COMPUTERIZED AUDITORY TRAINING IN ADULTS WITH HEARING LOSS: AN EXAMINATION OF CLEAR-CUSTOMIZED LEARNING EXERCISES FOR AURAL REHABILITATION

by

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Abstract

Although hearing aids are the primary intervention method used by individuals with hearing loss, hearing aids alone may not ensure successful communication, and the use of auditory training can improve listening outcomes. Technological advances and limited access to services have increased the computerization of auditory training. The purpose of this research project is to examine a computerized auditory training program, clEAR- customized learning: Exercises for Aural Rehabilitation. This investigation should determine whether completing clEAR improves an individual's ability to listen in noise. Randomization occurred by dividing participants into two randomly assigned groups. The experimental group completed the clEAR program, and the control group engaged with a language-based mobile application. The pre-test evaluated participants' ability listening in noise by completing a self-questionnaire (Abbreviated Profile of Hearing Aid Benefit- APHAB) and speech-in-noise testing with recorded speech materials. After completing an assigned program or app for two months, participants attended post-testing, which used the same protocol as pre-testing. This study investigated the change from pre-test to post-test scores in both speech- in- noise performance and perceived benefit in reverberation, background noise, aversiveness to sound, and ease of communication. Researchers found that compared to the language-based application, completing clEAR for two months improved participant's perceived benefit in reverberant conditions. We found no statistically significant change in other measures. The discrepancies in findings highlight the importance of conducting independent external validation for auditory training programs. This study underscores the need for further investigation of clEAR-customized learning: Exercises for Aural Rehabilitation because the program may not improve listening in noise. The sample size and duration may negatively affect this pilot program's results.

Introduction

A primary intervention applied to hearing loss includes amplification via hearing aids. A systematic review conducted by Sweetow and Palmer (2005) argued that, although hearing aids improve access to acoustic information, technology alone cannot ensure successful communication for individuals with hearing loss. Communicative abilities improve when individuals not only have access to acoustic information but also listen with intention and correctly comprehend the accessible information. Thus, to achieve successful communication and increase satisfaction with amplification, individuals with hearing loss should use aural rehabilitation alongside technology. Aural rehabilitation encompasses amplification, assistive listening devices, counseling, and auditory training. Aural rehabilitation decreases listening obstacles caused by either internal factors such as hearing loss or external factors such as noise.

The present project focuses explicitly on auditory training. Blamey and Alcantara (1994) defined auditory training as the "use of instruction, drill, or practice designed to increase the amount of information that hearing contributes to a person's total perception" (p.163). Most auditory trainings focus on a variety of auditory skills, which include detection, discrimination, identification, and comprehension. Successful speech understanding with auditory training relies on cognitive processing skills and knowledge of language. In evaluating the effectiveness of auditory training, factors include the listening environment, client personality, evaluation methods, training type, hearing aid quality, and hearing loss severity and type (Blamey & Alcantara, 1994). Historically, practitioners have provided auditory training in person. Today, auditory training options are available through computer-based formats and smartphone applications. Both computerized-auditory training and mobile apps give individuals low-cost options that are more convenient than in-person auditory training at a clinic or other facility. The use of home auditory training programs has increased in adults because of flexibility (Olson, 2015). Henshaw and Ferguson (2013) also found that individuals use computer-based auditory training programs because they can tailor the program to their specific individual needs and can capture data over the internet.

Neural plasticity underlines successful auditory training programs. Researchers explain neural plasticity as the central auditory nervous system changing to facilitate the learning of new response patterns. During childhood, the brain has the most plasticity; however, evidence shows that appropriate stimulation enables plasticity in adult nervous systems (Pizarek et al., (2013). Henshaw and Ferguson (2013) discuss how cognitive function also plays a role in listening because greater working memory capacity and language comprehension are linked. Another article by Ferguson and Henshaw (2015), suggests that attention switching and memory updates are integral for successful listening, especially in challenging conditions in noise.

