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Research Article

Comparing the Performance of a Novel-BCI-Based Headset with a Conventional Hearing Aid While Watching TV

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ABSTRACT

Nowadays, TV viewership and watching time are increasing rapidly. Many organizations now allow employees to watch the news in the recreation hall during official hours to stay updated. This investigation focuses on the comparison of nano-porous membrane sensitivity-loss compensation (support for hearing) with a novel brain-computer interface (BCI)-based hearing headset, while watching television. The hearing headset has a thought-based navigation of the hearing volume of the opponent's voice. The hearing aid is already chosen based on the audiometry test. The novel BCI-based hearing headset provides a supplement of voice to one ear at a time similar to a hearing aid. Twenty impaired people were tested using both a hearing aid and BCI-based hearing headset and their responses were noted. Questions were asked individually in between watching TV. The responses were recorded in terms of percentage. The number of patients per group was predicted at a 'G' power of 80%. The results revealed that users with a novel BCI-based hearing headset outperformed those with a regular hearing aid. A statistical significance of < 0.001 was obtained while comparing the two categories. The proposed novel BCI-based hearing headset improved the membrane sensitivity-loss compensation performance of listening by 18.25% more than with the use of a regular hearing aid.

Keywords: Television watching; Nano-porous membrane sensitivity; Brain Computer Interface; Hearing aid.

1. INTRODUCTION

Many age-related hearing impairment patients face trouble while watching TV due to a lack of instant volume control. Consumption of various forms of media such as broadcast television, digital videos and DVDs has become an integral part of many people's lives. Nielsen, a consumer research organisation reported in 2017 that individuals aged 18 and above in the United States devoted an average of 5 hours and 22 minutes per day to media consumption. Moreover, the frequency of usage rises as individuals grow older. For example, individuals aged 50 and above spend an average of 7 hours per day watching T.V. This data was collected using ecological momentary evaluations (Nielsen, 2017). Three conventional auditory systems can be utilised for receiving media, such as television, stereo, or radio. Auditory systems encompass mechanisms for improved reception during telephone communication (David *et al.* 2010). Many researchers analyzed the listening activities of 19 individuals (aged 65 years or older) who wear hearing aids. Most common activities these individuals were engaged in were 33% discussions and 31% listening to media of total time. Two recent studies, one involving 28 individuals aged 64 years and above who use hearing aids (Gordon-Salant and Callahan, 2009), and another involving 29 individuals aged 55 years and above with mild nano-porous membrane sensitivity who do not use hearing aids (Hartley *et al.* 2010) reported media listening patients between 35% and 21%, respectively. It is worth noting that the 21% figure only includes listening to speech and does not include non-speech sounds like music. Like dialogues, media comprehension may be difficult. The British broadcasting consumer organization (Sancho-Aldridge and Davis, 1993) stated that the primary grievance they heard was the challenge of comprehending speech in television broadcasts. Jerger *et al.* (1996); Sendelbaugh, (1978); Okorokova *et al.* (2024) reported that British Broadcasting Corporation studied this issue for a considerable period of time and released a comprehensive set of guidelines for program creators in 2011 (Kadhim et al. 2023). Tao *et al.* (2021) worked with the aim of enhancing the clarity of speech on television by promoting effective practices at the first stages of production.

Despite the widespread occurrence of media listening, there is a noticeable lack of research on the unassisted and/or assisted media listening habits of those with hearing impairments. Consumer satisfaction ratings demonstrate a consistent pattern of growing contentment with hearing aids (HA) while watching television (Huo *et al.* 2024; Acuña *et al.*, 2024; Maiseli *et al.* 2023). The proportion of HA users who expressed happiness rose from less than 70% prior to the year 2000 to 80% in 2008.

Conversely, Munavalli *et al.* (2023) conducted a study to assess the impact of HA and/or closed captioning (CC) on the ability to recognize words in 15 individuals with mild to substantial hearing impairments, all of whom were aged 59 years or older. The researchers utilized standardized collections of audio-visual phrases extracted from three television programs (news, game shows, and dramas). These sentences were displayed on a flat-screen television at a sound level of 60 decibels A-weighted. While the usage of CC resulted in greater recognition scores compared to not using it, the use of HA did not lead to substantial improvements in performance. Nevertheless, the scores for recognition were consistently higher in the condition with hearing aids compared to the condition without aids. Therefore, the lack of a significant effect of the HA may be attributed to limited statistical power rather than the absence of benefits provided by the aids themselves. Out of the 15 individuals involved in the survey, 13 indicated that they never utilized closed captions while watching television (Falk *et al.* 2023).

