Impact of over 6 months of digital hearing aid usage on auditory working memory in acquired severe to profound hearing loss

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Abstract

Introduction: Hearing amplification devices provide ample auditory input that can help to decrease the cognitive strain caused by hearing loss. Depending on the kind and severity of hearing loss, using hearing aids has variable effects on auditory working memory. This study looked into the auditory working memory capacity after using hearing aids for more than 6 months. **Method:** Sixty individuals of a mean age of 53.4 ± 6.07 years with severe to profound hearing loss in the age range of 40–60 years participated. Out of them, 30 individuals with a mean age of 53.5 ± 6.7 were using digital hearing aids and another 30 individuals with a mean age of 53.3 ± 5.4 years were not using a hearing aid. Forward and backward digit span task (DST) and Mini-Mental Status Examination (MMSE) were investigated to estimate the auditory working memory capacity. **Results:** Mean MMSE scores of those individuals with severe to profound hearing loss (53.3 ± 5.43) using (HAU) a hearing aid (25.7 ± 2.97) and individuals not using (NHAU) a hearing aid (22.1 ± 5.11) were compared across each other. The result revealed that the mean MMSE score of HAU was significantly higher than the mean score of NHAU. The mean DST (forward, backward, and total) score of HAU (6.40 ± 1.47) was cosiderably higher than the mean score of NHAU (5.33 ± 1.12). **Conclusion:** Results showed that mean MMSE and DST scores were higher in the HAU category, but when compared across the gender, no statistical differences were observed. The change in auditory working memory and other cognitive abilities were attributed to the usage duration of the hearing aids.

Keywords: Auditory working memory, aural rehabilitation, hearing aids, hearing loss, mental health, social skills

Introduction

62.1% of all those with a hearing impairment were over the age of 50. Because nations with a low HAQ index had higher rates of years lived with disability, the Healthcare Access and Quality (HAQ) Index explained 65·8% of the variation in national age-standardized rates of years lived with disability.[1]

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As per World Health Organization, the prevalence of severe to profound hearing loss was 0.3 to 0.7% globally.

Hearing loss often impacts on physiological and sensory functions of the adults. Difficulty understanding speech in group and noisy environments are chief complaints reported by the hearing-impaired adults. There is no clinical and surgical management that restores the normal hearing of patients with sensorineural hearing loss. Only aural rehabilitation options are available, such as amplification devices. The cognitive load brought on by hearing loss and its effects can be lessened with the use of amplification devices that provide sufficient

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auditory input. There is auditory rehabilitation through digital devices (such as digital hearing aid, cochlear implant) in counteracting dementia.[2,3]

Aural rehabilitation can improve and re-establish the auditory perceptual abilities that are necessary for spoken language, and it also helps in the central management of cognitive resources related with speech and hearing processes. Hearing is an important variable to be considered in the assessment of cognitive function, and hearing loss is associated with incident dementia.[4] The hearing loss is high in elderly than hearing loss associated with falls and gait.[4,5] Recent advancement in hearing aid technology and digital signal processing help persons with hearing loss in working memory.[6] Hearing aid settings that facilitated the matching process between the incoming auditory signal and representations stored in long-term memory were more beneficial for speech understanding in users with lower cognitive functioning.[7] After using hearing aids for 18 months, the participant group showed a clinically and statistically significant improvement in their cognitive function, indicating that treating hearing loss with hearing aids may postpone cognitive decline.[8]

The initial objective of this study was to determine whether hearing aid user experience of more than 6 months can enhance cognitive abilities individuals having severe to profound hearing loss. Previous studies state the aural rehabilitation with amplification devices may aid cognitive functioning in older adults with presbycusis. Utilizing cochlear implants or hearing aids effectively can enhance social and emotional functioning, communication, cognitive function, and overall quality of life.[9]

Use of hearing aids could benefit in executive function and social interactions. Reduction in daily hearing impairment could have a beneficial impact on relationship with neighbors and family.[10] Cognitive abilities were assessed using MMSE score, and it was explored whether MMSE score was changed across the two age ranges, which were 40–50 years and 51–60 years. Second, it was explored whether auditory working memory capacity enhances after more than 6 months of hearing aid uses. Forward and backward digit span tasks were used to estimate the auditory working memory across the two age ranges, which were 40–50 years and 51–60 years.

