Evaluation of Speech Perception via the Use of Hearing Loops and Telecoils

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Razan Alfakir, M.D[1], Alice E. Holmes, Ph.D[1], Patricia B. Kricos, Ph.D[1], Laura Gaeta, BS[2], and Sheridan Martin, A.uD[2]

Abstract

A cross-sectional, experimental, and randomized repeated-measures design study was used to examine the objective and subjective value of telecoil and hearing loop systems. Word recognition and speech perception were tested in 12 older adult hearing aid users using the telecoil and microphone inputs in quiet and noise conditions. Participants were asked to subjectively rate cognitive listening effort and self-confidence for each condition. Significant improvement in speech perception with the telecoil over microphone input in both quiet and noise was found along with significantly less reported cognitive listening effort and high self-confidence. The use of telecoils with hearing aids should be recommended for older adults with hearing loss.

Keywords

telecoil, microphone, hearing loops, hearing loss, speech perception in quiet and noise, cognition, self-confidence

Introduction

According to the American Speech-Language-Hearing Association (ASHA), hearing is defined as the process of collecting, attending to, and understanding sound from the environment (ASHA, 2012). There is no doubt that our hearing sensory system is a primary window to discover the world. Throughout our lives, hearing input provides us with an incredible rich and nuanced source of information. Hearing function, along with other sensory systems, emotional and cognition functions, is critical for the aging population to participate in day-to-day interactions and social activities.

As we age, hearing acuity for high frequency sounds deteriorates, leading to hearing loss (HL) or what is known as a presbycusis condition. HL is the third most prevalent chronic disorder after arthritis and hypertension (Cruickshanks et al., 1998; Mitchell et al., 2011; National Center for Health Statistics, 1989). The global estimates of mild HL (≥40 dB) in adults above 55 years of age range from 15% to 25% (World Health Organization, 2012). Another global estimate is the vast increase in the numbers of aging people 65 years and above between 2010 and 2050. Considering both estimates together, hearing impairment will increasingly affect older adults in the future in all regions. The primary consequence of the HL significantly affects several aspects of the elderly's everyday life such as speech perception in noisy environments, cognitive listening effort, communication abilities, self-confidence, and emotional and social functions (Hallberg, Hallberg, & Kramer, 2007; Mick, Kawachi, & Lin, 2014; National Council on Aging, 1999).

Notably, in daily life activities, the ability to hear and listen depends on the integrity of the auditory neural system from the ascending auditory pathways to higher order functions and vice versa. As the auditory system ages, it indirectly develops central changes induced by peripheral lesions (degeneration of spiral ganglion) leading to a reduced input into the central auditory system. Also, the auditory system undergoes direct morphological and physiological changes induced by the biological effect of aging associated with a decline in central neural auditory processing ability. This leads to loss of speech understanding greater than would be expected from the audiometric thresholds and decreased ability to localize sounds and detect signals in noise. Therefore, central auditory changes in the aging population can essentially be classified into two major types. The first type is referred to as *the central effects of peripheral pathology*, which presents with changes in the cochlear nucleus driven by the decline of peripheral cochlear inputs that occur with age, typically starting with HL at high frequencies. The second type is referred

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[1] University of Florida, Gainesville, USA
[2] University of Oklahoma, Norman, USA

Corresponding Author:
Razan Alfakir, Department of Speech Language Hearing Sciences, University of Florida, P.O. Box 117420, Gainesville, FL 32611, USA.
Email: ralfakir69@ufl.edu

to as *the central effects of biological aging* or true aging. In reality, understanding the relationship between these two pathologies in the human auditory system is sophisticated and difficult to differentiate (Pichora-Fuller, 2003, 2008; Pichora-Fuller & Singh, 2006). Age-related changes in top–down processes such as listening appear to be attributable to a deficit in selective attention. The evidence in research demonstrates that older adults may exhibit declines in auditory selective attention when the source of distraction is uncertain (Humes, Lee, & Coughlin, 2006) and exhibit an additional decline in attending to speech when the distracting speech is meaningful (Rossi-Katz & Arehart, 2009; Tun, McCoy, & Wingfield, 2009; Tun, O'Kane, & Wingfield, 2002). Yet it is unclear whether the selective attention deficiency is due to cognitive decline or due to HL, aging, and noise. Therefore, future research should focus not only on sensory and cognitive effort as separate domains but also on the dynamics of their interaction.

