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The Effects of Working Memory Training on Speech Perception in Multi-Talker Environments

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Abstract

Older adults often experience difficulty distinguishing speech sounds with the presence of background noise. Some of the decreases in performance when listening to speech in noise have been attributed to deteriorations in executive functions with progressing age. Studies revealed that efforts to improve executive functions correlated with improved speech perception in noise; however, these studies implemented training paradigms created specifically for the laboratory setting and were altogether unavailable to the public. Therefore, the current study evaluated whether playing free internet based brain games for twenty minutes over a two week period improved working memory and garnered cross-modal improvements in speech perception in multi-talker environments. Participants included adults over the age of 65 years who earned a passing score on the mini-mental status exam and passed a pure tone hearing screen in at least one ear. Older adult participants completed a baseline assessment consisting of a standardized measure of mood, two speech perception in noise tasks, as well as a standard neuropsychology measure of working memory. Participants were randomly selected into a visual working memory training group or an auditory working memory training group. The study consisted of eight twenty minute training sessions spread across two weeks with a mid-study re-assessment of the baseline measures on the fourth training day. Upon completion of the training regimen, the baseline measures were repeated for a third time. While not statistically significant, descriptive statistics suggested that both training modalities resulted in minor improvements in working memory capacity averages. Generally, the auditory working memory group demonstrated slight improvements in one of the speech perception in noise measure compared to the visual working memory group. In both training groups, there was a large degree of individual variability.

Keywords: Speech perception in noise, working memory, brain games, older adults

1. Introduction

Older adults often have difficulty differentiating speech sounds in the presence of background noise [1,2,3,4].Auditory function and higher level cognitive factors explain most of the variance among individuals on speech-in-noise tasks[5,6,7,8,9]. Providing amplification to older adults supports improvement in auditory function, but does not necessarily address the changes in cognitive functions that result from the natural aging process. In recent literature, decreases in performance in speech in noise tasks among older adults were attributed to declines in the executive functions of working memory, inhibition, and speed of processing with advancing age [10,11,12].

With older adult performance indicating a decline in working memory, a reduced information capacity would be expected. Working memory decline is closely related to the concept of cognitive information capacity limits [13]. Such limitations can be considered within the framework of Cognitive Load Theory (CLT)[14].CLT simply states that there

is a limit to the amount of information that can be stored and processed in working memory.With a limited working memory capacity, a listener must concentrate on the spoken message in the presence of multiple background distracters. The distracters increase the cognitive load and detract from the available processing capacity for the target message therefore decreasing comprehension of the spoken message. Based on CLT, targeting improvements in working memory and cognitive capacity should result in improved speech perception in multi-talker environments.
Indeed, evidence exists supporting the role of brain training to improve cognitive functions and speech perception in background noise [15]. However, these studies have implemented training paradigms created specifically for the study. Often individuals were required to purchase the program if it became available post study or it was altogether unavailable to the public. Therefore, the current study evaluated whether playing free internet based brain games increased working memory capacity and revealed cross modal improvements in speech perception in noise.

2. Methods

2.1 Participants

Participants were recruited through social media and newsletter posts through the university office of continuing education. Five males and four females age 69-90 years (mean 78 years) participants in this study. In order to be included in the study, participants passed the mini-mental status exam[16] (a screen for dementia) and a pure tone hearing screen in at least one ear.

2.2 Standardized Assessment Measures

Based on the participant's preferences, training sessions were conducted in the department of communication sciences and disorders audiology lab or in a quiet room in the participant's home. Sound levels in testing locations met the American National Standard Criteria for maximum permissible ambient noise levels for audiometric test rooms [17]. The hearing screen and speech perception tests were delivered through headphones (DD45 headphones, MAICO Diagnostics, Eden Prairie, MN) attached to a portable audiometer (MAICO 41, MAICO Diagnostics, Eden Prairie, MN).

Participants completed three standardized measures and one laboratory designed task to evaluate the effect of the training. The first measure was a mood scale[18]. This measure was included in the test battery to control for the effect of mood on learning and memory. Evidence suggests that mood may impact performance[19]. Changes in working memory were evaluated by the digit span reversed test [20]. In this task the listener repeated, in reverse order, a series of numbers of increasing length that were presented verbally by the study team. This task involved no distracting stimuli, just an increasing number of targets.