Method and Materials

Participants

Sixty participants in this study age range from 40 to 60 years, with a mean age of 53.4 ± 6.07 years for those with significant hearing loss. Thirty people, with an average age of 53.5 years, were wearing hearing aids, while another 30 people, with an average age of 53.3 years, were not utilizing any form of amplification. An audiologist assessed each and every patient. Routine audiometry and speech audiometry threshold tests were performed. People having sensorineural and mixed hearing loss with severe to profound deafness (71–90 db) and amplification using digital hearing aids with at least 6 months of hearing aid usage were included. Participants were not allowed if they had any comorbid illnesses, such as difficulties with auditory processing, neurodegenerative disorders, psychological problems including stress, or any other major medical concerns. Ethics committee is obtained by JPR/2017/NS/1001 dated 17 Nov 2018.

Test material

Mini-Mental State Examination (MMSE) adapted from Folstein *et al.* (1983) was used in this study.[11] It is an assessment tool for evaluating the cognitive state of the participants. MMSE is a 30-point cognitive assessment tool that looks at different cognitive domains such as orientation (time and place) 10, Registration 3, Attention/concentration 5, and memory recall 3 but deliberately weighted toward tasks involving languages such as language naming 2, language comprehension 1, three stage command 3, language writing 1, language repetition (reading) 1, and visuospatial abilities (drawing) 1. Both the hearing aid user and nonuser groups each received 11 questions in total. The maximum score for each of the questions was varied from 1 to 5. The score of 25–30 suggested "Questionably significant", 20–25 as "mild cognitive impairment", 10–20 as "moderate cognitive impairment," and 0–10 as "severe cognitive impairment." Digit Span Test (DST) is a subtest of the working memory test used in the Multi-Ethnic Study of Atherosclerosis (MESA). This test is conducted in two segments and requires the participant to repeat gradually increasing spans of numbers (e.g., 2–7–4) first forward (8 items; in each item, there are two subtests, e.g. 1a. and 1b.) and then backward (7 items; in each item, there are two subtests, e.g., 1a. and 1b.). Two trials are conducted for each specified span length, and a point is given for each properly remembered span. Each span is scored '1' (Pass) or '0' (Fail). Scores range from 0 to 30. In forward digit span, the test maximum score was 16, and in the backward digit span, the test maximum score was 14. Forward Digit Span test: In this span task, in which the order of items of increasing length have to be reproduced in the order they were presented, they majorly assess the functioning of the working memory. Backward Digit Span test: In this span task, in which order of items have to reproduce in the opposite order, this task majorly assess the central executive memory. Combined Digit Span test: In this test combined the total score of backward and forward digit span task.

Procedure

The hearing aid center at Gurugram and Best Hearing Solutions, two famous hearing aid clinics located in the Delhi NCR region of India, were randomly chosen for the people with severe to profound degree of hearing loss. All participants in this study had their case histories and ears examined at first. Individuals with variable hearing loss and any middle ear pathology were excluded. The frequencies used for conventional audiometry were 250, 500, 1000, 2000, 4000, and 8000 Hz, while the TDH 39 headphone was used for speech audiometry (SRT and SDS) with the Arphi Proton DX3 digital audiometer. Pure tone threshold averages were calculated at 500, 1 kHz, 2 kHz, and

4 kHz frequencies. Demographic data were gathered from each participant. In MMSE set of questions, question numbers 1, 2, 3, 4, 5, and 8 assessed the cognitive domains, 6, 7, 9, and 10 for language learning and question number 11 for visuospatial ability. All participants were capable of verbal and written responses of set of questions. Before administering the set of questions, all participants provided their verbal and written consent. The set of questions was supervised by the certified audiologist.

