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RESEARCH ARTICLE

Prevention of Cognitive Impairment Through Audiocognitive Rehabilitation: Results of the NeuRea Method

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ABSTRACT

Background: The aging of the world´s population have led to an increase in the prevalence of neurodegenerative diseases.

Aims: The study aims to analyze the prevention of cognitive impairment through the application of audiocognitive rehabilitation (NeuRea Method) on people with hearing impairment.

Methods: A total of 409 patients met the inclusion criteria. They were divided into an Experimental (EG) and a Control Group (CG). The EG underwent an audiological and speech therapy program. These programs included neuroadaptation adjustment of hearing aids and rehabilitation of impaired auditory and cognitive functions. Patients without cognitive alterations in EG also received cognitive training. The CG did not receive any interventions. Both groups were cognitively assessed at the beginning and at the end of the study.

Results: Results showed that 85.16% of the EG obtained better results in the cognitive test, and no one contained worse results, compared to a 3% improvement in CG, 4% obtained worse results. 81% of the EG patients without cognitive impairment also improved.

Conclusion: The NeuRea method can be used as an additional treatment for wearing hearing aids to improve the language comprehension capacity of people with hearing loss, reduce their cognitive load, and improve their cognition whether already altered or not.

Keywords: Hearing loss, cognitive impairment, audiocognitive rehabilitation, phonemic adaptation, cognitive impairment prediction, dementia prevention.

Introduction

Aging is synonymous with altered levels of functioning. These variations are due to biological factors and occur both in the physical structures (muscles, organs, bones) and in the function of various systems: cardiovascular, respiratory, endocrine, auditory, and visual. Aging is a process that is marked by parallel events, some of a sociocultural nature and others physical or organic. The former are related to changes in daily life that consist of events such as losing a partner, stopping work (retiring), or living in a nursing home. The second kind are made up of changes in various functions, such as sensory (especially at the auditory and visual level), cognitive, and motor, worsening the understanding of oral or written messages, the efficiency in the use of technology, or response times to various stimuli. As part of the normal aging process, there is a deterioration of working memory, which limits the performance of the attentional and control system, especially in the processes of attention and inhibition that involve the selection, planning, and supervision of messages.[1-3] Cognitive decline begins many years before the diagnosis of dementia.[4,5]

The quality of the aging process depends on several variables. One of the most relevant has led to an increased interest in studying the relationship between hearing disorders and cognitive impairment in recent years.[6,7] The pioneering works by Lin and Amieva.[8,9] suggest that older adults who have a hearing loss that is not adequately cared for are more susceptible to developing cognitive impairment of various kinds. Lin's group concluded that people with hearing loss cognitively deteriorate 30-40% faster than people with normal hearing. Some consider that this deterioration may be slowed by an earlier diagnosis and the prescription of an adequate prosthetic adaptation.[8] In contrast, Nar Wong et al.[10] state that the use of hearing aids alone is not enough to slow cognitive decline in people with some types of hearing loss. What everyone agrees is that the loss of autonomy caused by cognitive decline is one of the pathologies that generate the highest cost worldwide (US$818,000 million annually) according to the Institute of Health Metrics and Evaluation (IHME), which is equivalent to more than 1% of the world's gross domestic product. IHME estimates that in 2050, the number of people suffering from dementia will triple from 50 million to 152 million. Finding solutions to this problem, therefore, is essential to having a brain-competent population.

The objective of this study was to determine whether the neuroadaptation of hearing aids in combination with an audiocognitive rehabilitation program can improve the cognitive performance of people with hearing loss who present some degree of cognitive impairment vs. no impairment. The method of neuroadaptation and audiocognitive rehabilitation presented in this article, hereinafter the NeuRea method, was born to respond to the need to stimulate the auditory cortex as much as possible and rehabilitate altered functions both at the auditory level (discrimination, recognition, comprehension, understanding in unfavorable auditory situations, and processing speed) and cognitive (memory, language, verbal fluency, naming, and executive functions). We also want to determine whether the type of hearing loss, measured by objective tests, plays an important role in cognitive impairment. These data could be key in prevention systems to improve quality of life, since dementia is a clinical syndrome characterized by a persistent and progressive deterioration of higher brain functions (memory, language, orientation, calculation, or spatial perception, among others).