Therefore, Gordon-Salant and Callahan (2009) proposed that increasing awareness of closed captions among those with hearing impairment who watch television might be an effective strategy to improve comprehension of speech on TV. The limited usage of closed captions in the study's sample may not accurately reflect the larger public. A recent study conducted in Germany among persons with disabilities revealed that 45% of the 65 participants with hearing impairments utilized CC at least sometimes. Among these participants, 79% were users of hearing aids. Woodman, (2010) investigated the advantages of delivering television dialogues to those with hearing impairments with a specialized central loudspeaker, as opposed to a stereo presentation by two loudspeakers with reduced sound quality. The individuals who reported wearing hearing aids while watching TV completed the tests with the assistance of their aids, whereas the remaining participants completed the exams without any aids. Shirley (year) discovered that using a specialized central loudspeaker greatly enhanced the intelligibility of voice when compared to a stereo setup.

The observed gain was ascribed to the decrease in cross-talks specifically in relation to the dedicated central speaker. Another possible reason for the advantage might be a heightened spatial release from masking in the dedicated-center condition (Romine and Reynolds, 2004; Calhoun *et al.* 2017). In addition to a specialized loudspeaker, several researchers have investigated the advantages of offering "clean audio" to viewers with hearing impairments. This refers to specific audio services that enhance the clarity of dialogue, resulting in improved intelligibility (Belkacem *et al.* 2018; Belkacem *et al.* 2015). Despite the positive results, it is yet uncertain when and if these audio services will be accessible to viewers. Lal *et al.* (2004) presented the results of an online survey conducted with 83 hearing-impaired individuals aged 60 years and above, who wear hearing aids. The study revealed that the majority of the participants (88%) preferred to watch television in the living room. Furthermore, it was observed that a significant proportion of them (93%) owned flat-screen televisions with loudspeakers either integrated into or positioned near the TV, rather than in a separate room. About 51% of the participants reported watching TV with a person who has normal hearing, 39% watched TV alone, 8% watched TV with a person who has hearing impairment, and 2% watched TV with a group of people. The participants had the most challenges with movies and discussion programs, whereas they encountered the least challenges with newscasts and documentaries. This finding aligns with the results of a previous poll (Belkacem *et al.* 2015). Moreover, the challenges escalated as the level of self-reported unassisted hearing impairment rose. With regards to adaption tactics, 78% of the participants indicated that they adjusted the level of the TV, while 49% altered the volume of their hearing aids. About 48% of respondents reported modifying the acoustic settings of their TV, either for themselves or for someone else, to suit their individual preferences, such as adjusting the balance between low and high frequencies (Lal *et al.* 2004). Additionally, 30% of participants stated that they utilized a dedicated TV-listening program in their hearing aids. Undoubtedly, the investigation of television use among those with hearing impairments seems to be a subject that has received little attention. This might be attributed to the belief that TV listening is simply another speech-in-noise issue that does not require additional investigation, given the extensive research already conducted on speech-in-noise communication (Ilić et al. 2018). Nevertheless, TV hearing exhibits significant differences compared to conversational speech in noisy situations. Previous research has typically identified background music, noise, and sound effects as the primary factors that hinder the clarity of speech on television (Jerger *et al.* 1997; Sendelbaugh, 1978; Ahmadian *et al.* 2013). However, recent studies have revealed that there are several other factors that contribute to audience dissatisfaction with the intelligibility of TV speech. Additional adverse aspects include the presence of foreign accents and dialects, individuals who mumble while speaking and have poor diction, quick speech, and communication in environments with reverberation (Sancho-Aldridge, 1993; Okorokova *et al.* 2024; Belkacem *et al.* 2015; Schalk *et al.* 2004). Television exposes viewers to a wide range of different and rapidly changing voices, dialects, speaking speeds, and sound environments. Importantly, this variability may exceed what most viewers encounter in their daily auditory circumstances. In addition, age-related hearing impairment might worsen the capacity to adapt to different speakers, speech speeds (McFarland *et al.* 2011), and unfamiliar accents (Schalk and Allison, 2018). Therefore, it is probable that the increased and faster variety of sounds on television present more difficulties for individuals with hearing impairments compared to those with normal hearing. Furthermore, most contemporary flat-screen televisions are equipped with compact integrated speakers that are positioned either downwards or towards the back, specifically aimed at the surface below or the wall behind the TV. Therefore, when compared to a scenario where a loudspeaker or talker is directly facing the listener (as is typically done in laboratory studies), the presence of reverberation is increased. This often leads to a decrease in the ratio of direct sound to reverberation, causing listeners to be positioned beyond the critical distance in the reverberant sound field. This likely aggravates the difficulties experienced by individuals with hearing impairment when trying to comprehend speech on television. Furthermore, it is worth noting that the majority of televisions have dynamic range compression on as a default setting. Consequently, the audio output of the television undergoes compression at least two times for those using hearing aids: first by the television itself and subsequently by their hearing aids. This may lead to excessive compression and consequently reduced clarity of speech (Guger *et al.* 2024; Lekova *et al.* 2024). Ultimately, watching television is a multisensory experience.