Hearing aids (HAs) have been shown to be efficacious in the rehabilitation of HL by successfully improving speech perception, communicative abilities, and overall quality of life (Kricos, Erdman, Bratt, & Williams, 2007; Weinstein, 1996). However, the use of HAs does not address all the challenges that are created by the presence of HL. Evidence-based research highlights the effectiveness of alternative interventions such as the use of hearing assistive technologies (HATs) and conversational-situational management to reduce limitations and participation restrictions of the elderly's social life. Undoubtedly, the role of amplification is to transmit the highest quality of bottom–up signal (e.g., audibility, noise, and localization) to the brain. The brain facilitates the top–down information processing including word recognition and speech perception in quiet. However, despite the incredible gains in HA technologies, barriers to listening to and understanding speech perception remain in noisy environments (Cox & Alexander, 1999; Humes, 2001, 2007; Humes, Halling, & Coughlin, 1996; McPherson & Wong, 2005; Wong, Hickson, & McPherson, 2003). These barriers pose serious problems even for listeners with mild HL and have led to emerging new technologies and strategies that target signal-to-noise ratio (SNR) and to improve word recognition and speech understanding in noise. Understanding speech perception in noisy environments requires constant listening effort from older adults with HL (Gatehouse & Noble, 2004) and certain self-confidence. Controlling the constant listening effort requires improvement of the SNR in that environment. In general, the average SNR required to achieve a 50% word recognition score increases with increasing HL (Killion, 1997). A one-decibel improvement in SNR corresponds to improvement by 6 to 12 percentage points in speech intelligibility in background noise (Christensen, 2000). Therefore, in addition to HAs, it has been suggested that HATs could be effective for all ages, especially for the aging population as it improves the audibility, word recognition, speech perception, quality of sound in specific situations, and most likely self-confidence (Pichora-Fuller & Robertson, 1997). A number of studies support the combined use of HAs (e.g., telecoil [t-coil] feature) and HATs (e.g., induction loop, frequency modulation [FM] system). For example, Noe, Davidson, and Mishler (1997) found that word recognition ability with the FM, induction loop, and infrared systems significantly improved in listeners with normal hearing and listeners with HL who were using the FM, induction loop, and infrared systems, as compared with performance in listeners with no HAT systems. However, the literature review showed the lack of quantitative studies that evaluate the objective value of the t-coil. Lederman and Hendricks (2003) highlighted that the looping systems were the elegant universal design solution for optimizing the SNR for HAs users. In 2005, Ross found that sound quality was improved more with a t-coil than with a microphone input as reported by listeners, and t-coil efficacy was based on subjective evaluation rather than objective speech recognition measures. Furthermore, a joint survey administered by the Hearing Loss Association of America and the American Academy of Audiology in 2006, showed that HA users who utilize a loop system are much more satisfied with their overall HAs and their experience with technology. Odelius (2010) showed that students with HL reported better audibility and awareness using the t-coil input rather than the microphone input especially in difficult listening situations. Interestingly, Putterman and Valente (2012) investigated the difference between the t-coil and programmed microphone frequency response in behind-the-ear HAs in a repeated-measures design study that utilized a 2-cc coupler measurement condition. The findings revealed that the mean t-coil output was significantly greater than microphone output at 4,000, 5,000, and 6,300 Hz, while the mean t-coil output was significantly lower than the mean microphone output at 400 Hz.

The Hearing Loss Association of America (2010) defined t-coil as a "copper coil that is an option on most HAs and is built into cochlear implant processors" that allows an electromagnetic sound source to be transmitted to the HA, with little, if any, background noise. The t-coils were originally designed for use with telephones, but the use was expanded to facilitate individuals with hearing impairment to hear more easily in other challenging listening environments, which consequently may lead to reduced participation restrictions in some cases. The t-coils work in conjunction with an induction loop system. The induction loop or hearing loop is connected to an electronic sound source such as a television, public address system, or a personal listening device. The loop creates an electromagnetic field, which in turn converts the sound source into a signal for a HA t-coil to receive, and converts it back into sound. A HA user can change their aid setting from “M” (for microphone) to “T” (for t-coil), allowing the t-coil to act like a microphone. The listener hears only the sound emitted from the source via the induction loop. Because the listener receives the input directly, the t-coil and induction loop can significantly reduce background noise, thereby increasing the SNR. As a result, listeners report an increased satisfaction and improvement in their hearing in these challenging environments. However, there is still a lack of literature that evaluates the efficacy of the t-coil and hearing loop system through both the objective and subjective outcome measures in aged people with hearing impairment. For example, Yanz and Pehringer (2003) surveyed 88 audiologists during the 2002 American Academy of Audiology convention. The audiologists were asked to report the telecoil (t-coil) performance assessment. The majority of the respondents reported that while the HA microphone performance was evaluated by objective tests, the t-coil performance was measured by subjective questionnaires.

The aim of this study was to investigate the objective value of t-coil and hearing loop systems in word recognition and speech perception in quiet and noise, and their subjective value on self-reported cognitive listening effort and self-confidence in older adults with HL.

Method

Twelve older adult participants (62-89 years of age) who were experienced HA users were recruited from a retirement community center as the study sample. Ten participants were wearing HAs that were in good condition with functional t-coils; the other two participants’ HAs, while in good condition, did not have t-coil options. Audiometric data on these participants were not available. All participants were consented to participate under an approved University of Florida Institutional Review Board protocol. Participants were seated in a lecture hall (measuring 73′7″ × 43′6″ with a 14′ × 27′7″ stage at the front) that had an installed and functional hearing loop system.

Prior to the study protocol, six randomly chosen locations in the seating area of the hall were selected for the measurements. Each location was measured from a reference point in the center of the room. The strength of the loop system was measured using the Contacta Loop-FSM (2013). The strength of the loop system met the ANSI/ISA-62382-2012 standards to be within ±3 dB in all tested-seating locations.

A cross-sectional, experimental, and randomized repeated-measures design study was used to examine differences between HA input types (microphone; t-coil), sound conditions (quiet; noise), testing types (Consonant Nucleus Consonant [CNC] and Bamford-Kowal-Bench [BKB]), and seating locations. These measures provided both objective scores (percent correct) and subjective scores (self-reported cognitive effort and self-confidence in the responses). The objective tests used were the CNC words (Peterson & Lehiste, 1962) and BKB sentences (Bench, Kowal, & Bamford, 1979). Both tests were presented at 70 dB sound pressure level (SPL) in quiet and at a constant +10 dB SNR as measured in the center of the seating arrangement. The “noise” was created by using a multi-talker babble CD played through two speakers connected to a laptop. The babble noise was setup at 60 dB as measured in the center of the seating arrangement. The noise level was verified by the sound level meter. The measure of SNR at each location was not part of this study, but from a previous study using the same room, it was estimated that the SNR at the front seats was around +6 dB and that the SNR at the back seats was around +15 dB. The locations and their respective measurements can be seen in Figure 1.