Methods

A clinical trial was carried out in which patients with bilateral and symmetric sensorineural hearing loss (SNH) were evaluated in audiological centers between 2019 and 2020. All patients who participated in the study were of legal age, had SNH, wore adapted hearing aids for a maximum of 2 weeks before the audiocognitive study, and had no diagnosis of cognitive impairment or neurological disease. Patients undergoing treatment with drugs capable of altering cognitive status (nonbenzodiazepine sedatives, dopamine agonists, narcotic analgesics, tricyclic antidepressants, anticonvulsants, and benzodiazepines) were excluded from the study. Likewise, patients who did not complete the therapy for reasons beyond the study were not included. All patients underwent a double medical and audiological interview, and those who met the inclusion criteria completed a cognitive interview for a full evaluation. Therefore, before the start of treatment, a medical interview and a hearing screening were carried out to verify that the patients met the inclusion criteria.

AUDITORY SCREENING

All patients underwent a hearing evaluation to determine the degree and type of loss. During the hearing screening, quantitative hearing loss was assessed by different audiometric tests: pure-tone audiometry, speech reception threshold, and speech audiometry. For pure-tone audiometry, pure tone threshold tests were performed with bone and air signals. Disability impairment was calculated for the four pure-tone average (PTA) arithmetic means of 500, 1000, 2000, and 4000 Hz. The data are expressed as hearing level in decibels (dB HL). Pure-tone air and bone conduction thresholds were obtained in a sound isolation chamber with a clinical computerized audiometer. Pure tone thresholds equal to or greater than 30 dB HL of PTA were considered hearing loss (hearing loss). For the speech reception threshold, the lowest intensity level was that at which the patient could correctly identify 50% of the common two-syllable words in Spanish from a phonetically balanced list. Speech audiometry was performed using phonetically balanced lists in Spanish from Tato et al. to determine the maximum individual intelligibility of the word list.

To measure the integrity and functionality of the middle ear, immittance was performed, consisting of tympanometry and the stapedial reflex. The tympanometry scale was read in decapascals (dPa). Static admittance (or compliance) and maximum pressure were measured in cm^3. Peaks less than 0.1 cm^3 (a reduced peak height or a flattened curve) or greater than 1.5 cm^3 were considered abnormal. In this study, pressures less than -125 dPa or greater than 100 dPa and a flat curve were considered abnormal. The tympanogram traces were grouped according to the classification provided by Margolis et al. On the other hand, to measure the stapedial reflex, ipsilateral reflexes were elicited at 500, 1000, and 2000 Hz using 105 dB HL and at 4000 Hz using 100 dB HL. Reflex amplitude, latency, and time (sustained or rapidly decaying) (reflex decay) were quantified. The absence of a reflex and latencies less than 40 or greater than 180 milliseconds were considered abnormal. Additionally, the short-term auditory sequential memory test was assessed using the Illinois Test of Psycholinguistic Abilities.

For the evaluation with hearing aids, two tests of acoustic perception of speech, the Ling test and the Glendonald auditory screening procedure (GASP), were used. This first test is composed of six phonemes, /m/, /a/, /i/, /u/, /sh/, and /s/, which sweep through the speech banana (Figures 1 and 2).

