Effectiveness of auditory perceptual learning programs in enhancing speech recognition in noisy environments for adults with sensorineural hearing loss

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ABSTRACT

Since hearing loss is typically associated with ageing, it is very common in the senior population. When elderly individuals with hearing impairments are in loud environments, problems arise. Even the hearing aids malfunction in these places, which poses a serious problem for those who are deaf or hard of hearing. This research aims to analyse the effectiveness of auditory perceptual learning programs in enhancing speech recognition in noisy environments for adults with sensorineural hearing loss. In this research context a systematic literature review has been chosen as the research methodology. A total of 12 articles have been chosen for the review process. Thematic analysis has been performed with the data extracted in the data extraction table. After conducting the systematic literature review it was found that the beneficial effects of auditory training on speech recognition, language development, cognitive skill development, speech improvement, and reacting better to untrained behaviours has been made clear by the critical examination of major data. For adults and children with hearing loss, cochlear implantation and auditory perceptual learning programs have demonstrated significant practical benefits. The research highlighted that several types of auditory training, including focused perceptual learning, music training, and pitch training, significantly influence neuroplasticity and enhance speech recognition skills.

Keywords: *Auditory perceptual learning, speech recognition, noisy environments, sensorineural hearing loss, auditory training, cochlear implants, neuroplasticity, language development, speech-in-noise perception, cognitive skill development*

INTRODUCTION

Hearing loss is mostly accompanied by ageing and is thus highly prevalent among older adults. According to a research paper, older adults affected by hearing loss use hearing aids (HAs) to compensate for their health condition (Karawani et al., 2016). However, the problem happens when older people with hearing issues are exposed to noisy areas. In these areas, even the HAs fail to function properly, creating a major issue for the people affected by hearing loss.

The benefits of HAs have been observed to be inconsistent and therefore it has been a focus of recent research too. Previously published studies have shown that HA benefits are primarily lowered in noisy environments (Woods et al., 2015). This means that user satisfaction with HAs decreases in noisy regions. Thus, the benefits of HA can be considered to be subjective in nature and also dependent on the type of environment to which the older people are exposed. Even though HAs are installed with advanced tools to reduce background noise, people still face issues in speech recognition in noisy environments.

A systematic review paper has shown that people affected by hearing impairment mostly benefit from using HAs in noisy areas, only when they are subjected to a combination of sensory rehabilitation training with HAs and training to enhance auditory rehabilitation also (Henshaw & Ferguson, 2013). In other words, it has been observed that users, who spent years in hearing to attenuated speech due to impairment of hearing functions, can now hear clearly in noisy regions after getting trained by the above-mentioned combinatorial training program. But that is not the only evidence for the benefits of training programs in enhancing speech recognition in noisy regions.

Objectives:

RO1: To assess the extent to which auditory perceptual learning programs improve speech recognition abilities in noisy environments for adults with sensorineural hearing loss.

RO2: To investigate the long-term retention of enhanced speech recognition skills in noisy environments among adults with sensorineural hearing loss who have completed auditory perceptual learning programs.

RO3: To compare the effectiveness of various auditory perceptual learning program regimens (e.g., duration, intensity, and type of exercises) in improving speech recognition in noisy environments for adults with sensorineural hearing loss.

Aim 2: long-term outcomes of cochlear implantation in prelingually deaf children by conducting a review of speech and language development.

RO1: To systematically review and evaluate the long-term speech development outcomes in prelingually deaf children who have undergone cochlear implantation.

RO2: To assess the progress in language development over the long term in prelingually deaf children following cochlear implantation.

RO3: To identify and analyse factors that influence the variability in long-term speech and language development outcomes in prelingually deaf children with cochlear

implants, such as age at implantation, duration of device use, and post-implantation therapy.

RH1: Auditory perceptual learning programs will not significantly enhance speech recognition in noisy environments for adults with sensorineural hearing loss compared to those who do not undergo such training.

RH2: Auditory perceptual learning programs will significantly enhance speech recognition in noisy environments for adults with sensorineural hearing loss compared to those who do not undergo such training.

RH3: There are no significant long-term improvements in speech and language development in prelingually deaf children who have undergone cochlear implantation compared to those who have not received the implantation.