Although research supports using aural rehabilitation and amplification for successful communication, research concerning auditory training varies and produces mixed results. A study conducted by Pizarek and colleagues (2013) found that although many studies show that computerized auditory training programs produce positive changes in speech perception, evidence may not be sufficient, and caution is needed. Additionally, a systematic review by Henshaw and Ferguson (2013) found that practitioners should not trust the efficacy of individual computer-based auditory training because of low-quality evidence. Researchers recommend further research and emphasize considering the multitude of auditory training programs and the different approaches that each one takes. The number and variety of programs make generalizing findings difficult. Sweetow and Palmer (2015) also discussed how patient motivation and adherence to assigned tasks determines patient success with computerized auditory training programs.

A scoping review by Gygi and Hall (2016) found hearing aid dissatisfaction in environments characterized by excess background noise. The review suggests that, despite advancements in hearing aid technology, device dissatisfaction remains in noisy environments and large group conversations. Dissatisfaction and complaints occur because hearing technology may amplify unwanted background noise. Two recurring complaints include interference from background noise on speech communication and aversiveness to background noise. The review found as users became acclimated to aided technology, individual self-ratings of speech communication improved; however, no improvement was seen in aversiveness to background noise or listening in challenging noisy environments.

Background noise negatively affects speech communication and increases listening effort. Perceptual or listening effort is an individual's limited capacity that only allows a certain amount of cognitive resources for completing listening tasks. Listening obstacles such as background noise and reverberation increase cognitive demand, which requires more of one's total cognitive capacity. Additionally, listening in noise requires more perceptual effort for individuals with hearing loss than those with normal hearing. Maintaining a certain level of performance and understanding in difficult listening situations increases the overall percentage of cognitive resources used during speech perception tasks. The increased resources used simply for speech perception decreases the resources available for other speech comprehension tasks. Another component of perceptual effort is that fatigue increases when listening tasks use more resources (Sommers at al., 2015). One way to minimize the negative effects of background noise on perceptual effort is to use meaning-based auditory training. Researchers from Washington

University found that through using an auditory training program called clEAR- customized learning: Exercises for Aural Rehabilitation, individuals with hearing aids could improve both speech recognition in noise and reduce the perceptual effort required to understand spoken language (Sommers at al., 2015).

This particular study focuses on the computerized auditory training program clEAR- customized learning: Exercises for Aural Rehabilitation and its effectiveness in improving an individual's ability to listen in noise. Scientists at Washington University School of Medicine (WUSM) developed clEAR. clEAR uses multiple games to train participants in seven different categories that are important for successful listening. These categories include auditory memory, auditory attention, phoneme discrimination, discourse comprehension, auditory processing speed, bound morpheme identification, and recognizing frequently used words. Additionally, clEAR claims that auditory brain training leads to reduced perceptual effort during listening, which directly improves an individual's ability listening in noise (clEAR: Learn More, n.d.).

Although research supports clEAR, researchers at Washington University School of Medicine conducted most of it (Sommers at al., 2015). This study provides further investigation from a university without biases or benefits factoring into our methodology or results. After reviewing current research on clEAR and specifically listening in noise, we designed our methodology to use a pre-test - post-test design with a self-assessment questionnaire and speech in noise testing. Our methodology differs in that although both studies used two groups, our study used an experimental - control group design. Both studies use a type of pre-test - post-test model; however, investigators took different measures. The study conducted by clEAR, utilized a memory recall task while this study used a recorded spondee repeated word list task. The participants of the clEAR study used the program for three months, whereas our study used clEAR for two months. Additionally, their study focused on perceptual effort, whereas this one focused on performance in noise and perceived benefit (Sommers at al., 2015).

Even though data from the creators of clEAR supports the use of the program for improving listening abilities in noise, we argue that there needs to be independent external validation completed by researchers independent from the clEAR program. This pilot project provides an unbiased investigation of the clEAR auditory training program for adults with hearing loss. Our findings will provide information to help individuals with hearing loss and help hearing professionals make decisions about audiological rehabilitation services. This study presents three research questions (a) does clEAR improve listening in noise as compared to a control group who does not use clEAR? (b) does clEAR improve perceived benefit? and (c) does pure tone average (PTA) affect perceived benefit and listening in noise?