Results

People with significant to severe hearing loss (53.3 ± 5.43) who were wearing (HAU) hearing aids (25.7 ± 2.97) and those who were not (NHAU) (22.1 ± 5.11) were compared on their mean MMSE scores. The average MMSE score was determined by adding the answers to questions 1 through 11. The two-tailed hypothesis was assumed at the level of significance of ($P < 0.05$). The *t*-test was employed to evaluate whether there was a statistically significant difference between these two groups. The outcome showed that HAU's mean MMSE score was substantially higher than NHAU's mean score [Figure 1].

The working memory under cognitive domain was investigated across hearing aid users and nonusers who had severe to profound deafness. An attempt was made to understand whether uses of hearing aids in severe to profound individuals can re-establish the cognitive abilities, specially the working memory abilities. Forward, backward, and combined digit span tasks were used to measure working memory abilities. One of the earliest and the evaluation of forward and backward digit span is one of the neuropsychological tests of short-term verbal memory that is most frequently employed. In each case, the digit span is measured for forward and backward (reverse order) recall of the digit sequences. Digit sequences are presented beginning with a length of 2 digits, and two trails are presented at each increasing list length. Only discontinue test when the participant failed both trails of the same span length (e.g., 3a and 3b) or when the maximal list length is reached (9 digit forward, 8 digit backward span test). The mean DST score of those wearing hearing aids and having severe to profound hearing loss (6.40 ± 1.47) and people not wearing amplification devices (5.33 ± 1.12) were contrasted across each other. The mean DST score was computed by adding the forward and backward digit span task. The two-tailed hypothesis was assumed at the level of significance of ($P < 0.05$). To determine whether there was a significant difference between these two groups, a separate *t*-test statistical analysis was carried out. The findings showed that the mean DST (forward, backward, and total) score of HAU (6.40 ± 1.47) was markedly higher than the mean score of NHAU (5.33 ± 1.12), [$t(1,59) = 3.6$, $P = .001$)] [Figure 2].

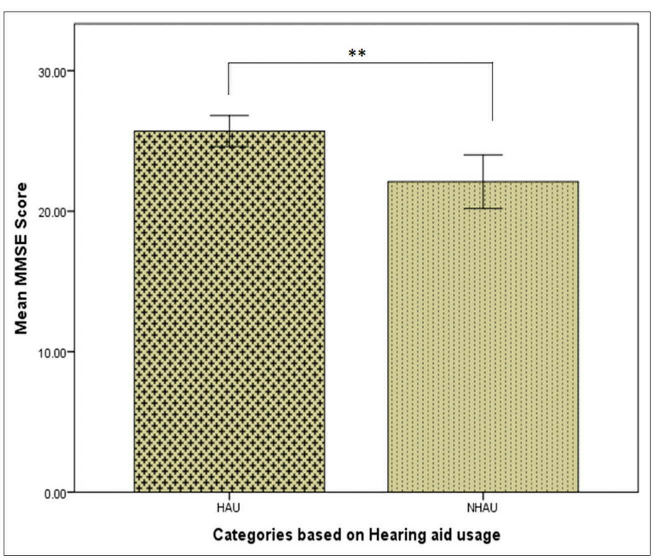

Figure 1: Mean MMSE Scores across HAU and NHAU

After noticing a large difference between the mean DST scores for the HAU and NHAU groups, it was also compared between genders, or, whether there was a difference in the mean DST score between genders. In other words, it was observed whether the mean DST score differed across the males (8.41 ± 2.17) and females (7.62 ± 1.85) in both HAU and NHAU groups. Independent *t*-test was performed at ($P < 0.05$) level of significance to check whether the mean DST score of gender differed significantly in the groups. The result revealed that no any statistically significant difference in mean DST score across gender was observed. In both HAU [$t(1, 58) = 0.22$, $P = 0.23$)] group and NHAU [$t(1, 58) = 0.44$, $P = .26$)] group, no any statistically significant difference in mean DST score across gender was observed [Figure 3].