RH4: There are significant long-term improvements in speech and language development in prelingually deaf children who have undergone cochlear implantation compared to those who have not received the implantation.

REVIEW OF LITERATURE

A recent research study has stated that home based auditory exercise programs are significantly effective to guide users to the adaptation process for HA (Whitton et al., 2017). This specific program was mainly developed during the COVID 19 pandemic, when people mostly stayed at their residence. The findings have revealed that participants generally faced hearing issues even after using HAs, only when they were exposed to noisy areas. In other words, it can be said that the overall perception of speech was poorer in noisy areas than in quiet areas.

There are two major theories that are in line with the chosen topic of the research. The first theory is known as the Perceptual Learning theory. Additionally, the second theory is known as the Signal Detection Theory. The perceptual learning theory has been observed to posit that continuous exposure to specific stimuli makes the brain effective in improving its capability to process sensory information. In other words, adults affected by hearing loss, who are subjected to auditory training programs to enhance their speech recognition are associated with this specific theory (Olson, 2015). On the other hand, the signal detection theory primarily aims to make people capable to discern speech from background noise. This means that the theory promotes the process of differentiating the hearing decision making process of people during the presence and absence of a specific stimuli. Thus, it is highly effective in boosting the effect of auditory training programs to restore speech recognition abilities among HA users in noisy regions.

Need of the study

However, the problem arises from the contradictory findings from some pieces of literature, which shows that auditory training does not always have bigger effects (Bieber & Gordon-Salant, 2021). This means that the training process cannot be generalized for a large and diverse population. For example, a 4 week home based training program was ineffective in enhancing speech recognition among the members of the residence who utilised HAs on a regular basis. Thus, the current research has been performed to solve

this contradiction that exists in the knowledge base surrounding the study topic.

METHOD

Aim of the study

To analyse the Effectiveness of Auditory Perceptual Learning Programs in Enhancing Speech Recognition in Noisy Environments for Adults with Sensorineural Hearing Loss.

Inclusion criteria

- Articles which are within 5 years were chosen for this study because many changes have been brought under auditory perceptual learning programs in recent times. It can be said for speech recognition in noisy environments as well.
- Only peer-reviewed articles were chosen with respect to this study. This is because of its reliability as well as credibility (Carneiro et al., 2020). Apart from that, scientific rigor and contribution to knowledge are several other factors which should not be ignored as well.
- Only English articles or reports were selected for conducting this research. No other languages were chosen in spite of having relevance and appropriateness of the topic.

Exclusion criteria

- Articles which are related to only one main keyword were excluded from the selection procedure. A minimum of two main keywords were required to be there in the article.
- Sources that did not have an overall analysis were strictly avoided because of the maintenance of quality in the study and in the overall procedure (Lynas et al., 2021).
- Any articles which were not opened in full PDF format were excluded from the selection criteria as well.

Procedure

In order to get accurate sources, specific keywords have been used, that comprises, “Auditory perceptual learning programs”, “speech recognition in noisy environments” and “sensorineural hearing loss” are some of the important keywords selected with respect to the particular study. Both inclusion and exclusion criteria were included in the process of search strategy. Along with these, Boolean operators like AND, NOT, and OR were also included in the process (Scells et al., 2021). Some articles were found which were based on English, but these were relevant and informative. Still, these were not chosen under the selection procedure.

Prisma flow diagram was followed in the screening and selection process. The details can be understood from the flowing diagram.

Based on the above figure, it can be said that a total of twelve articles were chosen at the end which would help in mitigating all objectives of the study. In the initial screening, it was decided that twenty sources would be chosen but later eight were included for different kinds of reasons like language rigidity and irrelevant information.

In order to extract data, a Data Extraction table was followed. A moderate one is considered in this case, and it can be well understood from the above table.

Table 1.

Format of data extraction table

Sl. No.	Author and Publication Year	Title	Study Design	Findings and Conclusion

From the above table, it can be said that there are five factors addressed in the table. All these factors are helpful to mitigate research objectives and research questions. Many words were not included in the column of Study Design.

A six-step process was followed under data synthesis with respect to this particular topic. It includes integration of findings, comparing and contrasting results, summarizing the evidence, drawing new conclusions, handling heterogeneity, and contextualizing the results (Dissanayake et al., 2020). Data interpretation is another important thing which should not be ignored as well. The importance of thematic analysis is also required to be mentioned as well. Considering the second stage, it can be said that consistency was followed properly and therefore findings look reliable. One of the most important parts of this is to identify the gap which was mitigated in the later stage (Saharan et al., 2020).

