Beyond hearing aids, is there a role for Auditory Training? – A Systematic Review

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ABSTRACT

For people with hearing loss, the ability to understand speech and communicate effectively is greatly diminished. Hearing aids can provide amplification to address the deficit associated with hearing loss; however, their ability to comprehend this information is often flawed. Given that individuals with similar audiometric results report variability of outcomes following hearing aid fitting, consideration needs to be given to other forms of complimentary therapies such as auditory training. Auditory training has been provided to people with hearing loss for decades and the delivery models have evolved over time, but the goal has always been to provide activities that aim to optimize speech perception, improve the ability to pick up acoustic cues and provide compensation for hearing deficit.

The current study consists of a review of literature to investigate whether inclusion of auditory training in an aural rehabilitation program provides additional benefit to adult hearing aid wears compared to rehabilitation programs that provide hearing aids alone. The level of evidence accepted was randomized controlled trials, within-participant repeated measure and before and after group design. Thirty-two studies were identified during the computerised database search; eighteen articles were reviewed with only five meeting selection criteria. The studies selected demonstrated improved performance on behavioural outcomes following auditory training in four of the five studies, however effects were modest and evidence was of low study quality. Future research needs to focus on high quality evidence and provide homogeneity across study models.

Keywords: *Auditory Training; Aural Rehabilitation Hearing Impaired; Auditory Rehabilitation; Hearing Loss; Hearing Aids*

Abbreviations: APHAB = Abbreviated Profile of Hearing Aid Benefit; AV = Audiovisual; CPHI = Communication Profile of Hearing Impaired; CST = Connected Speech Test; DOSO = Device Oriented Subjective Outcome Scale; DS = Digital Span; HHIE = Hearing Handicap Inventory for the Elderly; HINT = Hearing In Noise Test; IHR-STAR = Institute for Health Research for Testing Auditory Response; MCRM = Modified Coordinate Response Measures; RMQ = Read My Quips; R-SPIN = Revised Speech in Noise; WAIS-III = Wechsler Adult Intelligence Scale-Third Edition; WIN = Words in Noise

INTRODUCTION

Hearing loss has been described as an invisible disability and currently affects over 466 million people worldwide. Not surprisingly the proportion of those experiencing hearing loss increases significantly in people over the age of 65, with one in every three being affected by hearing loss. It is estimated that by 2050 this number will have nearly doubled to over 900 million or one in every ten people worldwide being affected by a disabling hearing loss (World Health Organization, [WHO], 2019). The impact of hearing loss is far reaching and includes not only significant difficulties in communication tasks, but also social, emotional and economic burdens. Often, ironically, it is suffered in silence, with people withdrawing from social interaction due to an inability to communicate effectively (Dalton et al., 2003). With hearing impairment being linked to social and emotional isolation, cognitive decline, quality of life issues and general well-being (Hickson et al., 2008; Mick, Kawachi & Lin, 2014) it is even more important that individuals with hearing impairment are provided with a rehabilitation solution that is more holistic in its delivery and provides the best possible outcomes.

The most common type of hearing loss in older adults is sensorineural hearing loss and is typically caused by changes to the central and peripheral hearing structures due to age related changes, noise exposure, ototoxicity or genetic factors (Katz, 2015). For the majority of older adults that acquire a hearing loss, the deterioration is generally gradual in decline, occurring over many years (Howarth & Shone, 2006). Usually those people with hearing impairment are unaware of the effect the hearing loss is having on their ability to communicate and it is often loved ones or significant others that instigate the initial investigation into treatment. Traditionally one of the most common forms of intervention for people with hearing loss is amplification provided by either hearing aids or some form of assistive listening device.

Hearing aids can provide amplification to address the deficit associated with the hearing loss, allowing the hearer to detect speech and environmental sounds but their ability to comprehend this information may be flawed (Henshaw & Ferguson, 2013).It is suggested that aging related declines in cognitive processing resources, such as working memory and executive function (Tun, Williams, Small &Hafter, 2012) and a decline in mental processing speed (Eckert, Keren, Roberts, Calhoun& Harris, 2010)can lead to a diminished ability to comprehend and remember speech. Interestingly, the inability to understand speech in challenging listening environments with competing background noise is one of the most commonly reported problems for people with hearing impairment (Katz, 2015).This may explain why approximately 15% to 20% of older adults using hearing aids find they receive less than satisfactory outcomes with their hearing aids and approximately 5% to 15% of hearing aids end up in the drawer, either no longer used at all or only worn very occasionally (Kochkin, 2010).