A significant number of persons with hearing impairments depend on the skill of lip reading (Caria *et al.* 2011). Conversing in real-world situations may be simpler compared to conversation on television, when the speaker may not be seen or may not directly face the camera (Woodman, 2010). Television offers closed captioning in comparison to real-life listening. In general, existing evidence indicates that TV listening is not just a challenge of comprehending speech in noisy environments. There are some unique aspects of television listening that have not been well investigated and require more research, particularly in relation to viewers with hearing impairments. Munavalli *et al.* (2023) have previously studied the impact of hearing aid usage on television listening. Nevertheless, their research solely concentrated on the comprehensibility of speech on television and utilized a rather limited sample size of 15 individuals with hearing impairments. This study aims to simplify voice control on hearing with instant control and maintain their secret of navigation while the conversation is in progress.

Invasive BCIs are can directly implanted into the brain, offering high precision but involving surgical risks (Caria *et al.* 2011). The non-invasive BCIs can utilize external devices like EEG caps or headsets. These are safer and more commonly used for consumer applications (Guger *et al.* 2024). The most common non-invasive method, capturing electrical activity from the scalp. It's portable and relatively affordable (Alkaff *et al.* 2024). Measures brain activity by detecting changes in blood flow. It's less common but offers better spatial resolution than EEG. Measures magnetic fields produced by neural activity (Mansouri, 2023). It's less portable and more expensive but provides high spatial and temporal resolution (Araújo *et al.* 2024). The BCI system should have robust signal processing algorithms to filter noise and extract relevant features. Machine learning models should be trained to accurately interpret the user's brain signals related to volume control commands (e.g., increase, decrease, mute) (Kumar *et al.* 2024). The device should be comfortable to wear for extended periods. It should have a user-friendly interface and easy setup process. The BCI system should provide high accuracy in interpreting the user's commands. It should have a low latency to ensure real-time control of the audio system. One must ensure the BCI is compatible with your existing audio system or can be easily integrated. Evaluate the cost of the BCI system and balance it with the features and performance it offers (Liu *et al.* 2024). In this investigation novelly tried a BCI-assisted headset was developed to test the instant voice control on hearing. The performance of instant voice control with a default set of hearing levels in the conventional hearing aid was examined. This study compares the hearing performance of age-related Nano-porous Membrane Sensitivity patients wearing hearing aids with the performance of a thought-assisted voice-controlled speaker headset while listening to the TV.

2. MATERIALS AND METHODS

This study setting consists of a TV with a media player in a room with neglected environmental noise disturbance. The TV was played with a listenable volume by a normal person. The patient is then requested to tell the story or convey their understanding. The average of both known and unknown video responses were recorded for further analysis. There was no display about the hearing volume measurement. Only the patient's response was considered for evaluation. There were 3 known and 3 unknown videos per patient to justify the hearing performance. Only one patient was tested at a time. There was no interaction permitted among patients. A sample size of 20 per type of hearing assistance was estimated with a G-power of 80%, error level of 5% and 95% confidence interval. Statistics were taken for both groups with conventional hearing aid and for patients with thought-assisted one-side speaker headset. The headset was equipped with a brain-computer interface for regulating hearing volume instantly through thoughts (Sargunapathi et al. 2020).

