ISSN: 2083-389X,
eISSN: 2084-3127

J Hear Sci, 2020; 10(4): 27–32
DOI: 10.17430/JHS.2020.10.4.3

Contributions:
A Study design/planning
B Data collection/entry
C Data analysis/statistics
D Data interpretation
E Preparation of manuscript
F Literature analysis/search
G Funds collection

INFLUENCE OF WORKING MEMORY AND SPEECH PERCEPTION ABILITY ON HEARING AID USE AND BENEFIT IN OLDER ADULTS

Vikas Mysore Dwarakanath[B-E], Manjula P.[A,C-E]

Audiology, All India Institute of Speech and Hearing, India

Corresponding author: Vikas Mysore Dwarakanath; Audiology, All India Institute of Speech and Hearing, Manasagangothri, 570006, Mysuru, India; email: vikasmdaud@gmail.com; Phone: +919741968193

Abstract

Background: Hearing aids are equipped with many features to improve the speech perception abilities in quiet as well as in challenging situations. Despite that, older adults who use and benefit from hearing aids remain less satisfied. The present study focuses on aspects such as working memory, speech perception in noise (SNR-50), hearing aid usage, and its impact on perceived hearing aid benefit in older adults.

Material and methods: Digit backward test and speech perception in noise test were administered on 34 older adults having mild to moderately-severe sensorineural hearing loss who were naïve users of hearing aids. The participants were divided into good and poor performers based on SNR-50. Two months later, the same tests were repeated along with administration of International Outcome Inventory - Hearing Aids (IOI-HA).

Results: There was a significant difference in working memory and speech perception in noise with hearing aid outcome measures. It was also seen that individuals with better working memory and lower SNR-50 scores benefited more from a hearing aid. Cognition plays an important role in determining the amount of benefit derived from hearing aids in older adults.

Conclusions: The present study highlights the importance of measuring working memory and speech perception abilities in older adults with hearing loss before fitting a hearing aid. These measures have a significant role in counselling about the realistic expectations of benefits from a hearing aid.

Key words: working memory • older adults • speech perception in noise • hearing aid use • hearing aid benefit

WPŁYW PAMIĘCI ROBOCZEJ I UMIEJĘTNOŚCI PERCEPCJI MOWY NA UŻYWANIE APARATÓW SŁUCHOWYCH I KORZYŚCI U OSÓB STARSZYCH

Streszczenie

Wstęp: Aparaty słuchowe są wyposażone w wiele funkcji poprawiających możliwości percepcji mowy zarówno w ciszy, jak i w trudnych sytuacjach akustycznych. Mimo to osoby starsze korzystające z aparatów słuchowych są z nich mniej zadowolone. Niniejsze badanie koncentruje się na takich aspektach, jak pamięć robocza, percepcja mowy w hałasie (SNR-50), używanie aparatów słuchowych i ich wpływ na korzyści słuchowe u osób starszych.

Materiał i metody: Digit backward test i badanie percepcji mowy w hałasie przeprowadzono u 34 osób starszych – użytkowników aparatów słuchowych, z niedosłuchem odbiorczym w stopniu od łagodnego do umiarkowanie ciężkiego. Uczestników podzielono na dwie grupy na podstawie SNR-50: z wynikami dobrymi i z wynikami słabymi. Po dwóch miesiącach badania te powtórzono wraz z wypełnieniem kwestionariusza *International Outcome Inventory – Hearing Aids* (IOI-HA).

Wyniki: Wyniki wskazują na znaczącą różnicę w pamięci roboczej i percepcji mowy w hałasie u pacjentów korzystających z aparatów słuchowych. Zaobserwowano również, że osoby z lepszą pamięcią roboczą i gorszymi wynikami SNR-50 mają większe korzyści z aparatów słuchowych. Wiedza ta odgrywa ważną rolę w określaniu stopnia odczuwanych korzyści z użytkowania aparatów słuchowych przez osoby starsze.

Wnioski: Niniejsza praca podkreśla znaczenie wykonywania pomiarów pamięci roboczej i percepcji mowy u osób starszych z niedosłuchem przed dopasowaniem aparatu słuchowego. Wyniki tych pomiarów odgrywają znaczącą rolę podczas konsultacji w celu przedstawienia pacjentowi realistycznych korzyści, jakie może on uzyskać podczas użytkowania aparatu słuchowego.