Given that individuals with similar audiometric results report variability of outcomes following hearing aid fitting, consideration needs to be given to other forms of complimentary therapies such as auditory training. There is mounting evidence suggesting that aural rehabilitation programs that include hearing aids and some method of formal auditory training can improve patient outcomes compared to hearing aid fitting alone (Anderson & Kraus, 2013; Beier, Pedroso & Costa-Ferreira, 2015; Henshaw & Ferguson, 2013; Sweetow & Palmer, 2005). Some of the benefits reported by individuals that undergo a combination of formal auditory training and hearing aid fitting are increased social interaction, improvement in quality of life and improved general well-being (Cardemill, Aguayo & Fuente, 2014).

Traditionally the aim of auditory training has been to provide a range of formal listening activities that aim to optimize speech perception (Boothroyd, 2010), improve the ability to pick up acoustic cues (Hassan et al., 2013) and provide compensation for deficiency in the auditory signal (Ferguson & Henshaw, 2015). Approaches to auditory training have typically been divided into either analytic (bottom-up) or synthetic (top-down) (Ross, 2011). Analytic training focuses on the elements of speech, providing coaching on identifying individual speech sounds by focusing on vowel and consonant recognition, focusing on the fundamental elements of speech (Katz, 2015). Synthetic training employs skills whereby the listener is required to focus on understanding the sentence meaning without focusing on competing noise and requires the listeners to engage their knowledge of language and context to fill in the gaps (Ross, 2011). Both methods aim to improve cognitive function and processes such as working memory, processing speed and attention switching (Lawrence, 2018).

Auditory training was originally used following World War II on returning veterans with noise induced hearing loss as part of their aural rehabilitation program and was delivered face to face by a clinician in a clinic environment (Ross, 1997). The delivery model has changed significantly over time thanks to increased access to computers and smartphones. There is now an expanding catalogue of auditory training programs available for hearing aid users to engage in at home and at their leisure. These computer-based programs are overcoming many of the difficulties that have prevented the use of auditory training in the past, such as inability to attend a face to face session in clinic, time constraints and expense of delivery. The central goal of these programs has been to make the training interesting for participates and more accessible by using computer programs that provide interactive components delivered at home, that provide improvement in speech perception and communication tactics.

With an increasing aging population, the number of people affected by hearing loss is estimated to grow significantly over the next twenty to thirty years. Improvement in hearing aid technology has improved outcomes slightly for hearing aid users, however poor performance in situations like reverberant environments and speech in background noise continue to be an issue, particularly for older adults (Kochkin, 2010). Cognitive resources are utilised to assist in these challenging listening situations, given this it is not surprising that this is a major factor that can undermine the success of treatment outcomes for individuals with hearing impairment (Kricos & McCarthy, 2007). Considering that decline in cognitive processing such as working memory, dividing attention, and speed of processing (Tun et al., 2012) are associated with aging (Murman, 2015),it is important that aural rehabilitation programs focus on treatments that include methods to potentially improve cognitive processes. With the mounting evidence regarding cognitive decline and hearing loss in the aged (Loughrey, Kelly, Kelley, Brennan & Lawlor, 2018; Murman, 2015; Tun et al., 2012), it is not surprising that there appears to be a renewed focus on auditory training amongst clinicians and researchers. Many studies have provided evidence regarding improved speech perception, listener confidence, reduced fatigue and heightened ability to focus (Dubno, 2013; Cardemil et al., 2014; Ferguson & Henshaw, 2015; Rao, Rishiq, Yu, Zhang, & Abrams, 2017) following participation in auditory training programs. With auditory training programs focusing on models to improve these cognitive processes, it is important to consider the efficacy of providing this service to hearing impaired individuals in conjunction with hearing aids.

The primary aim of this systematic review is to analyse existing research and determine if the inclusion of auditory training in an aural rehabilitation program provides additional benefit to adult hearing aid wears compared to rehabilitation programs that provide hearing aids alone. The results of this systematic review should provide information to adult rehabilitation clinicians regarding the efficacy of including some form of auditory training in their clinical practice. The question posed is: "When designing an aural rehabilitation program for the hearing impaired, are hearing aids the only solution or does auditory training assist to further improve speech discrimination and communication outcomes"?