In order to conduct this study, only qualitative data was chosen, and based on these articles were selected. It would be better if quantitative data could be incorporated into the overall process. In this case, the number of articles might be increased but it would provide much better results (Fox et al., 2020). It can be considered as a limitation of the study. There were several articles which were not chosen because of took time in the process of getting permission from the author. These could include valuable sources and therefore it can be considered another limitation in the present study.

Information from the sources selected was directly used during the analysis procedure. The aspect of interpretation of data can be mentioned in this regard as well. On a different note, it can be said that non-manipulation of data was followed in the overall process (Kang & Hwang, 2021). The personal opinion of the researcher was not included in the process. It is already mentioned in the above section that old information was not selected in this study and this factor can be mentioned under the ethical aspect as well.

From the above discussion, it can be summarized that a total of twelve articles were chosen for the analysis and interpretation of data. Any sources which are older than five years were totally excluded in this study. Only English sources were included in the overall process. Different keywords were chosen for search strategy, but articles were not chosen based on only one article. A Prisma diagram is followed, and the overall analysis could be understood well from the above-mentioned figure. Non-manipulation of data was followed under ethical consideration. The non-use of quantitative articles can be addressed as a limitation in the study.

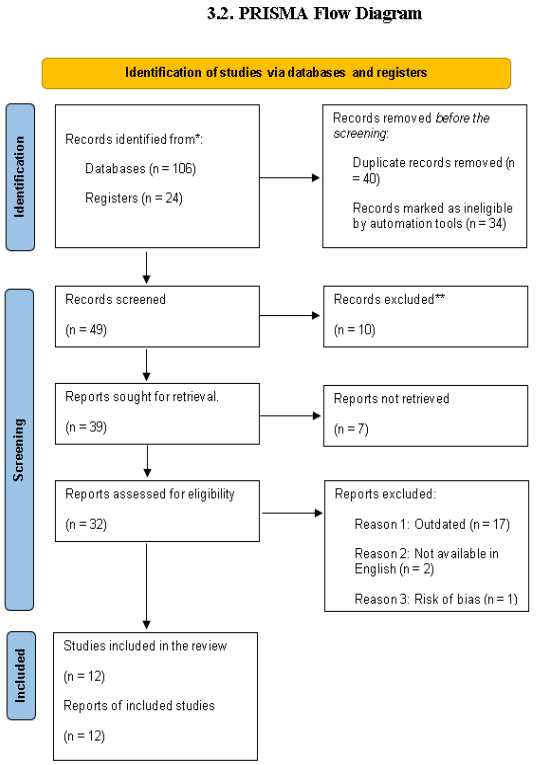
RESULTS

Within this chapter, a discussion is going to be highlight all data that are collected for the investigation and also all the findings those revealed from the collected data through the

thematic analysis. Creating a data extraction table all the collected data are showcased and using thematic analysis all the uncovered patterns and themes will be identified and provide a comprehensive understanding of the topic to the readers.

Figure 1.

PRISMA flow diagram



The studies presented in Table 2. (see **APPENDIX**) have delivered a variety of studies where both primary and secondary methodologies are present. The focus of most of these studies was on auditory training, cochlear implants, and speech-in-noise recognition among diverse populations. The characteristics of these studies involved mainly small to medium sizes of sample populations where children and adults were participants. The prevalence of longitudinal and cohort methodologies is evident. Cochlear implants, music training and auditory perceptual learning programs have been examined frequently as medical interventions to improve speech recognition in noisy environments.

In the case of risk of bias, the table mentioned several authors whose works imposed mild risk of bias. The small size of the sample, as mentioned in the study of Grandon & Vilain (2020) has limited the scope of generalisability. In addition, the study of Schneider et al. (2022) did not offer a comprehensive methodology which made it difficult to examine the robustness of the results. Moreover, the articles which relied on self-reported data have the potential of bias, in terms of inconsistent reporting and participant attrition.