Słowa kluczowe: pamięć robocza • osoby starsze • percepcja mowy w hałasie • używanie aparatów słuchowych • korzyści z aparatu słuchowego

Background

Hearing loss in older adults, also termed presbycusis, is one of the most frequently occurring problems in adults aged above 60 years [1]. The hearing loss not only affects audibility [2] but also other processes such as auditory processing [3], frequency resolution [4,5], temporal resolution [6], and working memory [7].

Studies on listening difficulties in older adults have consistently shown that they have greater difficulties in comprehending or understanding speech, particularly in noisy environments. Although researchers have provided various explanations for these age-related effects, the major factor that is being stressed is central auditory effects [8]. The factors other than hearing loss [9] include cognition [10]. The factors considered by an audiologist while fitting a hearing aid are the degree of hearing loss, type of hearing loss, audiogram configuration, speech identification ability, and loudness discomfort level. A major focus of the present audiological rehabilitation is an outcome-based approach [11,12]. Despite the technical advances in hearing aid technology, hearing aid uptake and sustained use of it remains low, especially in older adults. Studies have shown that the acceptance and consistent use of hearing aids is from as low as 6% to 41% [13–15].

It has been reported that even though benefits are derived from hearing aids, very few users use the devices consistently [13,16]. Older adults typically exhibit different characteristics and needs compared to young adults. The audiologist must consider various aspects including speech or signal processing in order to meet their unique needs. Hence, it is crucial for an audiologist to consider certain of these other factors while fitting the hearing aid, not only for a better outcome but also for the degree of satisfaction that an individual gets from a hearing aid. This will to some extent ensure continued use of the hearing aid.

It is necessary for an audiologist to measure and document treatment efficacy. There are various tools available to measure the effectiveness of hearing aids and their outcome. However, research has shown that many audiologists hardly use these outcome measures in their clinical practice [17]. A survey of 250 audiologists dealing with hearing aids indicated that factors such as cosmetic appearance and the stigma associated with hearing aids were reasons for non-acceptance [18]. In a survey of 50–65-year-old participants reporting hearing loss, 50% of them were reluctant to use their hearing aid [19], even though they received benefits from it. Even when such individuals procure hearing aids, there is considerable reluctance to use it as it is perceived as an aspect of getting older [20,21].

The potential benefits of deriving hearing aid outcome measures include the ability to better counsel patients on the impact that hearing loss has on quality of life [22,23]. The overall purpose of an outcome measure is to assess the performance of an individual after they have received the treatment. Studies published in the last decade have revealed some interesting findings [22,24–26], including that there is a significant possible interaction between amplification and cognition. Individuals with better working memory perform well with hearing aids [24,25]. On the other hand, one finding has been that individuals with lower cognitive abilities also perform well with hearing aids [26]. It seems there are older adults who are either perform well or perform poorly with a hearing aid.

Other related studies aslo reveal equivocal findings [7,25,26]. Thus, more evidence is warranted to strengthen the relationship between cognition, speech perception ability, and hearing aid use. The present study was undertaken in order to address the question of whether working memory and speech perception in noise have any association with hearing aid use and its benefit.

Aim and Objectives

1. To study the association between working memory and hearing aid benefit, in good and poor performing older adults.
2. To study the association between speech perception ability and hearing aid benefit, in good and poor performing older adults.

The null hypotheses framed were i) that there is no significant effect of working memory on hearing aid benefit; and ii) there is no significant effect of speech perception ability on hearing aid benefit, in either good or poor performing older adults.

Methods

To investigate the objectives, the present study involved assessing various factors such as working memory and speech perception in noise (SNR-50) in older adults before fitting a hearing aid. These factors were re-assessed after 1 month and 2 months of hearing aid use. It was ensured that the ‘Ethical Guidelines for Bio-behavioural Research Involving Human Subjects [27] were followed.