Methods

Participants

This study included ten adults with hearing loss who reported having used hearing aids successfully for at least a year. Participants were recruited at the Miller Speech and Hearing Clinic in Fort Worth, Texas and through email. Nine participants were over the age of 60, and the other participant was 24 years old. Seven participants were female, and three participants were male. Randomization occurred by dividing participants into two randomly assigned groups. The experimental group completed clEAR, and the control group completed a language-based app called Word Cookies. For participation in this study, each participant must have had audiological testing within the past nine months that included unaided pure-tone testing, aided pure-tone testing, and verification of hearing aid benefit. Participants without recent audiological testing within the past nine months received updated testing during the pre-test, which revealed no significant changes for inclusion criteria in this study.

Procedure

Participants participated in the study for two months. All participants attended a pre-test appointment, completed an assigned program for two months, and attended a follow up post-test appointment. At the beginning of the pre-test appointment, a self-assessment questionnaire, Abbreviated Profile of Hearing Aid Benefit (APHAB), was administered. The APHAB is a self-assessment inventory of 24 items concerning one's perceived abilities in different listening conditions. The questions comprise four different subscales that evaluate one's ease of communication in easy listening conditions, speech understanding in moderately reverberant rooms, speech understanding in background noise, and negative reactions (aversiveness) to environmental sounds (Cox & Alexander, 1995). The APHAB questionnaire has two columns: "without my hearing aid" and "with my hearing aid." Investigators modified the APHAB questionnaire in which the first column contained pre-test perceived performance with hearing aids, and the second column contained post-test perceived performance with hearing aids after completing a randomly assigned program. The investigator provided the questionnaire and explained the directions. The participant completed the questionnaire independently in the waiting room.

After completing the questionnaire, the investigator escorted the participant to an audiology booth to complete the audiological protocols selected for this study. Investigators determined the extent of the audiological testing based on protocols that were administered before the pre-test. Participants who had recent audiological testing within nine months of the pre-test only received the speech-in-noise protocol. Participants without recent audiological testing received all of the audiological protocols during the pre-test appointment.

The audiological protocols of this study included the following measures. Unaided pure-tone testing was administered through inserts and aided pure-tone testing was administered through soundfield using a GSI 61 Clinical Audiometer. Hearing thresholds were obtained for 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 3000 Hz, 4000 Hz, and 8000 Hz. The Verifit measured the acoustic output of loud and gain targets of the hearing aid through real-ear measurements to ensure that the hearing aids met targets and remained optimally set to maximize speech perception abilities. Every participant received speech in noise testing at the pre-test appointment. Participants listened to 50 spondee words through soundfield speakers. The first 25 words were presented at 60 dB HL in quiet. The next 25 words were presented at 60 dB HL with 45 dB HL speech noise (+15 SNR) presented simultaneously. The participant repeated the word immediately after the presentation. The investigator calculated the number of correct and incorrect productions and documented percent correct.

After completing the audiological protocol, the investigator trained each participant on the usage of either the computer-based auditory training program or the language-based program. Training for the clEAR program included setting up accounts, distributing lesson plans, and practicing games. Training for Word Cookies included downloading the app and practicing the game. The investigator answered any questions and distributed contact information for any questions during program completion. After the pre-test, the investigator calculated pure tone average (PTA) for the right, left, and binaural aided thresholds. The thresholds used in calculating PTA include 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz. The investigator also converted all Verifit measurements into a scale of 0-3 based on how acoustic output met gain targets and maximized speech perception abilities. The scaling was as follows, a score of 0 indicated that acoustic output did not meet targets, a score of 1 indicated that acoustic output poorly met targets, a score of 2 indicated that acoustic output essentially met targets, and a score of 3 indicated that acoustic outputs optimally met targets.

For the next two months following the pre-test, participants completed their assigned program. The clEAR program offered lesson plans related to listening in background noise. The lesson plans included specific games and a selection of talker stimuli . Word Cookies progressed by level, and control group participants played the game with the background music on. Participants completed the program for at least twenty minutes twice a week.