Analysing the extent to which auditory perceptual learning programs improve speech recognition abilities

According to Bieber & Gordon-Salant (2021), auditory trainings and perceptual learning programs have significant impacts on older people. The findings of this study revealed that these training programmes and learning programmes help in improving the ability to effectively understand speech within challenging environments. In addition, the study of Gao et al. (2020), the finding of this study is highlighted that auditory trainings and perceptual learning not only benefited people in effectively improving speech recognition in specific contexts but also border areas such as new and untrained contexts. In noisy environments, this ability plays a significant role in effectively recognised speech. Both of the studies highlight a positive as well as

measurable impact of auditory trainings and perceptual learning programmes on speech resignation skills in a complex environment.

Impacts of auditory perceptual learning programs

The study by Lo et al. (2020) highlighted that there is a huge role of music training in improving speech in noise perception among the children who have prelingual sensorineural hearing loss. The findings of the study revealed that music training improved the neuroplasticity in auditory processing. As auditory functions are important for the recognition of speech, this indicates how music training has an important role in improving speech recognition abilities in noisy environments for adults with sensorineural hearing loss. Moreover, in the study of Gohari et al. (2023), different types of auditory perceptual learning programmes impacts are highlighted such as pitch training, fundamental frequency training, localisation training, and temporal training that help in improving the speech recognition ability of the targeted population. Both of the studies provide an effective understanding of this topic.

Comparing the effectiveness of various auditory perceptual learning program regimens

In the study by Schneider et al. (2022), the author highlighted that short-term auditory training has moderate effectiveness in improving speech recognition. Within this study, the authors are focused on the duration and highlight how music trainings acted as effective auditory training and has moderate effectiveness in improving speech recognition. The study of Mastromarino (2022), revealed that high-intensity programmes have the potential to effectively improve cognitive functions. The high duration such as 12 weeks and high-intensity programmes are appropriate in improving speech recognition in noisy environments for adults with sensorineural hearing loss.

Evaluating impacts of cochlear implantation

According to Rasmussen et al. (2022), the targeted population has cochlear implants (CI) reported significant improvement in both patient-oriented outcomes as well as speech perception. Within the study, the data was collected from the prelingually deaf population, and it is noted that through auditory learning there is a significant improvement in speech recognition over time. This helps in effectively improving the quality of life of adults. In addition, the findings of the study also highlighted how CI leads to a long-lasting improvement in speech understanding in both quiet as well as noise conditions. The noise and quiet conditions are noticed in everyday settings in effective speech understanding different conditions in everyday settings are crucial for people who have CI implants. Furthermore, the study by Grandon & Vilain (2020), also revealed that CI implants have the potential for long-term outcomes in speech production and recognition. The CI impacts children who experience lower pitch frequencies, different vowel effects and others. Both of the studies contributed to providing a better understanding of the long-term speech development outcomes in prelingually deaf children who have undergone cochlear implantation.

Progress in language development over the long term after cochlear implantation

According to Scarabello et al. (2020), children with CI have experienced an improvement in understanding oral language over time. The other finding revealed from this study is the improvement in expressive language skills by the targeted population who have CI. The other finding that is highlighted by reviewing this literature is cochlear implants at an early stage have better improvement in the understanding of oral language for children. Moving forward, according to the study by Kronenberger *et al.* (2020), the targeted population with CI have a much higher vocabulary growth compared to the other targeted group. The findings of this study have also revealed that the PLS-4 score is much higher among people who have cochlear implants. Both of the studies highlighted valuable information on the topic.

Factors that influence the variability in long-term speech and language development outcomes

Analysing both of the studies such as Mateus (2021) and Hassanzadeh et al. (2021), the duration of cochlear implications in the targeted population and age in cochlear implicated in the targeted population are the factors that influence the variability in long-term speech and language development outcomes. Implication of cochlear at an early stage has a more positive impact on speech development compared to the late cochlear implants in the targeted population. Both of the studies provide real-world information and achieve the targeted objective of this study.

Analysing the overall discussion, it can be said that auditory perceptual learning programmes have a positive role in enhancing speech recognition in noisy environments for adults with sensorineural hearing loss. Though this programme's cognitive function is improved motivates the targeted people to leverage these programmes. On the other hand, the findings also revealed the positive impacts of CI in the context of speech recognition production and understanding oral language. These findings also allow it and the implication of the findings in real-world context ensured better patient outcomes. Though some risks are also noticed, through careful investigations those can be mitigated.