Participants

A total of 42 individuals in the age range from 60 to 78 years, with a mean age of 71.6 years, participated in the study. There were 34 who completed 1- and 2-month follow-ups. These 34 data were considered for the study, while data from 8 individuals was not considered as they did not return for the follow-up testing sessions. The participants were diagnosed with mild to moderately-severe sensorineural hearing loss (SNHL) in the test ear. If the hearing loss was symmetrical, either the right or left ear was considered as the test ear. In case the hearing loss was asymmetrical, the better ear was considered as the test ear for the study. All participants had bilateral type A tympanograms and the presence of at least ipsilateral reflexes at 500 Hz and 1000 Hz. Individuals with any neurological, medical, or other otological (other than hearing loss) history were not included in the study. All the participants were naïve hearing aid users. The participants were fitted with a 4-channel digital programmable behind the ear (BTE) hearing aid. The participants were selected using a purposive convenient sampling technique. The purpose and nature of the study were explained to each participant and written informed consent was taken before the commencement of testing. It was also ensured that the participants either did not have any problem related to vision or had corrected vision. The participants were divided into two groups, GOOD performers and POOR performers based on the mean unaided SNR-50 scores. The participants with lesser scores than mean values –1 SD were considered as GOOD performers and similarly participants with greater scores than mean +1 SD values were considered as POOR performers. The participants were divided into two groups based on SNR-50, as studies in the literature have shown a positive relation between speech perception and hearing aid benefit. In contrast, there are a group of the population who fall under the category of neural presbycusis or having poorer speech perception due to aging. Hence, to study the effect of speech perception ability, the participants were categorized into GOOD and POOR performers.

Procedure

A detailed case history followed by otoscopic examination was performed on all participants to rule out the presence of contraindications for conducting hearing and hearing aid testing. The participants were subjected to routine audiological procedures which included pure-tone audiometry, speech audiometry, and immittance evaluation. This was done in order to ensure that the participants met the inclusion criteria.

The programmable digital BTE hearing aid was connected to the computer through HiPro (version 2) using appropriate cables. The computer had the NOAH (version 4.6) and hearing aid specific software to program the digital BTE hearing aid. The hearing aid was programmed using the NAL-NL1 fitting formula with the acclimatization level set to 'Non-experienced' or 'Naïve' hearing aid users. The hearing aid was programmed with a single program in omni directionality mode and with noise cancellation activated. A custom ear mould was used to couple the BTE to the test ear of the participant. The data logging feature of the hearing aid, which enables the audiologist to verify the number of hours of hearing aid use, was enabled in the hearing aid at the time it was issued to the participant. This was followed by obtaining aided speech identification scores for the phonemically balanced (PB) wordlist [28] and a set of five questions. The hearing aid programming, counselling about use, care, and maintenance were done after the purchase of the prescribed hearing aid by the participant. The present study consisted of participants who were unilateral hearing aid users due to various reasons such as socioeconomic status and affordability of two hearing aids at one time (many of them use one hearing aid for a few days and then procure a second one).

For obtaining the unaided SNR-50, the phonemically balanced (PB) list (list 1) of recorded Kannada sentences developed by Geetha et al. [29] was presented through a laptop routed through the calibrated diagnostic audiometer to a loudspeaker located 1 m away and at 45° azimuth from the participant. The presentation level of speech was constant at 40 dB HL. The task for the participant was to repeat the sentences presented. The signal-to-noise ratio (SNR) was varied from +10 to –6 dB, in 2 dB steps. The level of speech noise was varied and the level at which the participant could repeat a minimum of 50% of the words presented in the sentence was noted. This was considered for computation of SNR-50 using the Spearman–Karber equation:

$$\text{SNR-50} = i + 1/2(d) - (d)(\# / w),$$

where i = the initial presentation level (dB SNR); d = the attenuation or step-size (decrement); w = the number of items per decrement; and # is the number of correctly identified words.

Based on the mean SNR-50 scores, the participants were divided into GOOD and POOR performers. The test was repeated in follow-up sessions after 1 and 2 months of hearing aid use. The stimuli used were the second (list 2) and third (list 3) PB sentence list [29] respectively.

Working memory was assessed using the digit backward (DB) test. The digits were presented in visual modality and were presented through Smriti Shravan software (Kumar & Sandeep, 2017: unpublished institutional software). The software was installed in the laptop computer, kept at a comfortable distance where the individual could clearly see the display of the digits on the laptop screen. The participants were instructed about the task, that is, to repeat the digits in backward order of its appearance on the computer monitor. A practice trial was given in order to confirm the comprehension of the instructions. The test was repeated in follow-up sessions, after 1 and 2 months of hearing aid use.

