (2.75m x 2.5 m x 2m internal dimension). During the pre-test, the participant were seated in a comfortable chair with earphones on and access to a seven-option response pad (Cedrus RBX 730), both hooked up to a dedicated personal computer running Superlab 4.5 stimulus presentation and data collection program (Cedrus, CA). Nonsense syllables were presented through the earphones at 5 dB SNR, and 10 dB speech to noise ratio (SNR). SNR is the difference in the speech stimulus and the background noise when both are presented simultaneously. Zero dB SNR occurs when both the speech stimulus and the background noise are presented at the same decibel level. Each nonsense syllable was presented to the participant through earphones while the response was collected by pressing one of the seven response buttons in a closed-set paradigm. After the auditory stimulus was presented, the participant's goal was to quickly select the correct nonsense syllable. Each of the seven nonsense syllable options was presented in random order. After the first round of nonsense syllables was presented, there were eight more sets of different nonsense syllables to complete the reaction time task. The Superlab software recorded both the participant's response time as well as their accuracy.



Figure 2. A participant completing the response time test component of this study

The second component of the pre-test consists of a self-reported five-question questionnaire in which participants subjectively rate their listening effort on a five-point scale (from 1 = *least amount of effort exerted* and 5 = *maximum amount of effort exerted*) during the response time test. The five questions are below:

1. *Did you have to concentrate very much when listening to someone or something?*
2. *Did you have to put in a lot of effort to hear what is being said in conversation with others?*
3. *Could you easily ignore other sounds when trying to listen to something?*
4. *How well can you maintain your focus and attention right now?*
5. *How mentally/physically drained are you right now?*

Immediately following the pre-test, the participant engaged in the effortful listening task. This task required the participant to listen to 30 minutes of speech in noise at -2 SNR at a comfortable listening level (see figure 2 below for calibration procedure). This portion of the study was taken from the Connected Speech Test (CST); the speech listened to was both meaningful and grammatically correct. This portion of the study introduces effortful listening, as it requires participants to listen and take notes despite the noise level being 2 dB higher than the speech presented at an 8-talker babble. This requires maximum effort and attention in order to attain consistent results. To ensure that the participants were not tuning out, they were required to write down the gist of what they heard during the effortful listening task.



Figure 3. A participant adjusting the volume of the iPod to a comfortable listening level.

Immediately after the thirty minutes portion of the effortful listening task, the participants started the post-test. The post test involved exactly the same reaction time and subjective questionnaire.

Data Analysis

After the pre-test, fatigue-inducing condition, and the post-test were completed the data was coded, analyzed, and sorted onto an Excel spreadsheet. As a research assistant my primary job was to provide quality control and organize the data in the Excel format. These data files were later exported into SPSS for detailed statistical analysis. The reaction time and self-reported scores from the pre and post-tests were compared to find out if the fatigue inducing condition resulted in a significant change. A poster presented at the Annual conference of the American Academy of Audiology is attached in Appendix I.

Self-Reflection

Participating and observing this study on listening fatigue has given me insight into the professional world of research, which has been a vital experience in my pre-graduate education as well as preparing me for further educational endeavors. It has taught me how to approach research with an adaptable, passionate, and motivated attitude in order to successfully understand, ask questions, and examine the reasons for conclusive or inconclusive results.

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Appendix I

Effect of Signal to Noise Ratio on Reaction Time Before and After Effortful Listening

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INTRODUCTION

Hearing-impaired individuals often report listening-related fatigue at the end of the day. These individuals are forced to exert more cognitive effort as they strain to understand speech in an ever-changing auditory environment through an impaired auditory system (Downs, 1982; Rabbitt, 1991). Hearing aids attempt to increase audibility and relieve cognitive strain through advanced signal processing techniques such as digital noise reduction (DNR). Recent research regarding noise reduction and its effects on listening effort suggests that DNR may reduce the effects of listening effort at difficult signal to noise ratios (Desjardins and Doherty, 2014; Gustafson, 2014; Hornsby, 2013; Picou et al., 2013; Sarapalllis et al., 2009). Reaction time (RT) has been proposed as a tool to measure listening effort (Hornsby, 2013; Houben et al., 2013; Kalluri and Humes, 2012; Picou-Fuller and Singh, 2006; Sarapalllis et al., 2009). However, it is difficult to separate the effect of effort from prolonged RTs due to difficult signal to noise ratios. The present study was designed to control for the duration of effortful listening and measure reaction time before and after the listening task. A single task nonsense syllable identification in closed set at +5 and +10 dB SNR was used to measure reaction time.