DISCUSSION

In this chapter of the review, a comprehensive design has been prepared to broaden the scope of discussion on the findings achieved in the previous chapter. The chapter has discussed each section mentioned below following the guidelines in the PRISMA checklist to avoid facing the structural essence of this review. The first key section has presented the discussion on findings from the themes mentioned in the previous chapter. In the next part, the existing limitations of this entire review and the process of this study have been discussed with great concentration. Therefore, the implications of this review have been concisely discussed. It should be mentioned that the implications have been discussed with a concentration on future practice, policies, and research. At the end of this chapter, an overview has been presented to summarise the discussions under this chapter.

The findings of this study have been presented under different themes that reflected the key aspects of the same. Under the first theme of findings, the extent of auditory perceptual learning programs has been analysed to understand if they could improve the abilities of speech recognition among adults with hearing loss. The findings of Bieber & Gordon-Salant (2021) have strongly shown that auditory training and perceptual learning programs are quite impactful for the aged population. In noisy environments, where hearing-impaired people face the most challenges, the benefits of auditory training and perceptual learning can be observed. It has been shown that aged people with hearing impairment have benefitted from the auditory and perceptual training programs in recognising speech in noisy environments (Tye-Murray et al., 2021). Furthermore, the study of Gao et al., (2020) has shown that adult people can be helped through auditory training not just in case of recognition of speech, but also in case of untrained and new situations. Thus, it can be stated that auditory training is a necessary initiative to help aged people who lost their hearing (Tuz et al., 2021).

Under theme two of this review, the impacts of auditory perceptual training programmes on adults who have lost hearing have been concentrated. The reviewed study by Lo et al. (2020) stated the significance of music training for the focused population within a noisy environment. The improvement of neuroplasticity has been reported by the study of this author, which is an impact of music training. The study has created a great link between the improvement of speech recognition and music training through its findings. The multiple impacts of the auditory perceptual learning programmes have been examined by Gohari et al. (2023). The training included frequency training, pitch training, localisation training, and temporal training. The impact of this training was the improvement of the recognition ability of speech among the targeted population. Thus, adults with hearing impairment should consider involving in music training, pitch training, localisation training, and frequency training for better speech recognition (Lerousseau et al., 2020).

The third theme of this review has compared the effectiveness of multiple auditory perceptual learning programmes. Schneider et al. (2022) mentioned that mild effectiveness can be received from auditory training if it is designed for the short term. This outcome of the study has implied that adults with hearing issues should take long-term auditory training to improve their speech recognition ability. This decision can be supported by the conclusion of another article reviewed in this study. Mastromarino (2022) has mentioned that the cognitive functions among trained individuals can be improved through long-term and high-intensity auditory training programmes. Moreover, the author also argued that auditory training programmes should be 12 weeks for better effectiveness of cognitive skills and speech recognition among people. However, the study of Chae et al., (2023) found no statistical difference when two groups were included in auditory training where one group spent more than 600 minutes, and another spent less than 600 minutes.

Under the fourth theme of this review, the impacts of cochlear implantation have been evaluated. The reviewed study by Rasmussen et al. (2022) found that the study people who have accepted cochlear

implantation have benefitted. There was a prominent enhancement in the speech perception and other cognitive skills of people who had cochlear implantation. The significance of this reviewed article lies in the fact that it determined the intricate benefits of cochlear implantation within a noisy and quiet environment. This intervention has shown quite an improvement in speech recognition capabilities among people with hearing loss (Abdel-Latif & Meister, 2022). Grandon & Vilain (2020) noted the significant potential of cochlear implantation for speech production as well as recognition. Therefore, the adoption of cochlear to improve basic cognitive ability is supported and proven which should be used for future applications.

In these five, the progress in language development over the long term after the cochlear implantation has been explored. The study by Scarabello et al. (2020) mentioned that the understanding of oral language among children after the cochlear implantation has improved. People with cochlear implantation have also shown dynamic improvement in expressive language skills. In addition, children had a better understanding of language in the early stages of cochlear implantation. Moreover, the reviewed study by Kronenberger *et al.* (2020) seemed to provide similar observations as mentioned by Scarabello et al. (2020). Both the studies under this theme have revealed that hearing impairment can be supported crucially by vocabulary growth utilising cochlear implantation (Hilviu et al., 2021).