Each test was completed for both the t-coil and microphone inputs and for quiet and noise conditions. For the two participants with no t-coil options in their HAs, an Oval Window Audio’s HLR III Induction Loop Receiver was used for all t-coil conditions. Testing was completed in two sessions with 12 participants attending the first session and 7 participants of 12 returning for a second session. During each session, participants received eight speech perception tests in totally randomized order. In addition, immediately after each objective test measure, participants were asked to subjectively self-assess their cognitive effort and self-confidence on their performance using Likert-type scales. The Likert-type scale for listening effort ranged from 1 (*little to no effort*) to 6 (*a lot of effort*) with the lowest score indicating the least listening effort. The Likert-type scale for self-confidence ranges from 1 = *I got them all wrong* to 6 = *I got them all correct* with the higher rating indicating the better confidence level. The protocol was repeated again in a randomized order for the 7 participants who returned to the second session, with the participants each seated in different locations than their seating in Session 1.

Results

The descriptive statistics analysis showed the mean scores for speech perception, rate of self-confidence, and cognitive listening effort was significantly high across HA input for the 12 participants. The mean scores and standard deviations for each outcome measure compared with HA input are shown in Table 1 and Figures 2 to 4.

A multivariate analysis of variance (MANOVA) was conducted with three dependent variables (speech perception scores, confidence ratings, and effort ratings) to assess the efficacy of hearing loops and t-coils for improvement in speech perception in challenging hearing environments, reduced cognitive effort in listening, and increased self-confidence. The analyzed model consisted of 12 participants within four factors (HA input,

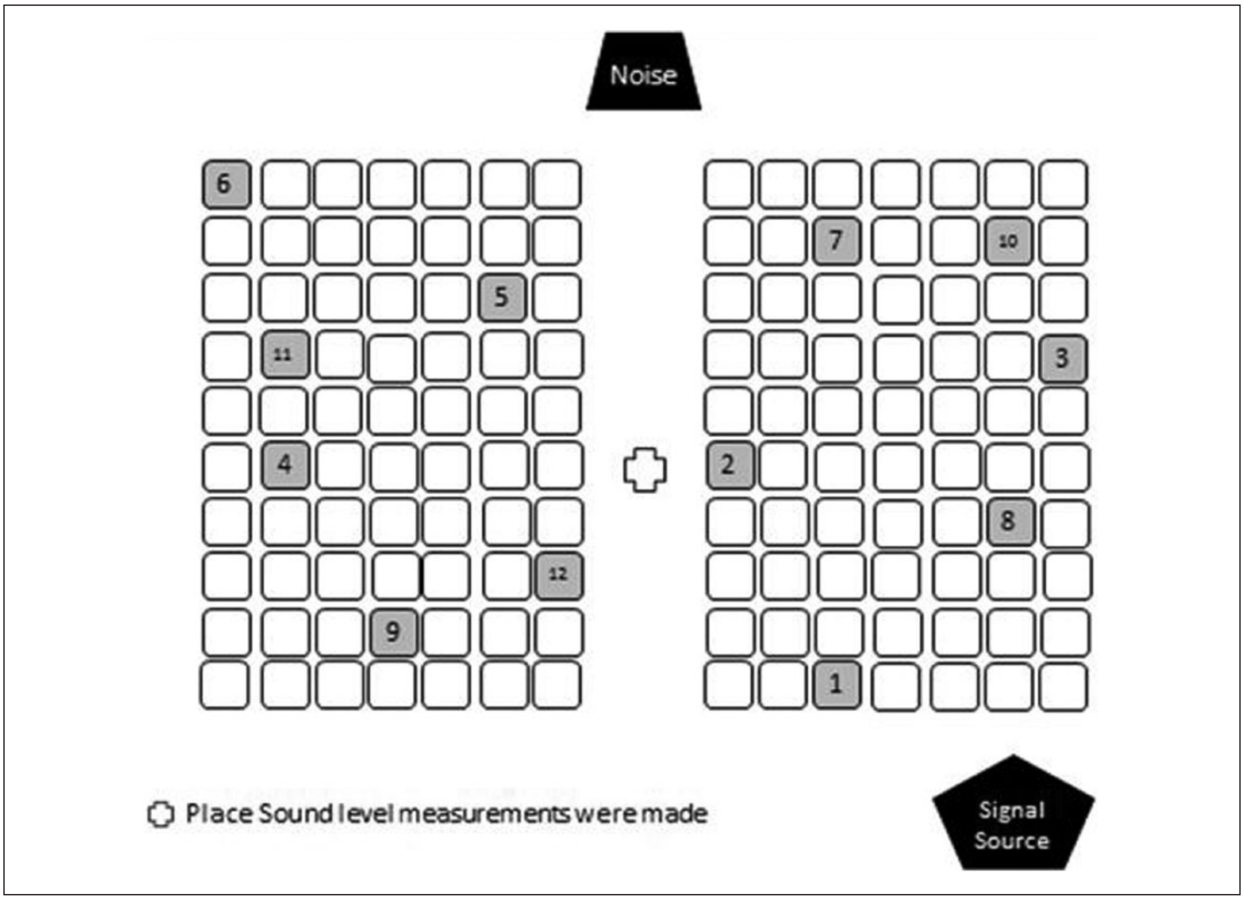

Figure 1. Illustration of the lecture hall measurement (73′7″ × 43′6″ room with a 14′ × 27′7″ stage at the front), the location of noise source, and the location of participants' location.

Note. Both tests were presented at 70 dB SPL in quiet and at a constant +10 dB SNR as measured in the center of the seating arrangement. SPL = sound pressure level; SNR = signal-to-noise ratio.

Table 1. The Mean Scores and Standard Deviations for Each Outcome Measure Compared With HA Input (t-Coil vs. Microphone).