METHODS

Types of studies

The studies selected for inclusion in this systematic review were those that used a medium to high level of evidence and included randomized control trials, within group repeated measures or before/after with control group, all other research designs were excluded from this evidence-based search.

Types of participants

Participants in the studies selected were required to be adults (≥ 16 years old) with postlingual bilateral sensorineural hearing loss. For inclusion the reported pure tone average was required to be greater than 25dB hearing level (HL) in the better ear averaged across three frequencies (500Hz, 1000Hz and 2000Hz), pure-tone thresholds no better than 40dB in the better ear at either 1000Hz or 2000Hz or the description of the hearing loss was noted as mild to moderate, which WHO (2013) defines as being mild 26 to 40dB HL or moderate 41 to 60dB HL. All participants were currently wearing hearing aids and were either new or experienced users.

Types of interventions

The accepted methods of auditory training intervention included were computer-based software packages performed on-line or programs delivered via DVD at home. Participants performed intervention tasks that required them to use either analytic training (bottom-up) which focuses on individual sound recognition and words rather than whole sentences or synthetic training (top-down) which involved approaches such as improved hearing attention, use of context and repair strategies that focus on gaining enhanced meaning of the message (Ross, 2011) or a combination of both tasks.

Types of outcome measures

Outcome measures performed in the selected studies were either behavioural or electrophysiological measures or a combination of both. The primary outcome measures collectively used across all studies were: Words in Noise Test (WIN) (Wilson, Carnell & Cleghorn, 2007), Revised Speech in Noise (R-SPIN) (Bilger, Nuetzel, Rabinowitz, & Rzeczkowski,1984), Hearing in Noise Test (HINT) (Nilsson, Soli & Sullivan, 1994), Connected Speech Test (CST) (Cox, Alexander & Moore, 1987), Rapid Speech Test (RST), Competing Word Test (CWT), Digital Span (DS), Speech in Noise Test (SIN), Memory for Verbal Sounds (MVS), Memory for Nonverbal Sounds (MNVS), Word Recognition Score Tests (WRS), Synthetic Sentence Identification (SSI) (Speaks & Jerger, 1966), sound localization, speech perception test, cognitive test and electrophysiological testing. Secondary outcome measures were subjective in nature and looked a patient reported outcomes for both hearing and health quality of life, these included: Abbreviated Profile of Hearing Aid Benefit (APHAB) (Cox & Alexander, 1995), Hearing Handicap Inventory for the Elderly (HHIE) (Ventry & Weinstein, 1982), Communication Profile of Hearing Impaired (CPHI) (Demorest & Erdman, 1987), Device Oriented Subjective Outcome Scale (DOSO) (Cox, Alexander & Xu, 2014).

Search Strategy

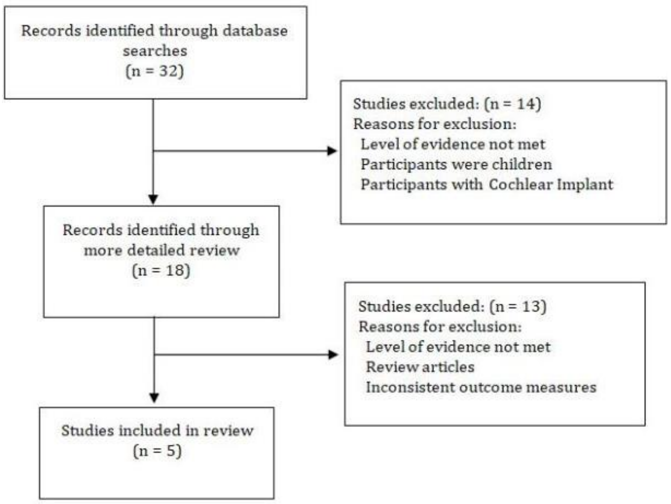
This systematic review of literature followed guidelines explained by Perestelo-Pérez (2013). A comprehensive investigation was undertaken by means of a computerised database search in PubMed, Medline, Google Scholar, Science Direct and Microsoft Academic. A combination of the following key words was used to conduct the search: “adult” and “hearing impaired” or “hearing loss” or “hearing aids” or “hearing difficulties” and “auditory training” or “aural rehabilitation” or “auditory rehabilitation” or “communication training” or “hearing training” or “speech training”. Limiting factors for the search were adult participants and publications in English language, no restrictions were placed on year of publication.