Changes in speech perception were evaluated by the use of two speech perception in noise tasks. Two tasks were selected to represent the two different types of auditory masking that occur: energetic masking and informational masking. Masking refers to the ability of one sound (the masker or unwanted sound) to make another sound (the target or signal) difficult or impossible to hear. Traditionally, energetic masking is thought to have a more peripheral origin stemming from the failure of frequency analysis at the level of the cochlea, when there is overlap in frequency and time between the target sound and the distracter sound [21]. Informational masking is masking that cannot be explained by known processes occurring at the auditory periphery[22, 23]. This type of masking is deemed to have its origin at a more central level in the auditory pathway, and is affected by such factors as uncertainty regarding the acoustic properties of the masker and perceived similarity of target and masker, attention and memory, and cognition[24].

The standardized test selected to evaluate the effect of training on energetic masking and speech perception in noise performance was the QuickSIN. The QuickSIN consisted of lists of target sentences[25]. For each target sentence there were five key words that the listener was asked to repeat. The sentences were played simultaneously with multi-talker babble as a background noise. The signal-to-noise-ratios (SNR) between the target sentence and the background babble ranged from 25 to 0. The SNR decreased for each progressing sentence presentation. The participant was asked to repeat the target sentence. The QuickSIN was used as a measure of energetic masking.

Due to the lack of available standardized tests to evaluate informational masking, a task was created by the study team mentor based off an existing laboratory paradigm called the BUG corpus[26]. The participant was asked to listen to two competing talkers (one target talker and one masker). Each talker said a five word sentence. The words of the target talker and the masker talker did not overlap in time, but were interleaved. The participant was then presented a closed-set, five by eight matrix of words to select the five words from the target sentence. A schematic of the task is presented in Figure 1. In the schematic the participant was listening through headphones for the words spoken by the target speaker (represented by the pink speech bubbles in Figure 1). Once the two competing sentences ended, the participant saw the matrix shown in Figure 1 and was asked to select the correct words from the target sentence. The participant had to select a word from each column in order to hear the next interleaved sentences. The participant completed this task for ten target sentences, identifying a total of fifty words. This was a task of informational masking. Each of the assessment measures were completed prior to the first training session, after the fourth (mid-point) training session, and after the final training session.