During the post-test appointment, participants completed the second column of the APHAB questionnaire, titled post-test. The investigator repeated the same pre-test questionnaire procedures. After the participant completed the questionnaire, the investigator escorted the participant to an audiology booth to answer questions and complete speech in noise testing. The investigator asked each participant questions regarding their satisfaction with the program and prescription frequency of 20 minutes a week. To gain more information regarding perceived benefit, investigators asked participants if they noticed a change in their ability listening in noise. The investigator took note of the answers. Participants received the same speech in noise testing from the pre-test appointment, and percent correct was calculated and documented. After the post-test appointment, the investigator scored the APHAB questionnaire. Using the APHAB items and subscales instructions for scoring, the investigator divided questions based on reverberation (RV) scale, background noise (BN) scale, aversiveness (AV) scale, and ease of communication (EC) scale. Investigators calculated the average pre-test and average post-scores for each subscale.

Data Analysis

To determine if a significant difference between the performance of our experimental and control groups existed, the investigator conducted *t*-tests. Analysis of descriptive data differences between groups was performed using *t*-tests on pre-test results in quiet, pre-test results in noise, Verifit scores, PTA for right thresholds, PTA for left thresholds, and PTA for binaural aided thresholds. To answer the research questions presented, a univariate analysis of variance determined if clEAR improved listening in noise as compared to the control group that used Word Cookies. Group served as the independent variable, and post-test listening in noise served as the dependent variable. Pre-test performance served as the covariate.

To determine if clEAR improved perceived benefit in listening in noise, investigators used additional univariate analysis of variances on each APHAB subscale. Group served as the independent variable, and perceived benefit associated with each particular subscale served as the dependent variable. Pre-test perceived abilities served as the covariate. Investigators also applied a test of correlation between PTA and speech in quiet and noise scores and each subsection of the APHAB to consider a possible relation between those variables.

Results

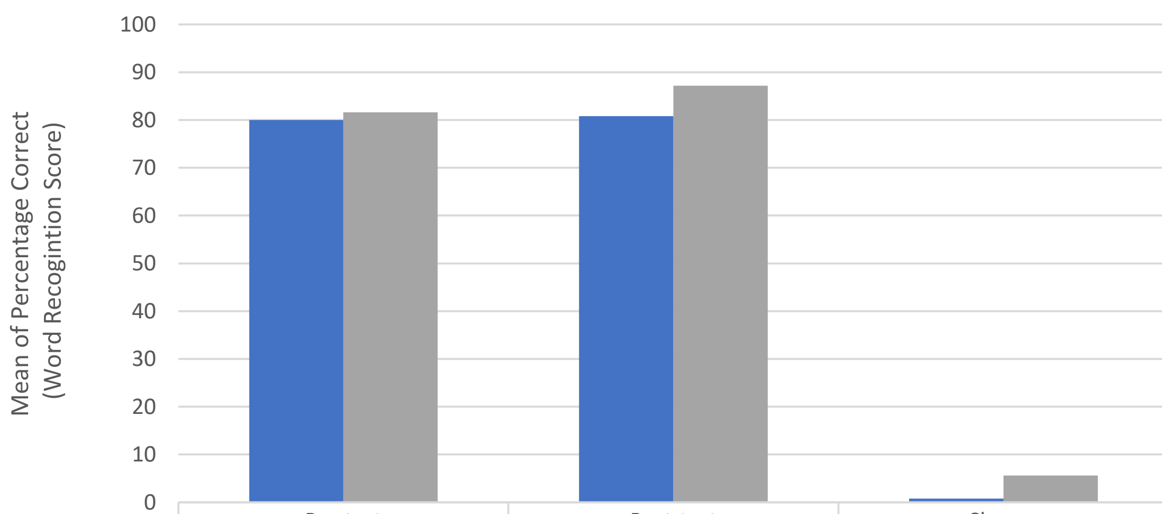
Quantitative data

This study presents three research questions (a) does clEAR improve listening in noise as compared to a control group who does not use clEAR? (b) does clEAR improve perceived benefit? and (c) does pure tone average (PTA) affect perceived benefit and listening in noise?

To consider how the experimental and control groups possibly differed, *t*-tests were conducted with the descriptive data. Specifically, investigators wanted to determine whether pre-test group differences were likely to influence the post-test results. A *t*-test indicated groups were not significantly different on pre-test quiet (*t* (8) = .286, p = .784), on pre-test noise (*t* (8) = -.222, p = .830), on Verifit (*t* (8) = -1.633, p = .178), on PTA right (*t* (8) = 1.168, p = .276), on PTA left (*t* (8) = 1.138, p = .288), or on aided PTA (*t* (8) = .350, p = .735).