	CNC quiet	CNC noise	BKB quiet	BKB noise
Speech test scores with microphone				
M ± *SD*	64.36 ± 26.34	24.84 ± 20.38	94.68 ± 12.27	82.63 ± 26.39
Speech test scores with t-coil				
M ± *SD*	84.44 ± 19.79	78.70 ± 20.61	97.73 ± 4.22	98.63 ± 3.05
Self-confidence with microphone				
M ± *SD*	3.73 ± 1.32	2.26 ± 0.93	5.05 ± 1.12	4.63 ± 1.38
Self-confidence with t-coil				
M ± *SD*	4.94 ± 0.87	4.58 ± 1.00	5.42 ± 0.96	5.42 ± 0.90
Cognitive listening effort with microphone				
M ± *SD*	3.10 ± 1.52	5.00 ± 1.41	2.31 ± 1.41	2.84 ± 1.64
Cognitive listening effort with t-coil				
M ± *SD*	2.05 ± 1.47	2.47 ± 1.50	1.89 ± 1.52	1.78 ± 1.08

Note. HA = hearing aid; t-coil = telecoil; CNC = Consonant Nucleus Consonant; BKB = Bamford-Kowal-Bench.

test type, condition, and location). Initial evaluations of the data suggested that the measurements had roughly normal univariate distributions. The Box-M test for the homogeneity of variance–covariance matrices across design cells produced a significant result ($p < .001$), and the Levene's test found that the assumption of homogeneity of variance could not be supported for the three variables ($p < .001$). Thus, the relatively conservative Pillai's trace was used for the estimation of F statistics in the analysis that follows. A variable of the inter-correlation matrix showed a modest correlation. The overall multiple analysis of variance showed significant ($p \leq 0.01$) interaction effects between

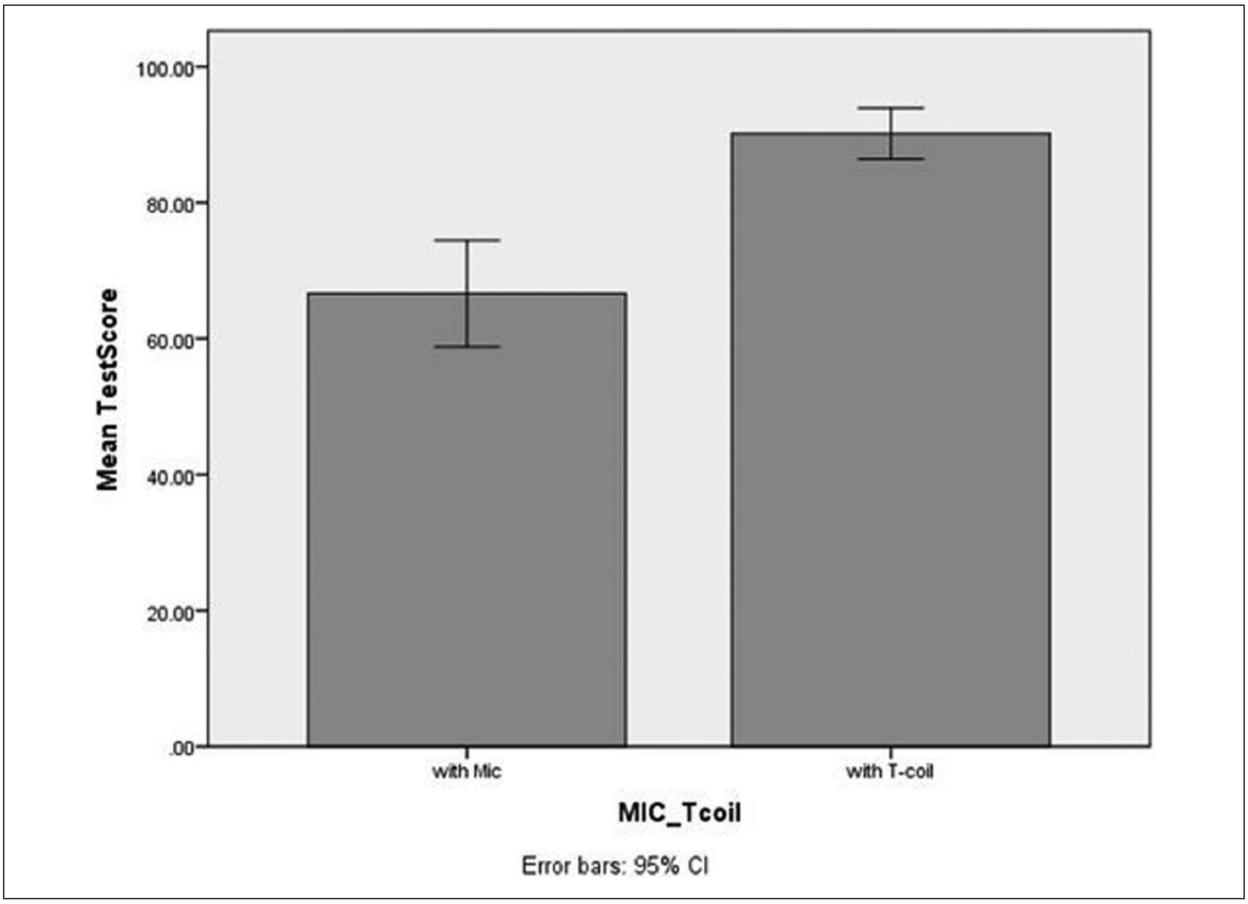

Figure 2. Mean speech perception scores across hearing aid inputs (the higher the better).