There was a 'Fixed' group with individuals of different age and different gender using hearing aids. They were prepared by explaining the testing procedure and the benefits of hearing aid while watching TV. The patients were randomly tested with different nano-porous membrane sensitivity levels. As patients used their hearing aid, they were considered to be hearing well with their hearing aid as normal human beings. The patients were allowed to use their hearing aid on the same ear as per their comfort. The other ear was kept free for listening together.

The patients belonging` to 'BCI_Navig' were trained to navigate the volume. The system navigates with the use of the key thought 'Oh my god' for reducing the volume; the key thought 'Okay' to stop navigation. The thought of 'pardon' was for increasing the volume until the patient said 'Okay'. Individuals were given practice as per their learning capacity. They were allowed to navigate the volume to their comfort zone. The headset was fixed to the patient's ear instead of the hearing aid for this investigation. Also, the patient was allowed to uncover another ear for listening.

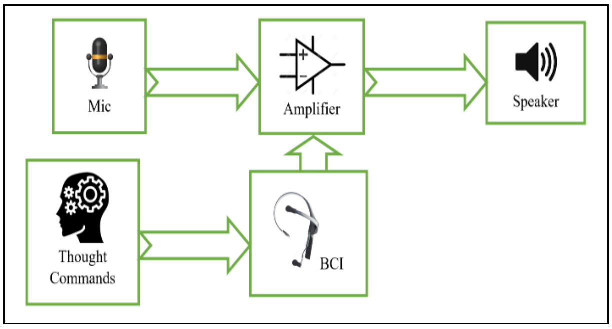

Fig. 1: Set up details of the headset

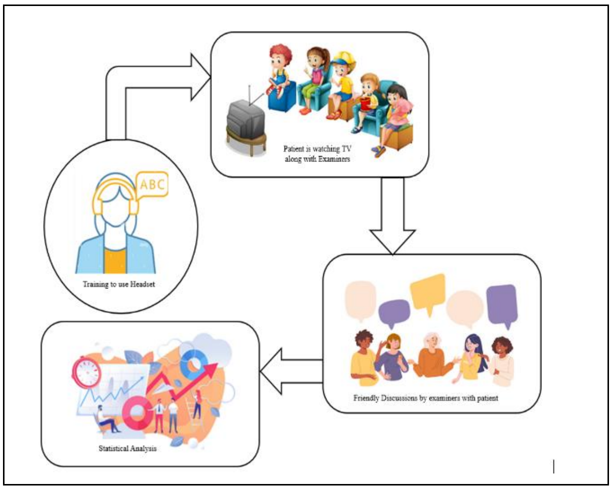

Fig. 2: Experimental setup of the examination process

The experimental setup on the headset is shown in Fig. 1. The Sony-made PHA-1A amplifier, the universal headset microphone of model SP-1167-v1.0- ME-II-3 and the 80 to 125 dB/mW headset speaker were obtained from Mercy Electronics Vadapalani, Chennai, Tamil Nadu. The mic which is fixed on the ear plug on the headset receives the opponent's voice and sends it to the amplifier. The amplifier modulates the volume of noise as desired by the user (the patient) based on the thought commands. Hence, instant navigation happens when the speaker is connected to the earbud which is located behind the mic. The amplifier works in between them.