To establish if clEAR improved listening in noise, a univariate analysis of variance was conducted. An analysis of variance was calculated with group as the independent variable and post-test listening in noise as the dependent variable with pre-test performance as the covariate. The groups did not significantly differ (*F* (1,7) = 1.084, p = .3332). An effect size calculation indicated that *d*= .49, a medium effect size, albeit non-significant, between groups.

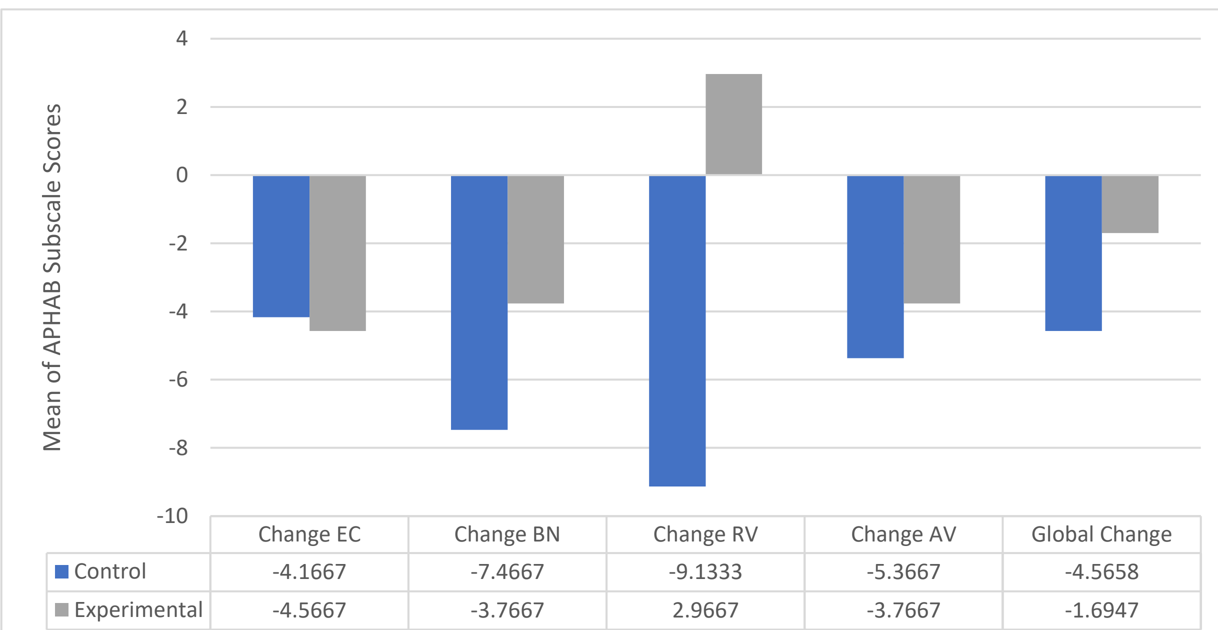
Table 1: Change in Pre-test and Post-test Noise



	Pre-test	Post-test	Change
Control	80	80.8	0.8
Experimental	81.6	87.2	5.6

To establish if clEAR improved perceived benefit in listening in noise, another univariate analysis of variance was conducted with group as the independent variable and perceived EC benefit as the dependent variable with pre-test perceived abilities as the covariate. The groups did not significantly differ (F (1,7) = .145, p = .715). An analysis of variance was calculated with group as the independent variable and perceived BN benefit as the dependent variable with pre-test perceived abilities as the covariate. The groups did not significantly differ (F (1,7) = .01, p = .921). An analysis of variance was calculated with group as the independent variable and perceived RV benefit as the dependent variable with pre-test perceived abilities as the covariate. The groups did significantly differ (F (1,7) = 10.217, p = .015). An analysis of variance was calculated with group as the independent variable and perceived AV benefit as the dependent variable with pre-test perceived abilities as the covariate. The groups did not significantly differ (F (1,7) = .027, p = .874).