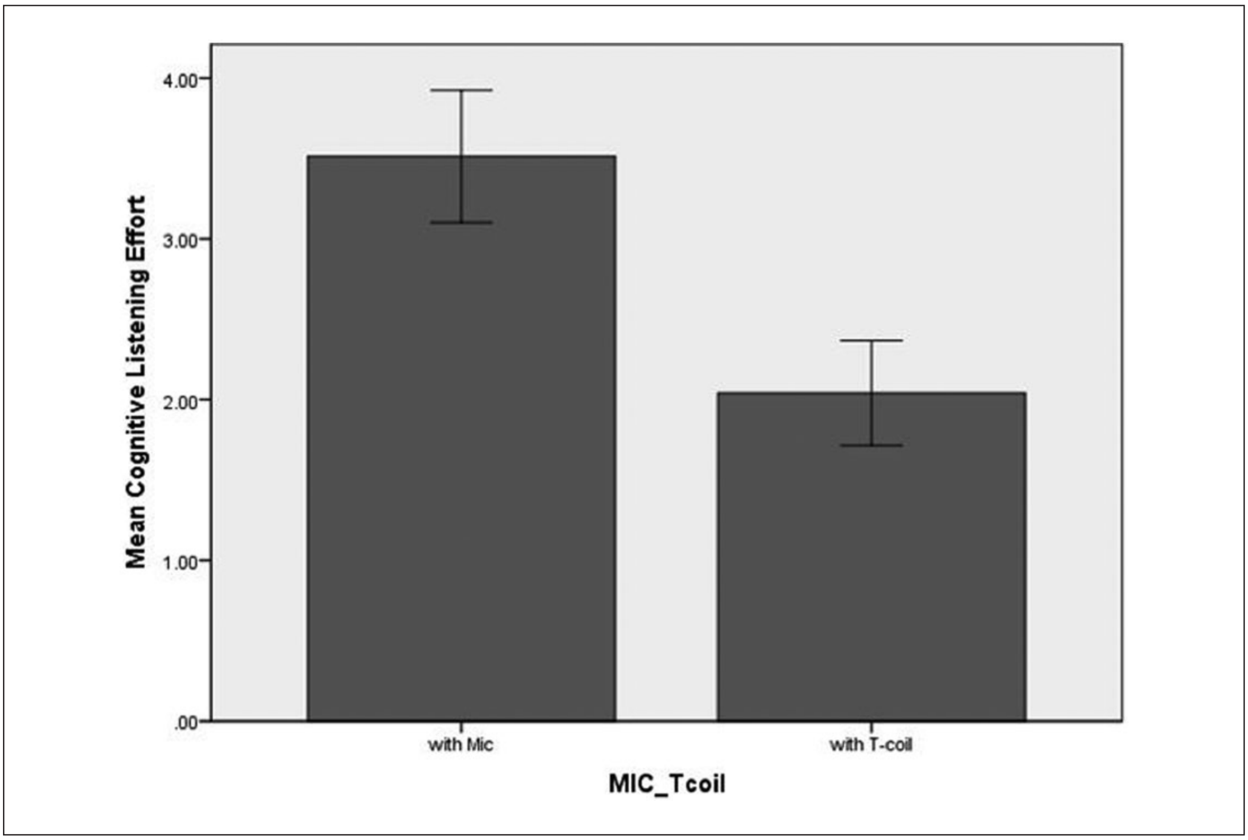

Figure 3. Mean cognitive listening effort scores across hearing aid inputs (the lower the better).