3. RESULTS AND DISCUSSION

The observations were evaluated by three therapy experts based on the response of the patient. The interaction questions were based on the content watched on the TV (Fig. 2). The evaluation was based on the understanding of the conversation made in the TV drama. The average of all observations was evaluated in percentage. There were two kinds of observations: Fixed and 'BCI_Navig'. The Fixed group was with patients watching TV with their hearing aids. 'BCI_Navig' group comprised of patients with BCI headsets to watch the TV. The samples per case (group) tested were 20 patients. It was observed that the average hearing response while watching TV improved by 18.25% with a BCI headset *i.e.*, the average response from the same set of patients improved from 64.25% to 82.50% with use of BCI headsets (Table 1). The performance is depicted by the G graph which is shown in Fig. 3. The graph was plotted with 95% confidence interval. The error bars shown in the graph were plotted with the standard deviation of ±1%. The Standard Deviation of hearing responses was found much higher (4.88688) for patients watching TV with their own hearing aid than those that watched with BCI headset (3.06937). Similarly, the Standard Error Mean of hearing responses for hearing aid and BCI headset users was 1.09274 and 0. 68633, respectively. Hence, it is obvious that the BCI headset decreased the Standard Deviation and Standard Error Mean of hearing responses considerably.

Table 1. Statistical analysis results

S. No.	Statistical parameters	Observations with Hearing Aid - 'Fixed' Group	Observations with BCI headset-'BCI_Navig' Group
1	Number of samples	20 patients	20 patients
2	Average hearing response (%)	64.2500%	82.5000%
3	Standard deviation of hearing responses	4.88688	3.06937
4	Standard Error Mean of hearing responses	1.09274	0. 68633

The observations were statistically analysed with independent samples test. Table 2 is results of Levene's test for equality of variances is hypothetical output. Any one case can be considered either "Assumed equal variances in hearing responses" or "NOT Assumed equal variances in hearing responses" if the value of significance less than 0.05 the Assumed equal variances in hearing responses case to be considered in Table 3 that is only column 3 values in the Table 3, else only column 4 values in the Table 3 are to be considered. From the statistical results it is observed that both group observations are statistically and significantly different. The proposed method shows considerable improvement. This is because of the significance value of 0.015 (Table 2). As the obtained significance value is less than 0.05, both the observations are considerably different and statistically accepted. The two-tailed significance (0.000) (Table 3) is greater than 0.05, confirming acceptable significant differences among the groups *i.e*., showing significant improvement recorded with proposed solution.

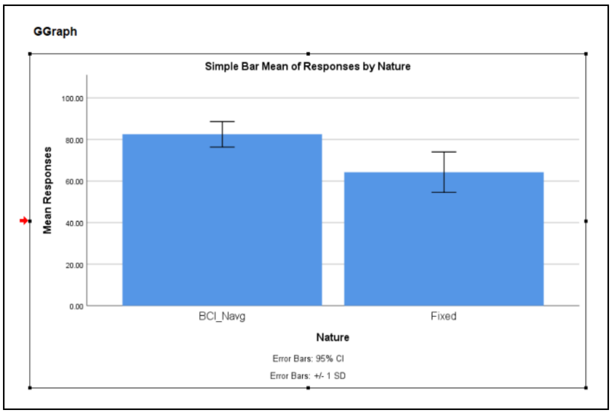

Fig. 3: Depiction of performance by G Graph

Table 2. Results of Levene's test for equality of variances

S. No.	Description of the Statistics	Assumed equal variances in hearing responses	NOT assumed as Equal variances in hearing responses
1	Value of F	6.512	-
2	Value of Significance	0.015	-

Table 3. t-Test results for equality of means for hearing response

S. No.	Description of the Statistics		Assumed equal variances in hearing responses	NOT assumed as Equal variances in hearing responses
1	Value of t		-14.143	-14.143
2	Value of df		38.000	31.972
3	Value of Sig. (2-tailed)		0.000	0.000
4	Value of mean difference		-18.25000	-18.25000
5	Value of Std. error difference		1.29040	1.29040
6	95% confidence interval of the difference	Lower Limit Value	-20.86228	-20.87855
		Upper Limit Value	-15.63772	-15.62145