Selection of Studies

A total of thirty-two articles were identified during the computerized database search and a preliminary review of article abstracts was undertaken with regards to selection criteria. Fourteen articles were eliminated following this initial review of abstracts, with the remaining articles retrieved and evaluated thoroughly. Following this detailed review, a further thirteen were eliminated based on inclusion criteria leaving five articles to be reviewed. Figure 1 is a flow chart which provides information regarding the process of exclusion.

Figure 1.

Flow chart of search results



Data Extraction

The information extracted from the studies included: study design, methods of randomization and blinding, inclusion and exclusion criteria, type of intervention and control, outcome measures and statistical tests. For both the intervention and control groups, data extraction included: participant characteristics (number, sex and age), details of their hearing loss (mean, standard deviation or range) and participant adherence to the training intervention. Where available for both the intervention and control groups, further information was extracted that related to participants experience with hearing aid use and hearing aid information (bilateral or monaural hearing aid fittings, style of device fitted, prescriptive fitting formula and fitting verification procedure used if reported).

Assessment of Quality and Risk of Bias

Six measures were used to assess study quality and methods adopted to minimize bias: control group, level of evidence (study design), blinding, power calculations, validated outcome measures, inclusion/exclusion criteria and participant drop out. Measures were rated as either meeting criteria, not meeting criteria or information not available and are summarized in Table 1.Three of the five studies were randomized control trials (Bock & Abrams, 2014; Gil & Iorio, 2010; Saunders et al., 2016), which offer the highest level of evidence, four reported inclusion of a control group (Bock & Abrams, 2014; Gil & Iorio, 2010; Kricos & Holmes, 1996; Saunders et al., 2016) and only one study incorporated blinding (Gil & Iorio, 2010). Due to differences in heterogeneity between the studies concerning training protocols, outcome measures implemented and participant variables, it was not possible to group results across all studies and a narrative synthesis is provided to assist with elucidation of outcomes across the five studies in this review.

Table 1.

Summary of Study Quality

Study	Level of Evidence	Control Group	Blinding	Power Analysis	Inclusion Exclusion	Validated Outcome Measures	Drop-outs Discussed
Kricos & Holmes (1996)	1	Y	N	N	Y	Y	N
Gil & Iorio (2010)	3	Y	Y	N	Y	Y	N
Henshaw & Ferguson (2014)	2	N	N	N	N	N/A	N
Bock & Abrams (2014)	1	Y	N	N	Y	Y	Y
Saunders et al. (2016)	1	Y	N	N	Y	Y	Y

Notes: 1 = randomized control trial; 2 = Within-participant repeated measure; 3 = Before/after with control group; Y = yes; N = no; NA = information not available

Results

Table 2 provides a summary of information extracted from the five studies selected for this review and includes study design, participants, interventions used, outcome measures and results. There were a total of 430 participants across the five studies with ages ranging from 16 to 85 years. Only one study included younger participants aged 16 years and older (Gil & Iorio, 2010), with the other four studies (Bock & Abrams, 2014; Henshaw & Ferguson, 2014; Kricos & Holmes, 1996; Saunders et al., 2016) focusing on older participants aged 60 years or above. Only one study had a sample size of over 40 participants (Saunders et al.2016) per group, with the other studies varying from 7 to 30 participants per group. Kricos & Holmes (1996) was the only study that provided information on gender and included a fairly even distribution of both maleand female participants in the study with similar demographic information. All of the studies included participants that were wearing hearing aids full time and one study separated hearing aid wearers into either new user (worn hearing aids < 6 months) or experienced user (worn hearing aids for > 6 months) (Saunders et al., 2016). Other inclusion criteria commonly applied across studies was that participants had a sensorineural hearing loss described as mild to moderate, have English as their first language, have corrected vision and have no evidence of dementia or cognitive disturbance.