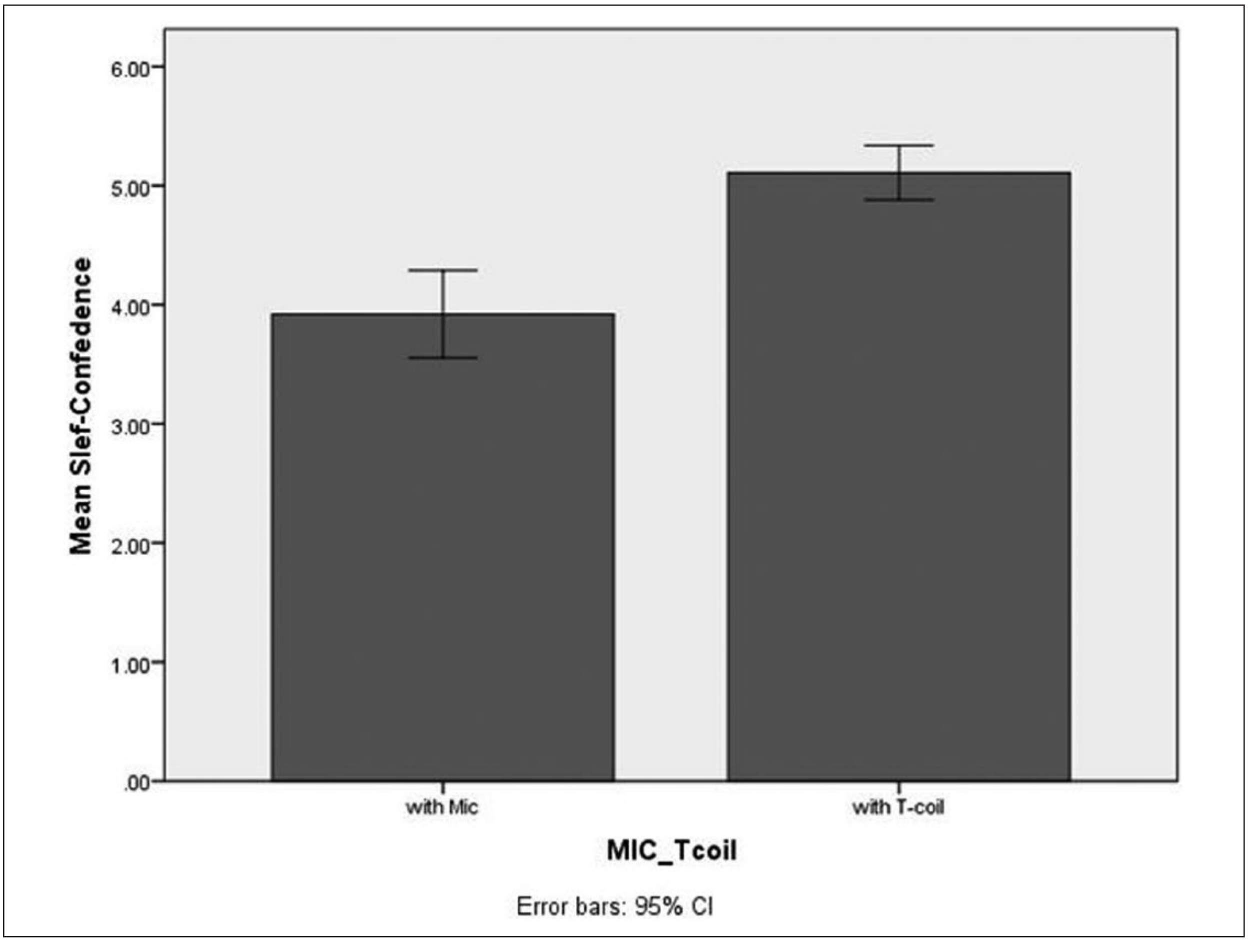

Figure 4. Mean self-confidence scores across hearing aid inputs (the higher the better).

HA input and test type, HA input and condition, and test type and location. The partial eta squared coefficients all suggest moderate to large effects for the HA input and test type predictors (Table 2).

Because of the significant MANOVA, we conducted a follow-up of univariate ANOVAs separately for each dependent variable. The results of the ANOVA for speech perception scores revealed significant ($p < .05$) main effects for all variables and the interactions between the HA input and test type, HA input and condition, and test type and condition. For the cognitive listening effort analysis, significant ($p < .05$) main effects were found for all variables except seating location and a significant interaction between HA input and test type. The ANOVA for the self-confidence measure indicated significant ($p < .05$) main effects for all variables and the interactions between the HA input and test type and between HA input and condition. All other interactions were non-significant ($p > .05$; Table 3).

To decompose the interactions, we examined each main effect at different levels of the second main effect, using Bonferroni corrections to control for alpha inflation due to the number of tests being conducted. For all outcomes measure, all participants produced significantly higher speech perception scores ($p < .001$), higher confidence ($p < .001$), and less effort ($p < .001$) with t-coil input. The participants produced significantly higher speech perception scores ($p < .001$), had higher confidence ($p < .001$), and had less effort ($p < .001$) for the BKB sentences for both HA inputs, but greater improvements were seen in the CNC scores ($p < .001$) and in the noise conditions ($p < .04$). In both speech perception scores and self-confidence ratings, participants performed significantly ($p \leq .001$) better in the second seating location, while the cognitive effort ratings between the seating locations was not significant ($p > .05$; Table 4 and Figure 5).

Discussion

The looped lecture hall at the retirement community center was selected for this study because of its size and its popularity for the residents with HAs for events and informative programs. The results highlighted the efficacy of the t-coil and hearing loop system and the role of the seating locations for HA users. Our model showed a significant difference between microphone and t-coil input with two objective outcome measures (CNC words and BKB-speech-in-noise [SIN] sentences) and two self-assessment Likert-type scales (cognitive effort and

Table 2. Summary of the Results of the MANOVA.

	df	*F* statistics	η^2	*p* value
Box's M	[72, 7,642.684]	2.579		$p < .001$
Levene's test for 3 outcomes				$p < .001$
HA input × Test type	[3, 131]	8.533	0.163	$p < .001$
HA input × Condition	[3, 131]	4.726	0.098	$p < .004$
HA input × Location	[3, 131]	1.217	.027	$p > .005$
Test type × Location	[3, 131]	3.958	0.057	$p < .010$

Note. The table shows (a) the Box-M test for the homogeneity of variance–covariance matrices and the Levene's test for the assumption of homogeneity of variance; (b) the statistics of the degree of freedom (*df*), *F* approximation, effect size (η^2), the significance *p* value for the significant interactions statistics among HA input (microphone; t-coil), condition (quiet; noise), and test type (CNC words; BKB sentences). MANOVA = multivariate analysis of variance; HA = hearing aid; CNC = Consonant Nucleus Consonant; BKB = Bamford-Kowal-Bench.

Table 3. Results of the ANOVA Follow-Up.

DV	*df*	*F* statistics	η^2	*p* value
HA input				
Speech perception tests	[1, 15]	58.665	0.306	$p \le .000$
Self-confidence	[1, 15]	42.617	0.243	$p \le .000$
Cognitive listening effort	[1, 15]	39.075	0.227	$p < .000$
Test type				
Speech perception tests	[1, 15]	90.629	0.405	$p \le .000$
Self-confidence	[1, 15]	47.990	0.265	$p \le .000$
Cognitive listening effort	[1, 15]	24.545	0.156	$p \le .000$
Condition				
Speech perception test	[1, 15]	19.887	0.130	$p \le .000$
Self-confidence	[1, 15]	9.248	0.065	$p \le .000$
Cognitive listening effort	[1, 15]	4.559	0.033	$p \le .035$
Location				
Speech perception tests	[1, 15]	18.871	0.124	$p \le .000$
Self-confidence	[1, 15]	11.341	0.079	$p \le .000$
Cognitive listening effort	[1, 15]	1.506	0.11	$p \ge .222$
HA input × Test type				
Speech perception tests	[1, 15]	24.489	0.155	$p \le .000$
Self-confidence	[1, 15]	11.291	0.078	$p \le .001$
Cognitive listening effort	[1, 15]	10.194	0.071	$p \le .002$
HA input × Condition				
Speech perception tests	[1, 15]	13.474	0.092	$p \le .000$
Self-confidence	[1, 15]	4.218	0.031	$p \le .042$
Cognitive listening effort	[1, 15]	1.831	0.014	$p \ge .178$
Test type × Condition				
Speech perception tests	[1, 15]	7.862	0.056	$p \le .006$
Self-confidence	[1, 15]	3.854	0.028	$p \ge .052$
Cognitive listening effort	[1, 15]	1.227	0.009	$p \ge .052$