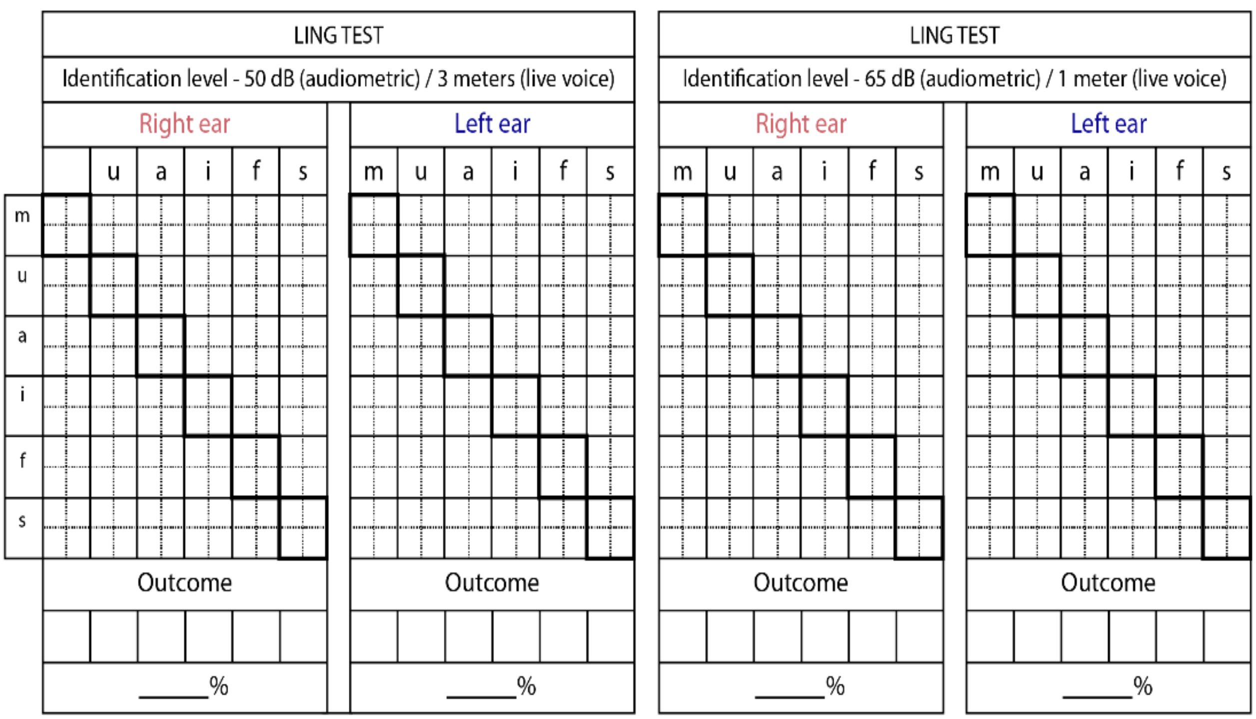

Figure 1. Ling's test. Otorhinolaryngology Service, Department of Surgery, HIBA

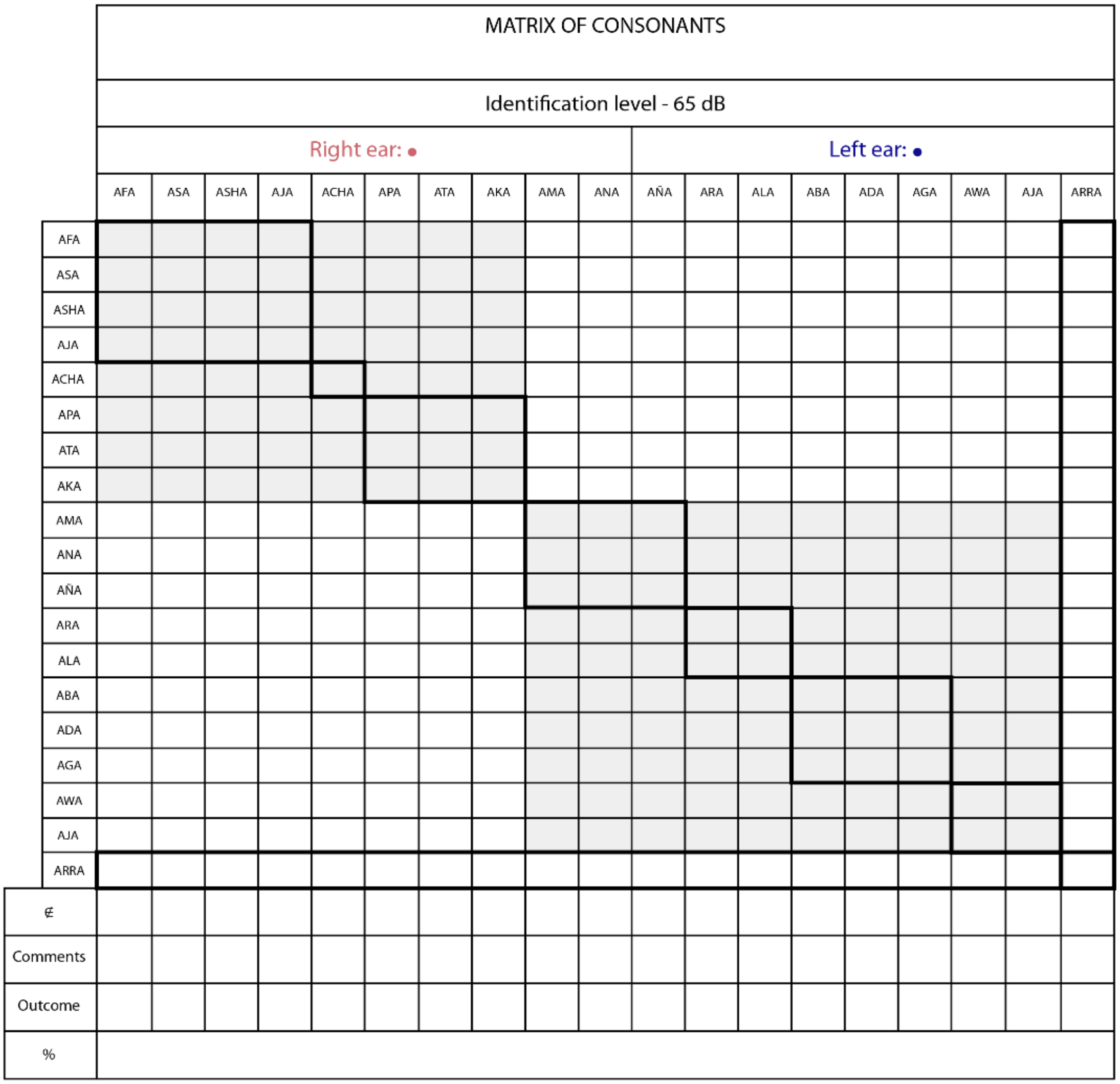

Figure 2. GASP test. Matrix of consonants.

These phonemes were used to create the Ling-6 HL test, a calibrated version of naturally produced speech sounds to measure detection thresholds. The test was recorded on a compact disc at the Western University Children's Amplification Laboratory and was used for the fitting of hearing aids[11] (Figure 1). GASP is an open-format test developed by NP Erber in 1982. It assesses the ability to recognize words and sentences, which are presented aloud. With this test, we registered and analyzed the specific characteristics of each consonant and the modification of the energy when part of it was fused with a vowel. In the event that any of the experimental group (EG) patients made errors in the mode or point of articulation when repeating vowel–consonant–vowel (VCV), the programming of the hearing aids was adjusted so that sound could reach the auditory cortex information more precisely, allowing maximum verbal recognition (Figure 2).

COGNITIVE SCREENING

Cognitive screening was assessed using the Montreal Cognitive Assessment Test (MoCA). This test is a brief instrument that specifically detects mild cognitive impairment and dementia. Its reliability and validity are high. When performing the test, hearing amplification was given at the comfort threshold so that hearing loss was not a factor that could give false-negatives. Scores of this test below 26 indicate that there is some type of cognitive impairment.[5,12,13]

If the inclusion criteria were met, the patients were randomized to one of the two study groups, the EG and the control group CG.

This protocol was approved by the institutional review committee Code CEIm HM Hospitales (22.06.2043-GHM), and all patients signed an informed consent after an explanation of the interventions. They study followed the Declaration of Helsinki.