Henshaw & Ferguson (2014)	Within-participant repeated measure	*N* = 30, *M* age= 67.4 years. Sex not reported	At home training using IHR-STAR, Competing speech task, Letter-number sequencing task, Dual-task of Listening and Memory 7 consecutive days, 2 x 15-minute sessions per day	Speech Perception Test (IHR-STAR, MCRM) Cognitive Test (WAIS-III)	Significant improvement shown for trained IHR-STAR tasks ($p < .001$) Significant transfer of learning to improvements in competing speech ($p < .05$) Significant post intervention improvement for Dual-Task of Listening and Memory ($p < .001$)
Bock & Abrams (2014)	Randomized Control	*N* = 29, sex not reported. Treatment Group (RMQ) *N* = 14, *M* age = 65.6 years, Control Group *N* = 15, *M* age = 61.8	At Home RMQ training program 3 x weeks, 30-minute session each day No training	HINT WIN APHAB DOSO	Significant improvement in HINT and WIN tests ($p < .05$) shown in RMQ group
Saunders et al. (2016)	Randomized Control	*N* = 279 adults *M* age = 68.5 years sex not reported LACE-DVD Group *N* = 68, *M* age = 68.2 years LACE-C Group *N* = 65, *M* age = 69 years Placebo Group *N* = 73, *M* age = 67 years Control Group *N* = 73, *M* age = 69.9 years	LACE-DVD home based training 2 weeks, 5 x per week, 30 minutes LACE-C computer-based home training 4 weeks, 5 x per week 30 minutes Placebo group home-based digitized book listening activity 4 weeks, 5 x per week, 30 minutes Control Group 1 x one-on-one 30-minute educational session with Audiologist	WIN Rapid Speech, Competing Speaker DS R-SPIN APHAB	No significant differences between AT (LACE) groups, Placebo or control

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Training interventions, number of training sessions and training period varied considerably across the five studies. Two studies employed analytic training that involved verbal repetition, pointing to sentences, figures and completing puzzles (Bock & Abrams, 2014; Gil & Iorio, 2010) and three studies focused on an intervention with both analytic and synthetic training (Henshaw & Ferguson, 2014; Kricos & Holmes, 1996; Saunders et al., 2016). Two of the studies involved training programs totalling eight hours which was completed over a four-week period and was made up of one-hour session performed twice a week (Gil & Iorio, 2010; Kricos & Holmes, 1996). Another study varied slightly from this with a total of ten and a half hours of training across a three-week period involving thirty minutes of training each day (Bock & Abrams, 2014). One study had a much shorter training period, only 7 days with a total of three and half hours training which consisted of two fifteen-minute sessions per day (Henshaw & Ferguson, 2014). One study had training programs that varied across the two intervention groups, with one group receiving a total of five hours training delivered over two weeks with five thirty-minute sessions each week and the other received a total of ten hours training over four weeks with five thirty-minute sessions each week (Saunders et al., 2016).

Compliance to the training programs was reported by three of the five studies, with Bock & Abrams (2014) recording very low compliance, only four of the fourteen participants completing the full training task of 630 minutes and one participant in the intervention group did not complete the program. Henshaw and Ferguson (2014) did not indicate the dropout rate of participants in the study, but reported the average time the participants spent on the training task was 197.8 minutes which was less than the 210 minutes required to complete the intervention program design. Saunders et al. (2016) indicated that compliance was measured differently across the two intervention groups. The LACE-DVD relied on patient reported compliance which was approximately 85% following completion of the ten sessions. For the LACE-Cgroup data was accessed from the LACE server and of the 65 participants in this group data was retrieved from 50 and compliance was 84%, with 42 completing all 20 training sessions. Compliance with the training program and participant dropout rate was not reported in the studies performed by Gil and Iorio (2010) or Kricos and Holmes (1996).

Outcome measures varied across all studies and include a combination of behavioural measures, electrophysiological evaluations and self-reported questionnaires and the results can be seen following review of Table 2. All studies implemented at least one of the following validated behavioural speech in noise tests(SIN, WIN, R-SPIN, CST, HINT or MCRM)and with the exception of one, Saunders et al. (2016),all reported statistically significant improvements following auditory training intervention. The study by Kricos and Holmes (1996) included two treatment groups; one underwent analytic auditory training and the other active listening training. Speech recognition was measured using CST under two conditions, auditory alone and auditory-visual, compared to the analytic and control group, the active listening group showed improvement in speech recognition post training for auditory-visual condition. Two studies reported significant improvement in speech in noise on the HINT and WIN (Bock & Abrams, 2016) and SIN (Gil & Iorio, 2010) for the intervention group following treatment. Gil and Ioria (2010) examined results from other behaviour tests focusing on speech perception and memory with statistically significant results for sound localisation, dichotic digits, MNCS and SSI tests. The study by Henshaw and Ferguson (2014) found a significant main effect of time on speech reception thresholds using the MCRM. They also reported results for on-task learning and found a highly significant main effect of both block and phoneme discrimination over time, suggesting generalisation of on-task learning.