Note. The table shows the degree of freedom (*df*), *F* approximation, and effect size (η^2) of each outcome measures separately for different factors (hearing aids input, test type, condition, and location). The *p* value is also shown for each test among each factor. HA = hearing aid.

self-confidence) under two conditions (quiet and noise) and two different seating locations.

During the last few decades, there has been considerable progress in understanding the relationship between auditory, poor SIN, and cognitive functions. Older adults substantially experience difficulties understanding speech in noise as well as in quiet compared with younger adults (Gordon-Salant, Frisina, Fay, & Popper, 2010; Pichora-Fuller, 2011; Rawool & Keihl, 2008). Undeniably, that noise affects many aspects of the elderly's day-to-day activities such as listening, understanding speech signal, and conversing with others by placing greater demands on attention and working memory, which interferes with information processing (Tyler, Hertel, Mccallum, & Ellis, 1979). To handle these strains, older adults with or without HL depend on the cognitive ability and or HAs to interpret and store information and to integrate information (Lunner, 2003). The important question here is, "How can older adults with HL meet these demands and function, if they have an undiagnosed mild cognitive decline?" In 2008,

Table 4. Results of the Bonferroni Corrections Testing.

Bonferroni corrections	Mean difference	*SE*	*p* value
HA input (telecoil vs. microphone)			
Speech perception test	23.11	3.01	$p < .000$
Self-confidence	1.19	0.18	$p < .000$
Cognitive listening effort	−1.55	0.24	$p < .000$
First location versus second location			
Speech perception test	13.11	3.01	$p < .000$
Self-confidence	1.19	0.18	$p < .000$
Cognitive listening effort	−0.30	—	$p > .222$

Note. The *p* values are also shown for each outcome measures. HA = hearing aid.