During the first and second follow-up visit, the hearing aid was connected to the programming software and information about the number of hours of hearing aid use (HA-Use) per day was collected using the information provided by the client and also from the data-logging feature of the hearing aid. The number of hours of hearing aid use was noted after 1 and 2 months of HA-Use. This was done in order to cross-check the number of hours of hearing aid usage with the subjective report by the participant. For subjective assessment of outcome from the hearing aid, the International Outcome Inventory - Hearing Aid (IOI-HA) in Kannada [30,31] was administered. The IOI-HA comprises seven questions each on a five-point rating scale. The total score is 35. Higher scores on IOI-HA reflect better outcome from the hearing aid. The questions cover seven domains: hearing aid use, benefit, residual activity limitations, satisfaction, residual participation restrictions, impact on others, and quality of life.

Results

The data obtained from the tests were tabulated for statistical analyses using SPSS software (SPSS 20). The SNR-50 was used to classify the hearing aid users as good or poor performers. The mean SNR-50 score obtained was 4.98 and the standard deviation was 0.9. Hence, those with a SNR-50 of ≤4 dB were considered as GOOD performers (n = 16 participants) and those with ≥5.8 dB were considered as POOR performers (n = 18). Table 1 represents the mean and standard deviation of the scores obtained on digit backward (DB), SNR-50, hearing aid use (HA-Use), and IOI-HA measured in the study.

In order to test for distribution of the data on dependent variables, a Shapiro–Wilk test was performed. The results showed that the variables were not normally distributed ($p < 0.05$). Hence, a non-parametric test was conducted. A Mann–Whitney *U*-test was administered in order to assess if there was any significant difference between the mean values of test scores between the two groups i.e., GOOD and POOR performers, for pre- and post- hearing aid fitting. The results of the Mann–Whitney *U*-test showed a significant difference in mean values of digit backward test ($U = 27$, $p < 0.001$) and SNR-50 ($U = 20$, $p < 0.001$) for 2 months post hearing aid fitting between GOOD and POOR performers. This infers that the hearing aid had an impact on all the measures considered in the study, such as working memory and speech perception in noise. When compared to pre-fitting conditions, the Mann–Whitney *U*-test showed no significant difference in mean values for the digit backward test ($U = 50$, $p > 0.5$).

To further investigate the benefit in each group before fitting of hearing aids and after 2 months of use for

Table 1. Mean scores and standard deviations (SD) of digit backwards, SNR-50, hearing aid use, and IOI-HA scores

Test	Score	GOOD performers (n = 16)			POOR performers (n = 18)		
		Pre-fitting	Post fitting		Pre-fitting	Post fitting	
			Post 1 month	Post 2 month		Post 1 month	Post 1 month
DB (max. score = 8)	Mean	2.96	3.1	4.6	2.34	2.53	3.8
	SD	0.46	0.52	0.55	0.51	0.51	0.56
SNR-50	Mean	4.45	2.95	1.32	5.4	4.31	3.48
	SD	0.94	0.37	0.4	0.88	0.8	0.67
HA-Use (no. of hours per day)	Mean	not applicable	5.24	6.26	not applicable	2.97	3.05
	SD		0.9	1.2		0.81	0.78
IOI-HA (max. score = 35)	Mean		28.6	32.4		24.5	24.9
	SD		1.9	1.4		1.9	1.68

Key: DB, digit backward; SNR-50, signal to noise ratio; HA-Use, hearing aid use; IOI-HA, International Outcome Inventory – Hearing Aids in Kannada

SNR-50 and DB, a paired sample t-test was administered. Results shows highly statistical significant difference for SNR-50 for better performers (t = 8.57, p <0.001) and poor performers (t = 7.87, p <0.001); and for DB for better performers (t = –9.79, p <0.001) and poor performers (t = –12.47, p <0.001). The scores of SNR-50 and DB showed improvement in both groups during hearing aid use, but the extent of improvement varied.