NeuRea METHOD
In the EG, the hearing aids were readapted through neuroadaptation, and a rehabilitation program was applied for the altered auditory aspects and for the affected cognitive functions, the NeuRea method. The CG did not receive either of the two services, so the traditional hearing aid programming with which the patient came was maintained (adjustment based on the hearing aid manufacturer's programming software proposal).

The neuroadaptation of hearing aids is an adjustment that is based on the modification of the information that reaches the auditory cortex through the programming of the hearing aids through the verification tests described above. This adjustment was performed by professionals highly specialized in acoustics, phonetics, phonology, linguistics, and auditory processing (central). The protocol was designed to evaluate all the isolated phonemes, both vowels and consonants and a combination of them, to determine what information the patient could repeat correctly without the aid of lip reading. Subsequently, the altered values were adjusted based on the formants of voice F1, F2 and F3. Once adjusted, the patient was re-evaluated to confirm that he could recognize them without difficulty.

After evaluating the patient's audiocognitive functioning, a program of speech therapy and neuropsychological rehabilitation of altered auditory and cognitive functions was designed specific for each patient. This was modified weekly according to individual progress. In these sessions, aspects of hearing and auditory processing were worked on, as was the improvement of mental abilities such as attention, memory, language, and executive functions. After 6 months of the program, a second evaluation was carried out on both groups, aimed at assessing the level of performance of all participants.