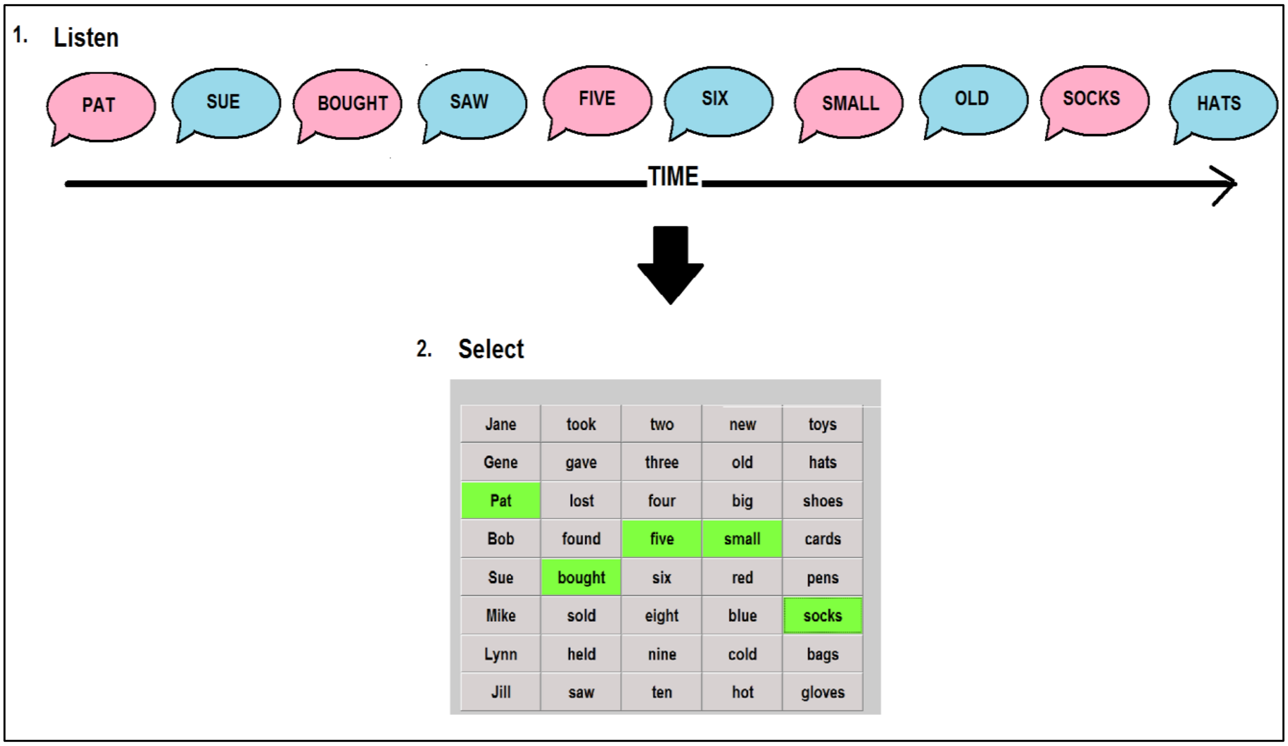

Figure 1. Informational masking task schematic

2.3 Brain Training Sessions

Training included eight twenty-minute training sessions with four sessions occurring each week over a two week period. Participants were randomly assigned to either the visual working memory training or the auditory working memory training. Each twenty-minute session consisted of two free internet based games. The participant played the first game for the first 10 minutes of the session and then switch to the second game for the final 10 minutes of the session. The study team member observed the adult while they completed the games in order to keep track of time and record performance scores.

The participants in the visual working memory training group spent ten minutes of each training session completing a digital crossword puzzle[27]. The participants then spent the remaining ten minutes completing a digital Sudoku puzzle[28].

The participants in the auditory working memory group spent ten minutes of each training session completing a music memory game[29]. The game started with the presentation of a series of musical notes. The listener was then asked to select buttons in an array to match the musical tones presented. The number and complexity of the tones adapted to performance. During the final ten minutes of the training the participants completed an auditory“Nback” game[30].The participant was presented a continuous series of sounds and had to indicate when the current sound matched the one from at least 2 sounds earlier. The task continued to increase in difficulty depending on participant performance. As participants improved they were asked to indicate when the current sound matched a sound from 3-7 sounds earlier.

3. Results

Data revealed a large degree of individual variability in performance. See Figure 2 for individual and training group average performance data across the training sessions. Individual data was represented by the thin lines. Each thin orange line represented an individual in the auditory training group. Each thin blue line represented an individual in the visual training group. Thick lines represented average data. The thick red line represented the average change of the auditory training group. The thick dark blue line represented the average change of the visual training group. Panel A plotted changes in working memory on the digit span reversed. Panel B plotted changes in energetic masking performance on the QuickSIN. Panel C plotted changes in informational masking task on the BUG corpus.