A study was conducted using randomised, repeated-measures design with 15 older adults (aged 59 to 82) with bilateral sensorineural hearing impairments who wear hearing aids. Just 13% of the participants had utilised closed captioning, whereas the majority (73%) used their hearing devices while enjoying TV on a daily basis (Gordon-Salant and Callahan, 2009). A total of 2956 residents of the Blue Mountains, west of Sydney, among the 3914 eligible individuals between the ages of 49 and 99 (mean age 67.4 years), completed a hearing study carried out between 1997 and 2003. Thirty-three percent of those who responded to the poll experienced nano-porous membrane sensitivity in their better ear. Eleven percent of the respondents had a hearing aid and 4.4% had used an assistive listening device in the previous 12 months. Of those who now possess aids, 24% have never worn them. It has been discovered that using hearing aids and assistive listening devices is linked to ageing, nano-porous membrane sensitivity, and self-perceived hearing impairment (Hartley *et al.* 2010). Two thirds of hard-of-hearing viewers over the age of 51 who were granted accessibility to the teletext subtitle service said that subtitles helped them comprehend television shows (Dülger and Dülger, 2022). The viewers who are hard of hearing reported using subtitles the most out of all those who had teletext. About 13% of hearing-impaired adults over the age of 51 reported using subtitles for every program they watched, while other 26% of those over 55 reported doing so on a frequent basis for certain program (Sancho-Aldridge and Davis, 1993). 180 elderly people with nano-porous membrane sensitivity participated in a prospective study that included neuro psychologic, quality-of-life and audiologic assessments. The participants were divided into four groups and given four treatment conditions: one that involved no amplification at all and one that involved three different forms of amplification (conventional hearing aid, assistive listening device, and combination of the two systems). Every individual agreed to take part in research comparing various amplification devices in exchange for payment. There was a significant preference for the traditional hearing aid in daily usage by the older users who were often unwilling to put up with the challenges that come with using remote microphone devices (Jerger *et al.* 1996). In the Chicago metropolitan region, research was conducted to compare adolescent television viewers with normal hearing versus those with hearing impairments. In the first comparison, the duration of time spent watching television was examined. For all adolescent television watchers, the average weekly time spent watching television was 20.43 hours; for hard-of-hearing viewers, it was 30.98 hours; and for deaf respondents, it was 36.75 hours. The preference of viewers for different programmes by title was the second component of television watching that was studied. The findings showed that the three categories of television viewers—those with normal hearing, those who are hard of hearing, and those who are deaf—each had distinct preferences for the shows they watch. The final area under investigation was limited to the responder with hearing impairment (Sendelbaugh, 1978).

The limitation of this research is that, though the headset wearing supports good hearing, continuous wearing of headset is not acceptable by the user. The social acceptance for different kinds of wear is a time taking process, but this concept may include an instant control of hearing aid which is much useful to the user to enjoy TV shows. Training of aged people near 70 has some difficulties and consumes more time.

4. CONCLUSION

The instant voice control for the nano-porous membrane sensitivity-loss compensation requirements through key thoughts is employed with the help of a BCI headset with a speaker assembly set. The use of such headsets with 20 different users irrespective of gender between the age group 50 to 70 was tested. Different shows were involved in the evaluation including known and unknown shows. Each participant underwent individual testing sessions while watching television, with their responses recorded and analyzed quantitatively. This investigation compared the support provided by traditional hearing aids with a novel BCI-based hearing headset, specifically tailored for television watching. The BCI-based hearing headset incorporated thought-based navigation to adjust the volume of the opponent's voice, offering a personalized and intuitive hearing experience. The novel BCI-based hearing headset surpassed traditional hearing aids in terms of performance, where a statistically significant (p-value < 0.001) improvement in listening performance with the BCI-based hearing headset was found. On average, users experienced an 18.25% enhancement in their ability to perceive and comprehend speech while utilizing the novel headset.

These findings underscore the potential of BCI technology in revolutionizing hearing assistance, offering individuals with hearing impairments a more effective and tailored solution. However, it's important to acknowledge the limitations of this study, including the relatively small sample size and the need for further research to explore additional factors influencing the effectiveness of BCI-based hearing solutions. In future endeavours, efforts should be directed towards addressing these limitations and refining the BCI-based hearing headset to optimize its performance and usability. Collaborative efforts between researchers, engineers, and healthcare professionals will be crucial in advancing this technology and bringing about meaningful improvements in the quality of life for individuals with hearing impairments. Overall, this study provides compelling evidence of the potential benefits of BCI-based hearing solutions, paving the way for future innovations in the field of assistive technology and personalized healthcare.

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CONFLICT OF INTEREST

The authors declared no conflict of interest in this manuscript regarding publication.

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