As main aspects, the audiological characteristics were evaluated, as were other variables such as cognitive impairment, measured as a score <26 on the MoCA test. The level of hearing loss was categorized as mild, moderate, severe, or profound. Improvement at 6 months, measured as the difference between the baseline and 6-month scores. A differential value >0 represented an improvement. Once all these data had been collected, a correlation map was created to visualize and quantify the interrelationships between the different variables.

Statistical analysis
To test the significance of differences between groups, an ANOVA model was used with a cutoff of $p \leq 0.05$.

Results
A total of 506 patients were included in this study, of whom 409 met the inclusion criteria. These were randomized to the EG (n = 310) and the CG (n = 99). All patients had varying degrees of hearing loss, from mild to severe, and were recent hearing aid wearers. Of the 409 patients, 46.8% were female, 53.2% male, and 49% used hearing aids before the study. The MoCA test detected 213 patients with cognitive impairment and 196 with scores greater than 26 (without impairment). The NeuRea method was applied to the EG patients, while the CG patients were not treated. All the people were evaluated again at 6 months using the MoCA test to see if there had been changes in that time.

Figure 3 shows how cognitive impairment was directly related to the level of hearing loss. In yellow, the relevance of cognitive impairment and the application of the NeuRea method on improvement have been highlighted. Regarding the type of hearing loss, among the people evaluated with a mild level of hearing loss, only 20% had cognitive impairment, compared to 54% and 65% of the people with moderate and severe hearing loss, respectively.

Next, a model for the prediction of cognitive impairment was built using a logistic regression model .[14] The same variables as above were used, and 80% accuracy at predicting cognitive decline was achieved. Second, the efficacy of the NeuRea method was validated using the same patient database.

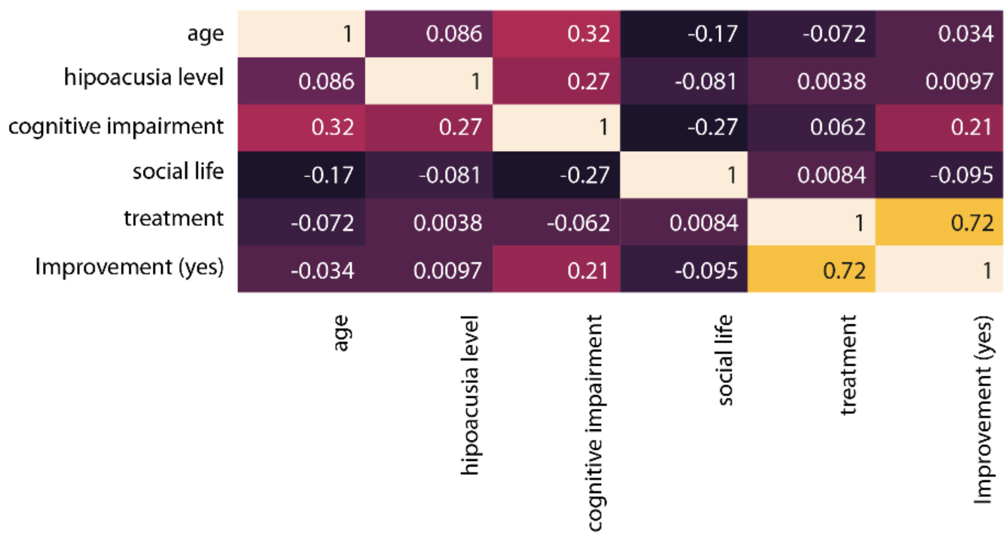

Figure 3: Correlation map

Discussion

Age-related hearing loss is a common problem among older people, causing communication difficulties, isolation, and cognitive impairment .[15] The prevalence of hearing loss increases with age, affecting 40% of people older than 50 years and approximately 71% of those older than 70 years .[15] In fact, the World Health Organization estimates that 466 million people worldwide suffer from disabling hearing loss, which is expected to increase to 900 million by 2050 due to the aging of the population .[16] Luckily, most of the consequences of hearing loss can be mitigated by early detection and intervention .[16]