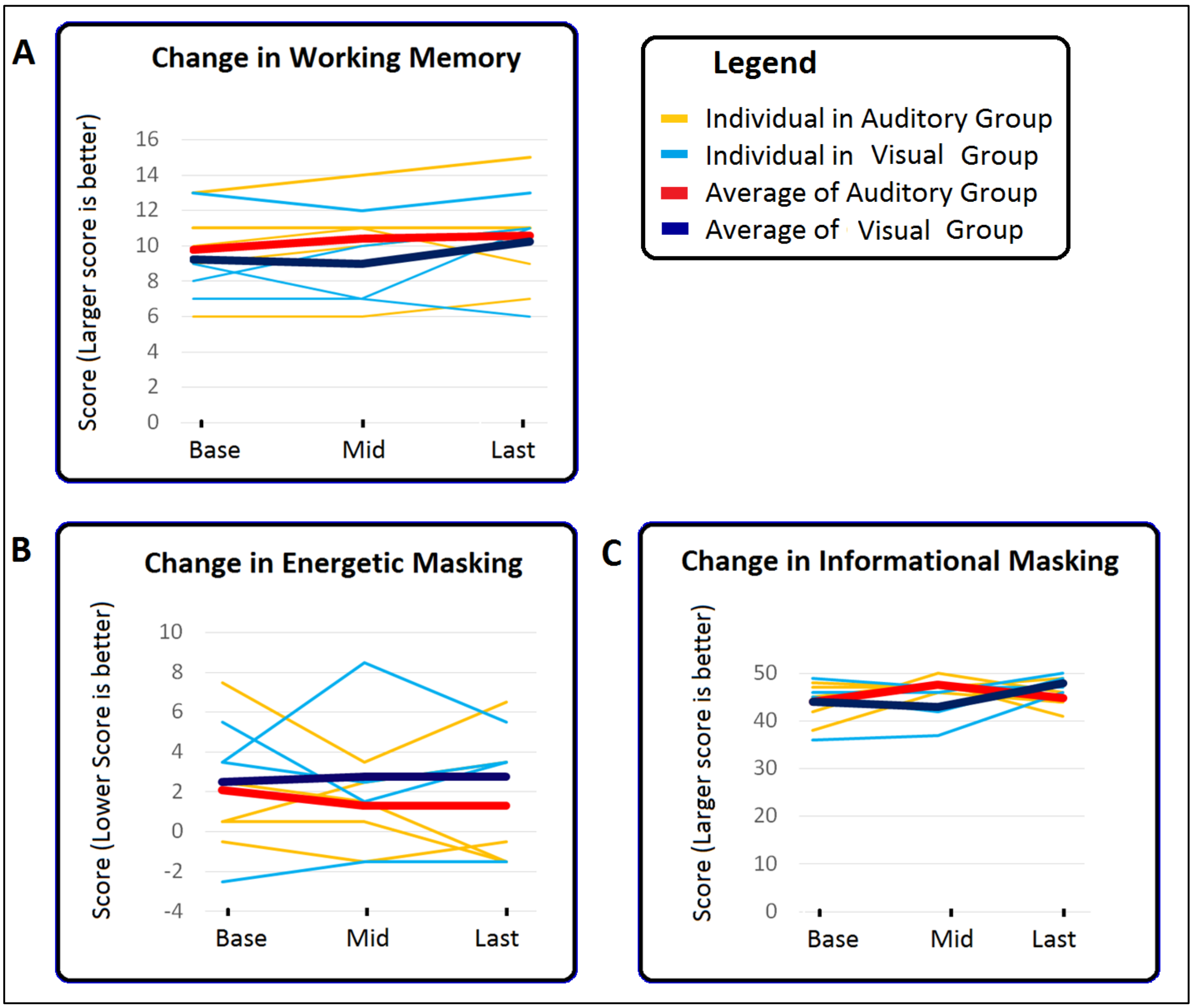

Figure 2. Change in working memory and speech perception measures across training

An analysis of variance was calculated to evaluate the effect of training group (auditory or visual) on the dependent variables. Given the sample size and individual variability, no significant effects were found. The descriptive statistics revealed some possible trends. Average performance for both training groups across all tasks was relatively similar at baseline indicated by the proximity of the thick blue and red lines at the “Base” time point in Figure 2. Review of the average performance changes in each training group in panel A of Figure 2 suggested that on average participants in both training groups incurred very small improvements in working memory span from baseline to the final training session. Review of the average performance changes in each training group in panel B of Figure 2 suggested that the visual training group maintained performance on the energetic masking speech perception task; however, the auditory group demonstrated slightly larger improvements from baseline to training completion (although not statistically significant). Better performance on the energetic masking task was indicated by lower scores, therefore, improvements in performance over the training resulted in an average line with a negative slope. The informational masking speech perception task revealed smaller individual differences and no clear trend in average data across the training groups due to ceiling effects. Max performance on the task was 50, and most participants performed close to the max during the baseline assessment leaving little room for improvement over the course of the training. The results from the standardized measure of mood were not plotted as there were negligible changes in participant mood in either training condition across the three time points measured.

4. Discussion

Due to sample size and individual variability, statistical analysis did not reveal statistically significant effects of working memory training on speech perception in multi-talker environments. However, some small trends did appear in the descriptive data. The average performance data suggested that completing twenty minutes of a working memory activity, whether visual or auditory in modality, may result in improvements in working memory. Current data also suggested the possibility of a slight (although not statistically significant) advantage of auditory working memory games in improving speech perception in in multi-talker environments. Because both training groups started off with similar average performance and there were minimal differences in mood scores, the small average changes in performance from baseline to training completion were likely due to the training regimen. It was impossible to control all variables that may have impacted results, but participants were asked to maintain a similar pattern of activity in their daily lives during the two week training and to report any major changes to the study team. Further investigation is needed to determine the optimal pacing and quantity of training and to explore the individual differences. Additionally, qualitative data from participants evaluating functional changes in performance after training might determine if training working memory leads to increased participation and efficiency during every day social communication opportunities among older adults. It may be possible that even though the small changes in quantitative measures are statistically insignificant that participants report significant functional improvement. The current study served as pilot data for future investigation. With improvements in study design, future work may reveal that free brain games have potential to serve as a cost effective method to improve cognitive functions as well as other daily tasks that involve cognitive processing, such as speech perception in multi-talker environments.

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