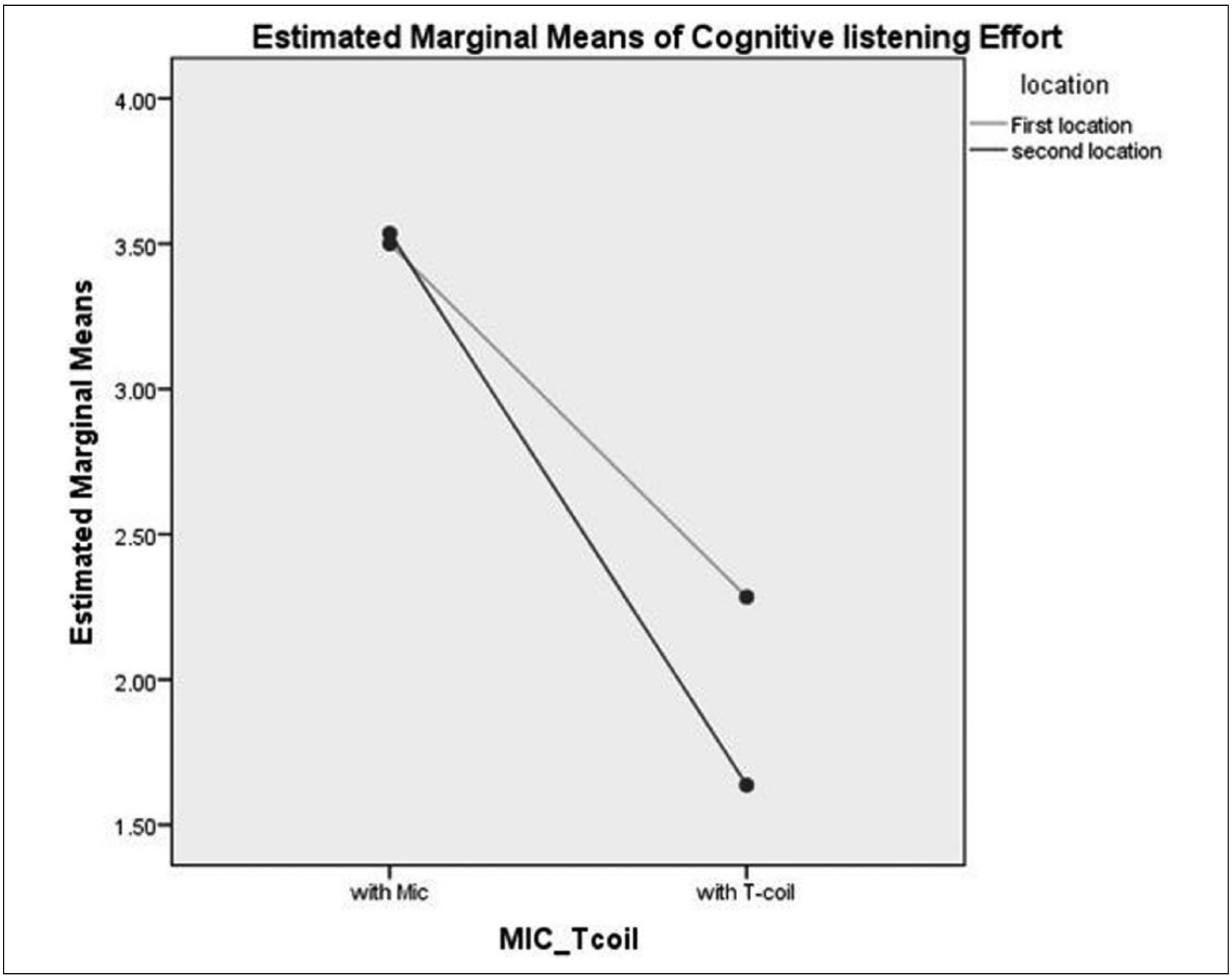

Figure 5. Non-significant difference in cognitive listening effort with t-coil input and the interaction with microphone input when seven participants changed their seating location in second session.
Note. t-coil = telecoil.

Schum and Beck suggested that when aging and hearing disorders are combined, a series of negative synergistic challenges and functional problems occur, such as increased effort in listening ability, diminished cognitive capabilities, and poor word finding and speech perception. Accordingly, negative synergy might be a potential property of the individual differences and interaction between the HA input and test type, HA input and condition, test type and condition, and age. Therefore, when audiologists or other health professionals are working with the aging brain, it is important to recognize that effective rehabilitation requires more than enhancing the audibility via the use of HAs to balance the bottom–up (hearing). Essentially enhancing the top–down processing is a must. Therefore, despite the limitations of the hearing loop system (e.g., high cost) and the t-coil (e.g., electromagnetic interference, larger HAs instrument, marginal sound quality), our model highlighted the effectiveness of t-coil input on improving scores for word recognition and speech perception in quiet and noisy environments raising the self-confidence rate, and reducing the cognitive listening effort rate.

Loop systems in Northern Europe are therefore becoming ubiquitous to the extent that, in some countries, 90% of HAs have the t-coil feature. For example, in the United Kingdom, nearly all HAs provided by the National Health Service are now compatible with t-coil, most churches and cathedrals are now looped, and in the next several years, all London taxis and all London Underground ticket windows will be looped. Regrettably, there is a lag between the United States and Europe in the public accessibility of loop systems for HA users. We believe that the present study may help health policy decision making to improve the progress toward more accessibility to looping services in America, as was being proposed by Kricos (2010) and Myers (2010). Improving accessibility to looping services may enhance participation in social activities and reduce social isolation, a major concern for public health.

Interestingly, the use of t-coil in different seating locations significantly enhanced speech perception scores in both conditions and the self-confidence rate, but did not significantly influence cognitive listening effort. The authors attribute these results to the differences between speech perception, cognitive capacity, and subjective rating of cognitive listening effort (Lunner, Rudner, & Rönnberg, 2009; Schulte et al., 2009) or due to the small sample size in the second session (where 7 of 12 participants were tested in different locations). For example, Lunner and colleagues showed that individual differences in cognitive processing resources may determine listening success. As evidence, studies show that the subjective listening effort rating may be a predictor of cognitive load due to the level of SNR and individual willingness to accept noise level (Nabelek, Tampas, & Burchfield, 2004), types of noise (Rudner, Rönnberg, & Lunner, 2011), and cognitive capacity (Rudner, Lunner, Behrens, Sundewall Thore, & Rönnberg, 2012). Rudner and colleagues found that while there is a strong and significant relation between rated listening effort and SNR that was independent of individual working memory capacity, the relation between rated listening effort and noise type seemed to be influenced by individual working memory capacity. Indeed, functional performance in older adults with hearing disorders is multifaceted as many elder people with peripheral, central auditory and cognitive problems have a considerable difficulty in separating desired speech from other sounds when they merge together in a meeting area, an auditorium, or a lecture hall (Helfer, 1991; Pichora-Fuller, 2003; Ross, 1992). Background noise is a significant factor influencing satisfaction with HAs and the wearer's behavior. The two most typical behaviors are either to avoid attending events or to participate by using any strategy that might be helpful in reducing the distance between communicators, such as asking others to talk louder, using HAs, and changing seats. In 1992, Ross found that any trivial change in distance can significantly reduce the received level of speech as sound energy spreads and dissipates throughout the meeting area. Hence, it is crucial for audiologic rehabilitation (AR) providers to consider situation management as part of communication therapy as it positively influences self-confidence in older adults (Erber, 1996). Beyond hearing technology, situational management is another important rehabilitative therapy that could be provided to older adults, which may reduce listening effort over the long term, increase the benefits of the t-coil compatibility with the looping system, and overall, enhance participation in social events.

One drawback of this study was the lack of audiometric data on the participants, which might affect the level of generalization. However, the results from this study can be generalized because it aligns with the recommendation of the World Health Organization's International Classification of Functioning, Disability, and Health (WHO-ICF, 2001). Our model was focused on the functional performance of older adults regardless of the hearing impairment and the interaction between functional performance, activities limitation (listening), environmental factors such as the noise level of the environment, and the use of hearing technologies (WHO-ICF, 2001). Further research should include this information to see whether audiometric configurations, type of HL, type of HA, experience with HATs, cognition (memory, attention, and speed of processing), and acceptable noise level (ANL) have an effect on the benefits of HATs.

Conclusion

Hearing loops and t-coil technology can make a dramatic difference in an individual's ability to hear clearly and understand speech. A versatile, functional, and relatively inexpensive fix in these situations is the use of t-coils and hearing loops by people who use HAs. The use of t-coils should be recommended for most HAs users. Audiologists can play a number of roles in helping the consumer obtain maximum use of their HAT and in advocating the services and policy-making decisions to increase the number of hearing loop systems installed in public areas.

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