The association between age-related hearing loss and cognitive impairment has become very important in recent years since hearing loss has been identified as a potentially preventable risk factor for dementia, which is a disorder characterized by slow and progressing cognitive decline[17-19] that drastically affects daily functioning and independence.[20] In fact, the meta-analysis conducted by Loughrey et al.[21] revealed that age-related hearing loss is a possible biomarker and modifiable risk factor for cognitive decline, cognitive impairment, and dementia. Moreover, undiagnosed or untreated hearing loss can lead to misdiagnosis or overestimation of the level of cognitive impairment .[15] Hearing aids are currently the most common therapeutic option for people with aging-related hearing loss, but they only seem to help improve cognitive load in people with recent hearing deprivation, leaving many patients who do not benefit from their use. This gap underscores the necessity for a comprehensive approach that integrates the use of hearing aids with tailored neuroadaptation and audiocognitive rehabilitation programs to address the complex interplay of anatomical, physiological, and cognitive factors affecting this patient demographic.[22]

The NeuRea method, a novel approach in audiocognitive rehabilitation, is specifically designed to enhance cognitive functions in patients with hearing loss, particularly those showing signs of accelerated brain aging. Unlike traditional methods that may rely solely on patient self-reporting which have been reported to present limited accuracy and are not sufficiently sensitive in order to evaluate hearing loss.[23] The method of the study includes a complete audiological evaluation and not just an interview where the patient declares his hearing level. Here, 89.1% of patients with cognitive impairment improved their cognitive performance after applying the NeuRea method. Additionally, even among those initially without cognitive impairments, a notable percentage achieved higher cognitive performance scores after six weeks. This evidence suggests that the NeuRea method serves as an effective intervention for not only ameliorating cognitive decline but also in potentially preempting it, thereby bolstering cognitive reserve capacities. The possible relationship between hearing aids and cochlear implants with cognitive decline and dementia is controversial. During the last years, several systematic reviews and meta-analysis have been published and their conclusions differ. Sanders et al.[24] concluded in their systematic review after the assessment of 17 studies that the effects of hearing aids on cognition or the prevention of cognitive decline are difficult to draw, mainly due to high risk of bias, and in particular, a short time of follow up. On the other hand, Yeo et al.[25] performed a meta-analysis using 31 studies, concluding that the usage of hearing restorative devices by patients with hearing loss is associated with a 19% decrease in the risk of suffering long-term cognitive decline, and the usage of these devices is significantly associated with a 3% improvement of general cognitive condition in the short term. A noteworthy finding from our research is the predictive model's 80% accuracy rate in identifying patients at risk of cognitive deterioration, emphasizing the model's utility in early detection with minimal patient information.

Looking ahead, our team is focused on understanding the weights of the different components of rehabilitation in improving deterioration, as well as determining whether the improvement persists over time and whether the learning achieved in the rehabilitation sessions is generalized to all contexts of the patient's daily life.

Moreover, contemporary studies underscore the importance of holistic approaches that consider both auditory and cognitive health, advocating for personalized treatment plans that cater to the unique needs of everyone. Insights from global rehabilitation practices reveal the promising role of cutting-edge technologies, like virtual reality and specialized mobile applications for auditory and cognitive exercises, in significantly enhancing patients' life quality.[26] These innovations not only support consistent engagement with the rehabilitation process but also enable detailed monitoring of progress, allowing for the fine-tuning of interventions.[27]

As the world's population ages, the imperative to explore and refine intervention strategies that address hearing loss, and its broader cognitive and well-being implications becomes increasingly critical. The synergy between audiologists, neurologists, occupational therapists, and cognitive rehabilitation experts is pivotal in crafting and implementing comprehensive and efficacious audiocognitive rehabilitation programs. Through such collaborative efforts, there is a hopeful outlook for not just the auditory and cognitive improvement of those affected but also for their overall quality of life and societal participation.

Conclusions

The reported data scientifically validate the NeuRea method as an effective option to improve cognitive impairment in people with hearing loss. This means that it should be used along with hearing aids to improve the audiocognitive understanding of people with hearing loss, reduce their cognitive load, and improve their cognition whether it has begun deteriorating or not. Likewise, an aid tool has been developed for the screening of patients with anticipated dementia within hearing centers.

Conflict of Interest

The authors declare no conflict of interest.

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Author Contributions

RAB, project director, created and designed the method. Also contributed with the evaluation, neuroadaptation, and rehabilitation process. JMG and DBZ contributed with the evaluation, neuroadaptation and rehabilitation process. SAB analyzed the data. AHAC contributed with the medical interviews. CAN was the advisor and project coordinator.

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