RESEARCH QUESTIONS

1. Does reaction time increase after 30 minutes of effortful listening requiring complete attention?
2. Do subjects report greater levels of fatigue after effortful listening?

METHODS

Twenty young adults (8 M, 17 F), 19 to 30 years of age (mean 22.8) with normal hearing sensitivity participated in this study. Participants met the following criteria: pure tone air conduction thresholds <20 dB HL, no reported diagnosis of ADHD spectrum, no reported consumption of strong medication or alcohol, and no middle ear pathology. There were three parts to the testing: a pre-test, a fatigue inducing condition, and a post-test. Immediately following the pre-test, participants underwent an effortful listening task which was meant to induce auditory fatigue. After the fatigue inducing condition, participants completed the post-test.

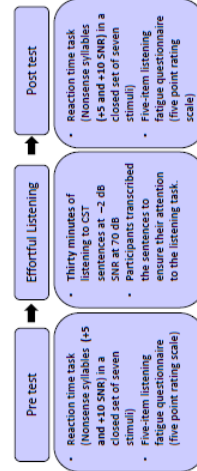


Figure 1. Flow chart of test conditions



Figure 2. Equipment set up: left panel- real ear measurements were taken with the iPod headphones to ensure each subject was listening at 70 dB; right – the reaction time was measured on a dedicated computer connected to a Cedrus RB-730 response pad.

RESULTS

A 2x2 within-subjects repeated measures ANOVA was conducted to evaluate the effect of listening fatigue (pre and post effortful listening) and listening effort (+10 and +5 dB SNR). Results indicated a significant effect of listening effort [$F(1,19) = 11.74, p < 0.005$]. However, there was no significant change in reaction time after the 30 minute effortful listening [$F(1,19) = 0.37, p > 0.05$].

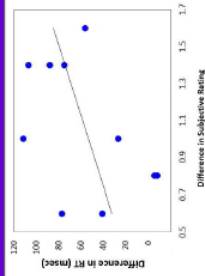
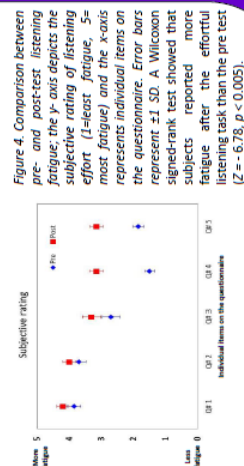
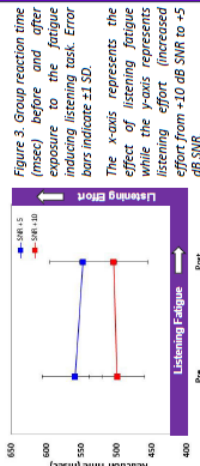


Figure 5. Scatter plot of the relationship between the reported fatigue and the corresponding change in reaction time. Ten subjects with the largest difference in reaction time showed moderate positive correlation (Pearson's $r = 0.45$) with their self-reported fatigue.

DISCUSSION

The thirty minute fatigue inducing condition resulted in a significantly higher level of self-reported fatigue. However, the objective measure did not result in prolonged reaction times at either signal to noise ratio indicating there was no effect of listening fatigue in this study. The group reaction time for +5 dB SNR was longer than that of +10 dB indicating a significant effect of listening effort. Our results agree with previous reports pointing to the prolongation of reaction time at difficult SNRs (Hornsby, 2013; Houben et al., 2013; Sarapalllis et al., 2009). The magnitude of change was also comparable to previous studies (~50 msec).

Limitations: The thirty minutes of effortful listening may not have been enough to induce a change in reaction time. The study included normal hearing subjects only. The results may be different with hearing-impaired individuals.

FUTURE DIRECTIONS

1. Longer periods of effortful listening (pre and post RTs for all day listening)
2. Hearing-impaired listeners.

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DISCLOSURE STATEMENT

We have no relevant financial relationships to disclose.

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