In order to further investigate the objectives of the study, the association between DB, SNR-50, and hearing aid benefit was measured using a Spearman rank correlation test. Table 2 shows the Spearman correlation coefficient (r) for DB and SNR-50 with IOI-HA and hearing aid use.

The Spearman rank correlation co-efficient (Table 2) shows a strong positive correlation between hearing aid use and IOI-HA, which shows that the number of hours of hearing aid use is reflected in terms of benefit from hearing aids; i.e., the more the number of hours of use, the better is the benefit. Further, the Spearman correlation coefficient showed a moderate positive correlation between digit backward score and IOI-HA, and also between digit backward score and hearing aid use. This implies that an individual possessing better working memory capacity tends to use the hearing aid for a larger number of hours and in turn gets greater benefit from the hearing aid. In addition, a moderate negative correlation was noted between IOI-HA and HA-Use with SNR-50. This indicates that an individual with lesser SNR-50 scores tends to use the hearing aid more and gets more benefit from the hearing aid. It is to be noted here that lower SNR-50 score means better performance.

Discussion

The results of the present study reveal some salient and interesting findings. The present study highlights the importance of working memory and speech perception ability as essential factors that can have an impact on hearing aid outcome measures, which is clearly reflected in the results of the Spearman correlation coefficient. In older adults, when listening to speech in challenging environments (like speech in noise or speech in a crowd), auditory perception can be adversely affected [32]. Thus, there is a reallocation of more cognitive resources to support auditory processing. This in turn affects the available resources for retrieval functions of working memory [32,33]. For example, when the task involves understanding the speech of a talker while concomitantly having to ignore a competing noise in the background, an increased load on attention control can occur because of the circumstances of divided attention at the cognitive level [32]. This results in a significant demand on executive function, the working memory component responsible for scheduling, organizing, and allocating resources for attending to ongoing activities gets disturbed, and thus the task is made difficult and fatiguing.

The participants were divided into good and poor performers based on the SNR-50. The results reveal that the working memory did not differ in the two groups before fitting the hearing aid. Despite this factor, the two groups fitted with hearing aid showed hearing aid benefit as observed after 2 months of hearing aid use. But the extent of the benefit varied among the groups, and individuals who consistently used the hearing aid benefitted the most. Thus, the present study rejects the null hypothesis that stated that

Table 2. Spearman rank correlation coefficient (r) between hearing aid use and DB, SNR-50, and IOI-HA

	DB		SNR-50		IOI - HA	
	***r*-value**	***p*-value**	***r*-value**	***p*-value**	***r*-value**	***p*-value**
IOI-HA (Max. score = 35)	0.62	0.01	–0.65	0.002	–	–
HA use (no. of hours per day)	0.76	0.008	–0.69	0.007	0.78	0.000

Key as per Table 1

there is no association between working memory and perceived benefit. That is, there is an association between working memory and the perceived benefit from hearing aids in older adults.

It can be noted from the results of the present study that individuals with lower SNR-50 had higher number of hours of HA-Use and IOI-HA scores, in turn having better benefit from the hearing aid. The difficulty in speech understanding ability, even in the presence of noise or difficult situations as measured using SNR-50, did not alter the use of hearing aid as observed from Spearman's correlation. Thus, the present study rejects the second null hypothesis that there is no association between SNR-50 and perceived benefit from a hearing aid.

The use of a hearing aid is closely associated with the benefit from it. Ng et al. [34] studied the relationship between hearing aid outcome measures with cognitive measures and found that better cognitive skills were associated with longer durations of use of hearing aids and better success with them. The relation between cognitive ability and speech recognition in noise is well established [34]. Regular use of hearing aids makes it easier for an individual to access amplified phonological representations which become familiar over time. The results of the present study support the findings of Akeroyd [35] where individuals who used hearing aids for a longer time had better speech perception in noise (SPIN) and IOI-HA scores.

The motivation to use a hearing aid also plays a crucial role for its use [36]. The motivation can be from self or from others, but hearing aids have a significant positive effect with motivation from self. Older adults with higher motivation tend to use the hearing aid more (more than 4 h per day), and thus benefiting more from it. A positive attitude towards rehabilitation, acceptance of hearing loss, and a positive attitude tend to increase hearing aid use, thus giving better benefits [36,37]. The present study highlights that individuals with better SNR-50 tend to use hearing aids more, indicating better acceptance and motivation towards hearing aid use.