Table 2: Change on APHAB



To determine if PTA predicted one's perceived benefit and ability listening in noise were correlated, a Pearson correlation was calculated between aided PTA, change in quiet, change in noise, and change in APHAB subscales. None of those correlations reached significance. The correlations ranged from -.304 to .853 and non were statistically significant at the $p < .05$ value.

Post-intervention qualitative observations

The experimental group offered varied responses about clEAR. Many participants complained about complications with the game, including the pictures not matching the word and difficultly understanding instructions, which frustrated participants. Several participants also noted motivation and technology issues. Overall, despite the complications throughout the program, participants liked the prescription, and some played more than required. The control group enjoyed Word Cookies and often found themselves playing more than the prescribed time. Most participants in both groups reported that they found little to no change in their ability to listen in noise.

Discussion

The purpose of this study was to determine if using clEAR improves one's ability to listen in noise by contributing independent external validation completed by investigators not associated with or benefiting financially from the clEAR program. The study hypothesized that a difference in the perceived benefit of listening in noise after participants used the clEAR program would be discovered. The data concluded no significant change in the perceived benefit of listening in noise or improved performance in speech-in-noise testing.

In contradiction with prior literature, the study found that the experimental group who used clEAR did not demonstrate improved speech recognition in noise. Previous literature suggested that meaning-based auditory training (clEAR) improves speech recognition in noise, as well as, reduces the perceptual effort required for spoken language understanding (Sommers at al., 2015).

Analysis of descriptive data determined that the distribution of the experimental and control groups did not differ and can be considered one group. All measurements between groups were equivalent, which suggests that scores on other data points were not affected by pre-existing group differences. Analysis of variance of improvement listening in noise determined no real significance of its value; therefore, no significant difference in group performance in listening in noise from the pre-test to the post-test. Effect sizes indicate that this particular study may be underpowered, but it is also possible that a larger sample would produce no group differences. These findings with this particular group suggest that participants who completed clEAR did not significantly improve their abilities listening in noise in comparison to the control group.

Perceived benefit was analyzed for all subscales on the APHAB and there was only a significant difference in the experimental group's perceived benefit in reverberant conditions compared to the control group. There was not a difference in the two groups' perceived benefits in background noise, aversiveness to sound, or ease of communication. These findings suggest that after completing clEAR, participants saw improvements in their perceived benefit in reverberation only. Results indicated no significant correlation between PTA and with the change in performance listening in noise or perceived benefit on the APHAB. These findings are not surprising because all participants' PTA were similar among both groups and in the range of normal. Qualitative data goes to suggest further that participants using clEAR do not see a difference listening in noise after using clEAR for two months.

Our findings suggest that clEAR improves one's perceived ability to understand speech in moderately reverberant rooms. The results are important because they provide evidence to show that clEAR needs external validation as the program may not improve listening in noise. However, the limitations of this study influence the degree of certainty that our evidence enables. Due to recruitment difficulties, our sample size was only ten individuals. A bigger sample size would allow results to be generalized to the public. A larger sample size may also validate a group difference: the effect size difference in groups was moderate, indicating that the present study may have been under-powered. In our sample, 90% of participants were over the age of 60. The age of our participants created a technology obstacle, which made both programs difficult for users. The participants completed the programs completed at home. By controlling the conditions in which participants completed the program, the findings would be more conclusive. Using the program for only two months may not be enough time to observe a change in performance compared to the previous study with longer duration of usage. The limitations of this study can influence future research directions. Future studies may consider examining the effects of clEAR in younger adults. Another direction could be designing the methodology in which participants complete the program inside the clinic with controlled conditions. Throughout this study, investigators kept constant contact with the participants. A future study could look at the motivation of the clients to determine if weekly check-ins influenced participation.

Conclusion

Although the creators of clEAR have data supporting that the program improves listening abilities in noise, we argued that investigators not associated with the clEAR program needed to complete independent external validation. By providing an unbiased investigation of clEAR, our pilot program found no significant difference between the experimental and control groups' performance in listening in noise or perceived ability listening in noise. After completing the clEAR program, participants noticed improvements in perceived benefit in reverberation. This study shows the importance of presenting external validation for auditory training programs. Further research is recommended, and users should use auditory training programs with an understanding of its limitations.

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