Discussion

In this study, AWM was investigated in people with severe to profound hearing loss who were equally divided into two groups, one wearing hearing aid (HAU) and the other not wearing hearing aid (NHAU). According to the examination of the data, the two groups (HAU and NHAU) had significantly different mean MMSE scores and mean DST scores. In case of severe to profound hearing loss, the decoding of auditory stimulus is not executed owing to neural disconnect. Restoration of hearing by the amplification devices re-establishes the neural

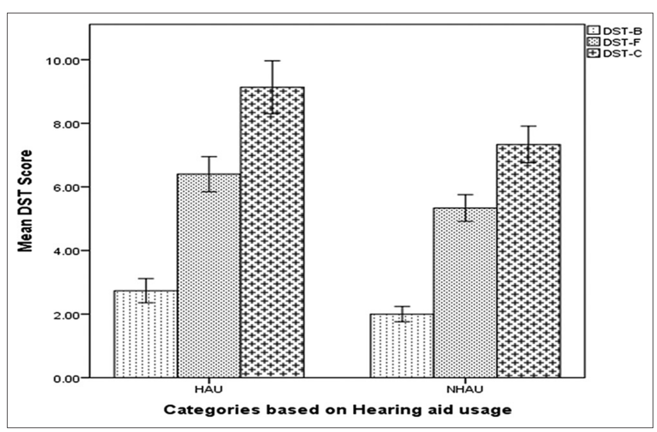

Figure 2: Mean DST (Backward, Forward and combined Score) across HAU and NHAU groups

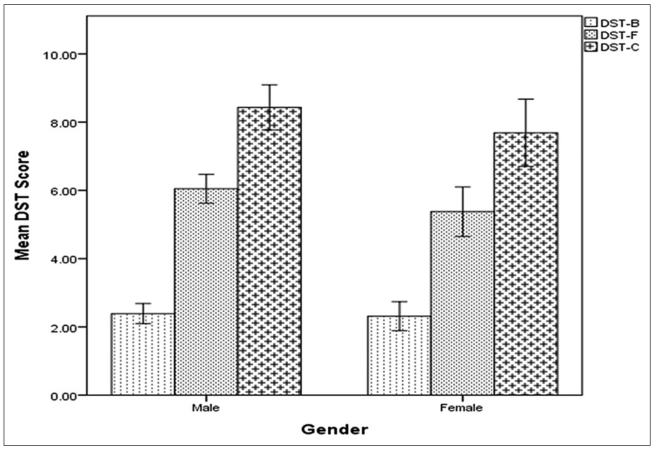

Figure 3: Mean DST S (Backward, Forward and combined Score) across gender

link between the auditory processing pathway and the cognitive processing centers. Advancement in hearing aids technology further reduces the interference of environmental noise to improve the signal quality, which is essential for auditory signal processing.[12]

However, individuals wearing hearing aids had much greater cognitive abilities than nonusers, including reading comprehension, visual and auditory working memory, and long-term declarative memory. But when the mean DST scores across genders in both the groups are compared, no any statistical differences were observed. Amplification of hearing after hearing aid uses enhances cognitive ability as evident in this study as restoration of hearing strengthens cognitive skills uniformly across gender. With improved listening and cognitive skills, social communication improves hugely for both men and women. Similar findings are also reported by Williams *et al.* in (2009)[13] and Asghari *et al.* in (2017).[14] Performance on any span task was unaffected by gender in a substantial way. As evident in this study, the rationale behind significant impact of hearing aid uses on cognitive performance and auditory working memory in the person with hearing loss depends on several factors. Review of literature supports the findings in our study for reducing social isolation and improving depressive symptoms could explain the early effects of treatment for hearing loss in senior persons, particularly for short-term memory, cognitive function, and depression[10,15]; Using electrical stimulation, the function and three-dimensional structure of the peripheral and central synapses may be preserved[16,17]; auditory rehabilitation can counteract negative neuroplasticity processes[18]; Working memory and learning capacities may benefit from auditory/speech training, and gains in self-motivation, self-esteem, or self-confidence after rehabilitation treatments may also have a good impact on cognitive abilities. The central auditory system's capacity to combine binaural information and binaural loudness summation was improved by binaural hearing amplification.[19,20] Participants who received hearing aid rehabilitation within 6 months were included in the study. Less than 6 months of HA use might not be enough to restore working memory and cognitive functions, which are significantly damaged by the effects of severe to profound hearing loss.