The present study focused on crucial aspects such as working memory, speech perception ability, and aspects of hearing aid benefit in older adults. The study highlights these processes which also need to be given importance when fitting a hearing aid, as these processes can affect the outcome measures. These factors also play a role in counselling regarding hearing aid use and benefit.

Conclusions

The present study evaluated the association of working memory and speech perception abilities on hearing aid outcome measures, in older adults with hearing loss. The individuals fitted with hearing aids were administered a digit backward test and SNR-50 during fitting of the hearing aid and at 1 and 2 months afterwards. Along with these tests, IOI-HA was administered, and hearing aid use was determined by the data logging feature in the hearing aid. The results of the present study show that there is an association between working memory and hearing aid benefit, and also between speech perception ability and hearing aid benefit. Individuals who had better cognitive ability performed well on speech identification task and perceived better benefit with the hearing aid. It can be inferred from the results that there is a strong correlation between working memory and SNR-50 with hearing aid use and hearing aid benefit. Hence, it can be construed that individuals having lesser SNR-50 scores may require lesser cognitive load to understand speech in noisy backgrounds. Thus, it can be inferred that measures for working memory and speech perception ability in noise need to be administered when fitting a hearing aid so that the expected perceived benefit can be predicted and thus appropriate counselling given.

Funding: The authors did not approach or obtain any funding or grants for carrying out the present study.

References

1. Sprinzl GM, Riechelmann H. Current trends in treating hearing loss in elderly people: a review of the technology and treatment options – a mini review. Gerontology, 2010; 56: 351–8.
2. Arlinger S. (). Negative consequences of untreated hearing loss: a review. Int J Audiol, 2003; 42: 2S17–2S21.
3. Willott JF, Chisolm TH, Lister JJ. Modulation of presbycusis: current status and future directions. Audiol Neurootol, 2001; 6: 231–49.
4. Fitzgibbons P, Gordon-Salant S. Auditory temporal processing in elderly listeners. J Am Acad Audiol, 1996; 7: 183–9.
5. Pichora-Fuller MK, Souza PE. Effects of aging on auditory processing of speech. Int J Audiol, 2003; 42: 2S11–2S16.
6. Florentine M, Buus S. Temporal gap detection in sensorineural and simulated hearing impairments. J Sp Lang Hear Res, 1984; 27(3): 449–55.
7. Souza P, Arehart K, Neher T. Working memory and hearing aid processing: literature findings, future directions, and clinical applications. Front Psychol, 2015; 6: 1894.
8. Kiessling J, Pichora-Fuller MK, Gatehouse S, et al. Candidature for and delivery of audiological services: special needs of older people. Int J Audiol, 2003; 42: 2S92–2S101.
9. Cheesman MG. Speech perception by elderly listeners: basic knowledge and implications for audiology. J Speech Lang Pathol Audiol 1996; 21: 104–110.
10. Jain C, Dwarakanath VM, Amritha G. Influence of subcortical auditory processing and cognitive measures on cocktail party listening in younger and older adults. Int J Audiol, 2019; 58: 87–96.
11. Goff AE. The use of hearing aid outcome measures in the audiologic treatment of older adults. PhD thesis: Ohio State University, 2013.
12. Abrams HB, McArdle R, Chisolm TH. From outcomes to evidence: establishing best practices for audiologists. Sem Hear, 2005; 26(3): 157–69.
13. Popelka MM, Cruickshanks KJ, Wiley TL, Tweed TS, Klein BE, Klein R. Low prevalence of hearing aid use among older adults with hearing loss: the epidemiology of hearing loss study. J Am Geriatr Soc, 1998; 46: 1075–8.
14. Davis A. Population study of the ability to benefit from amplification and the provision of a hearing aid in 55–74-year-old first-time hearing aid users. Int J Audiol, 2003; 42: 2S39–2S52.