A number of studies reported on measures of self-reported hearing handicap with Gil and Iorio (2010) demonstrating an improvement in reverberation and background noise sub-scale on the APHAB following auditory training intervention. Kricos and Holmes (1996) demonstrated a significant main effect for the verbal, nonverbal and behaviour subscale in the active listening group as measured by the CPHI, but did not find any treatment effects when using the HHIE to assess self-reported hearing difficulties. Both Bock and Abrams (2016) and Saunders et al. (2016) investigated hearing handicap measured by using the APHAB and found no significant improvement post training between groups. Bock and Abrams (2016) also measured hearing aid outcome using the DOSO and again found no significant improvement post training between groups. Of the other studies that measured self-reported hearing handicap, none reported any significant improvement post training. Only one study reported on electrophysiological evaluations (Gil & Iorio, 2010) and found a statistically significant reduction in P3 latency in the experimental group when comparing pre and post training evaluations.

DISCUSSION

The current review of literature on the benefit of auditory training as a complimentary rehabilitation tool indicates that there is evidence to support the use of auditory training in conjunction with hearing aids for adults with hearing loss.

Findings from the present review reported significant improvement in some of the behavioural auditory processing test results for both on-task-learning and untrained measures following completion of the various auditory training programs in four out of five studies. Improvement in speech recognition and perception following trained tasks was also significant and supported results from previous studies (Beier et al., 2015;Lawrence et al., 2018). This suggests that there may be potential for generalisation of learning to provide real world benefit for speech intelligibility and speech perception following auditory training. However, in a previous study on the effectiveness of auditory training these results were not reported (Sweetow & Palmer, 2005) with little evidence supporting transfer of learning to real world benefit after auditory training.

Findings from this review regarding subjective outcome measures on hearing handicap indicated improvement following intervention in only two of the studies. These results could have been due to a lack of homogeneity in the outcome measures used across the five studies. Only three of the five studies used APHAB as one of the subjective outcome measures, with two of these studies reporting significant improvement on pre to post results following training for the intervention groups (Brock & Abram, 2014; Gil & Ioria, 2010).Both studies found participant perceived improvement in reverberant environments and background noise, with Brock and Abram (2014) also reporting improvement with ease of communication. These outcomes suggest that following auditory training there may been a potential effect that improves cognitive function to allow the participant to better cope in situations that typically require more cognitive load (Tun et al., 2012).

The studies selected had various study designs and included within-participant repeated measure, before and after group design and randomized controlled trials. Only three of the studies implemented randomized controlled trials which provided the highest level of evidence. One of the studies reported a design of doubling blinding (Gil & Iorio, 2010), which provided even greater level of evidence and more strength to the evidence obtained. One of the randomized controlled trials (Saunders et al., 2016) described masking (blinding) of the two intervention groups and the placebo group only, not the control group or clinicians administering the treatment. Participant numbers varied across the studies in this review with the smallest group made up of seven participants (Gil and Iorio, 2010) and the largest group with 73 (Saunders et al., 2016) and all lacked power calculations. Intervention duration varied significantly across the studies from seven days and ranging up to four weeks. None of the studies reported on long term outcomes following auditory training unlike in previous studies (Dubno, 2013).

A weakness of the current review is the lack of study quality reported above, which is low across all studies included in this review. There is a lack of homogeneity between the studies regarding outcome measure, study design, participant numbers and reporting protocol. These factors may result in a number of study bias and weaken the validity of the findings in the current review.

This review has demonstrated that auditory training for adults with a hearing loss as complimentary intervention may provide additional benefit over hearing aids alone. However, inconsistencies and weakness in the research studies provides weak to moderate evidence on the efficacy of auditory training to improve speech perception, intelligibility and cognitive processing for adults with hearing loss. Future studies should focus on high level evidence, the standardisation of outcome measures and long-term outcomes across training protocols to adequately assess the efficacy of auditory training as an intervention for adults with hearing loss.

References

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Author, A. A. (Year of Publication). *Title of Book*. Publisher.

Smith, J. A. (2005). *The Dynamics of Urbanization*. Academic Press.

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