When hearing loss affects older people for a longer period of time, it frequently causes them to stop participating in many social activities because of communicative challenges in social settings.[21] Such isolation-related behaviors may have an impact on both quality of life and sociopersonal aspects of life. Reduced auditory and intellectual stimulation may result in central nervous system changes and may have an impact on the progression of dementia and cognitive decline.[5] As a result, a prolonged unaided hearing threshold may gradually lower overall quality of life.[22]

The findings of this study support the necessity for more research into cognition and working memory in people with greater degree of hearing loss who are wearing amplification devices. Hearing loss that ranges from severe to profound can have varying effects on one's mental health and listening challenges. An important public health issue, presbycusis, can develop in reduced lifestyle quality, loneliness, reliance, and dissatisfaction.[23] Similar to this, socioemotional stress brought on by hearing loss might result in varied degrees of difficulties as people get older.[24] Additional complicating factors in the presentation of symptoms related to working memory and cognitive function include familial support, personal stress coping mechanisms, socio-personal-professional participation, listening abilities, and prior experience. Elderly patients with cognitive impairment should not be denied the current possibilities for auditory rehabilitation since the hearing system should be viewed as a crucial window for research into neurodegenerative illnesses.[25,26] Therefore, thoroughly, for those with severe to profound hearing loss, a rehabilitation program is advised, which should include audiological intervention in addition to mental health enhancement.[27,28]

This finding generally corroborates the effortfulness hypothesis, which postulates that the additional effort required for a hearing-impaired listener to comprehend speech depletes cognitive processing resources that might otherwise be used to encode speech content in memory.[20] In other words, bottom-up and top-down cognitive processes that control the processing of auditory information influence speech understanding in daily life.[29,30] A hearing-impaired person can mentally make up for lost information by "filling in" the gaps because speech contains repetitive information. Consequently, top-down cognitive compensatory mechanisms can successfully conceal a peripheral hearing loss and aid the hearing-impaired listener in functioning more efficiently in ordinary listening contexts.[24,30]

The impact on cognition and memory in people who have been using hearing aids for longer than 6 months will be the subject of future research. The long-term effects of hearing aid use on mental health and working memory have not been thoroughly studied, as is the case in the literature.

Additional research shall clear the impact of cognition and memory in those people who wore hearing aids for more than

6 months. In this study, the impact of hearing aid use was investigated on individuals who have a minimum of 6 months of hearing aid use. The findings of this study advocate further exploration in individuals with more than 3 months or over 1 to 2 years of hearing aid use experience.

Conclusions

This study's primary goal was to determine whether the mean MMSE and DST scores were different for person with HAU when compared with NHAU. As a result, mean MMSE and DST scores were elevated in the HAU category, but when compared across the genders, no statistical differences were observed. It was clear that the duration and use of the hearing aids influence the pattern of cognitive and working memory recovery. These results can support the development of client-specific counseling for enhancement of cognitive and working memory tasks. Findings proposed when a user habituated to listening with a hearing aid helps to ease cognitive processing to understand speech.

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Author contributions

Conceptualization: all authors. Data curation; all authors. Formal analysis: Arun Kumar Yadav, Vijay Kumar. Funding acquisition: Arun Kumar Yadav, Amra Ahsan. Investigation; all Authors. Methodology: all authors. Project Administration: all authors. Resources: all authors. Software: Arun Kumar Yadav, Vijay Kumar. Supervision: Amra Ahsan, Vijay Kumar, Arun Banik. Validation: all authors. Visualization: all authors. Writing-original draft: Arun Kumar Yadav, Vijay Kumar. Writing-review and editing: Amra Ahsan, Vijay Kumar, Arun Banik. Approval of final manuscript: all authors.

Abbreviations

Mini-Mental State Examination (HHIA-S); Digit Span Test (DST); Hearing aid user (HAU); Non-hearing aid user (NHAU); Quality of Life (QOL).

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Nil.

Conflicts of interest

There are no conflicts of interest.

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