15. Duijvestijn JA, Anteunis LJ, Hoek CJ, Van Den Brink RH, Chenault MN, Manni JJ. Help-seeking behaviour of hearing-impaired persons aged > or = 55 years; effect of complaints, significant others and hearing aid image. Acta Otolaryngol, 2003; 123(7): 846–50.
16. Smits C, Kramer SE, Houtgast T. Speech-reception-thresholds in noise and self-reported hearing disability in a general adult population. Ear Hear, 2006; 27: 538–49.
17. Abrams HB, McArdle R, Chisolm TH. From outcomes to evidence: establishing best practices for audiologists. Sem Hear, 2005; 26(3), 157–69.
18. Kochkin S. Hearing professionals' views on market expansion. Hear Instr, 1991; 42: 6–8.
19. Stephens D, Hétu R. Impairment, disability and handicap in audiology: towards a consensus. Audiology, 1991; 30(4): 185–200.
20. Brooks DN. Some factors influencing choice of type of hearing aid in the UK: behind-the-ear or in-the-ear. Br J Audiol, 1994; 28: 91–8.
21. Garstecki DC. Hearing aid acceptance in adults. In: Clark JG and Martin FN, eds. Effective Counselling in Audiology. New Jersey: Prentice Hall, 1994, 210–46.
22. Cox RM, Alexander GC. Expectations about hearing aids and their relationship to fitting outcome. J Am Acad Audiol, 2000; 11(7): 368–82.
23. Gatehouse S, Naylor G, Elberling C. Benefits from hearing aids in relation to the interaction between the user and the environment. Int J Audiol, 2003; 42: 1S77–1S86.
24. Lunner T, Sundewall-Thorén E. Interactions between cognition, compression, and listening conditions: effects on speech-in-noise performance in a two-channel hearing aid. J Am Acad Audiol, 2007; 18: 604–17.
25. Foo C, Rudner M, Rönnberg J, et al. Recognition of speech in noise with new hearing instrument compression release settings requires explicit cognitive storage and processing capacity. J Am Acad Audiol, 2007;18: 618–31.
26. Cox RM, Xu J. Short and long compression release times: speech understanding, real-world preferences, and association with cognitive ability. J Am Acad Audiol, 2010; 21(2): 121–38.
27. AIISH. Ethical Guidelines for Bio-behavioral Research Involving Human Subjects. All India Institute of Speech and Hearing, Manasagangothri: Mysore, 2009.
28. Yathiraj A, Vijayalakshmi CS. Phonemically Balanced Word List in Kannada. Developed in Department of Audiology, AIISH, Mysore, 2005.
29. Geetha C, Kumar KS, Manjula P, Pavan M. Development and standardisation of the sentence identification test in the Kannada language. J Hear Sci, 2014; 4(1): 18–26.
30. Thammaiah S, Manchaiah V, Easwar V, Krishna R. Translation and adaptation of five English language self-report health measures to South Indian Kannada language. Audiol Res, 2016; 6(1): 153.
31. Mythri N, Krishna R. International Outcome Inventory for Hearing Aids (IOI-HA) in Kannada: Adaptation from (IOI-HA) English. Unpublished dissertation: University of Mysore, 2016.
32. Tun PA, O'Kane G, Wingfield A. Distraction by competing speech in young and older adult listeners. Psychol Aging, 2002; 17: 453–67.
33. Larsby B, Hällgren M, Lyxell B, et al. Cognitive performance and perceived effort in speech processing tasks: effects of different noise backgrounds in normal-hearing and hearing-impaired subjects. Int J Audiol, 2005; 44: 131–43.
34. Ng EH, Rudner M, Lunner T, Rönnberg J. Relationships between self-report and cognitive measures of hearing aid outcome. Speech Lang Hear, 2013; 16(4): 197–207.
35. Akeroyd MA. Are individual differences in speech reception related to individual differences in cognitive ability? A survey of twenty experimental studies with normal and hearing-impaired adults. Int J Audiol, 2008; 47(Suppl2): S53–S71.
36. Hickson L, Timm M, Worrall L. Hearing aid fitting: outcomes for older adults. Austr J Audiol, 1999; 21: 9–21.
37. Uriarte M, Denzin L, Dunstan A, Sellars J, Hickson L. Measuring hearing aid outcomes using the Satisfaction with Amplification in Daily Life (SADL) questionnaire: Australian data. J Am Acad Audiol, 2005; 16: 383–402.