The factors to influence the variability in long-term speech and language development outcomes have been presented under theme six. The studies reviewed under this theme have combinedly mentioned that the duration of implantation of cochlear, and age are the key factors. Therefore, it can be drawn from these findings that the cochlear implantation process should be done at an early age for better improvement of long-term speech and language development (Purcell et al., 2021).

The primary limitation of this review is the presence of variability of methodologies of the reviewed studies. The difference in the sample size and demographics of the participants have created a limitation to providing universal outcomes. Therefore, as a result of this variability, the score of comparison while discussing the findings has been limited. For instance, some of the reviewed studies are longitudinal, and others examined the short-term benefits of auditory training programmes. Another limitation of the review is the possibility of bias in the case of publication. Most of the publications have shown positive results for the interventions. As a result, the scope of creating an argument and broadening the scope of future research has been limited. The presentation of inconclusive results or negative outcomes is not observed at all in this review. The review has another limitation which impacted the quality and validity of the study which is the involvement of psychological and socioeconomic factors' impact on the interventions. The inclusion of these aspects would have improved the chance of applicability of this review findings in the future.

There are prominent implications of research findings for future research, practice, and policy. In the case of practice, the application of auditory training programmes, auditory perceptual learning programmes, and

cochlear implantation should be facilitated for adults requiring speech recognition improvement. The facility should consider high-intensity training and long-term as well. The findings could generate an argument for policy change and review for the duration of auditory training programmes as a little misalignment of findings is prevailing yet. The existing policies for auditory training programmes for adults should be reviewed and compared in terms of duration and intensity. Therefore, future research scope should concentrate on investigating the long-term effectiveness of various types of auditory perceptual learning programmes on speech recognition for the adult population through longitudinal study design. The application of statistical analysis should be considered for future research as it can provide deeper insights into the unresolved queries related to training duration, intensity, effectiveness, lasting results, and duration of impacts on hearing-impaired adults.

To enhance the rigor and applicability of systematic reviews in the field of auditory interventions, several recommendations should be considered. First, researchers should strive for greater standardization in study methodologies, including participant selection criteria, sample sizes, and outcome measures. This would facilitate more effective comparisons across studies and improve the robustness of conclusions drawn from aggregated data. Additionally, future systematic reviews should prioritize the inclusion of studies that report negative or inconclusive findings, as this can provide a more balanced view of the interventions' effectiveness. Incorporating diverse populations and settings will also enrich the generalizability of results, allowing for insights that reflect a broader spectrum of experiences. Furthermore, a systematic approach to evaluating psychological and socioeconomic factors should be implemented, as these elements can significantly influence intervention outcomes. By addressing these limitations, systematic reviews can provide more comprehensive insights and foster a deeper understanding of how auditory training and cochlear implantation impact individuals with hearing impairments.

In this chapter, the author has focused on presenting a discussion on multiple aspects of this review. The major significance of this chapter has been laid upon the findings. The findings of each theme of this review have been critically analysed to identify the trends underlying the research subject. The critical discussion on key findings has revealed the potential of auditory training on speech recognition, language development, cognitive skill development, speech improvement, and improvement of responding to untrained actions. Auditory perceptual learning programmes and cochlear implantation have shown major practical implications for hearing-impaired adults and children. The limitations of this review have been presented in this chapter indicating the underrepresentation of inconclusive and negative results of auditory training and cochlear implantation. However, the review is significant yet as the findings can be implied in future studies to assess the impact of the reviewed interventions covering the gaps in existing literature and create a scope for auditory training policy review to reassess its effectiveness for adults.

CONCLUSION

The findings from this systematic review highlight the profound benefits of auditory perceptual learning programmes and cochlear implantation in enhancing speech recognition and language development for individuals with hearing impairments. This review synthesizes evidence from a range of studies, demonstrating that auditory training can significantly improve the ability to understand speech, particularly in challenging environments characterised by background noise. The importance of effective communication cannot be overstated, as it is fundamental to the quality of life and social interactions for those affected by hearing loss. The analysis reveals that various forms of auditory training such as music training, pitch training, and targeted perceptual learning contribute positively to neuroplasticity, enabling improved speech recognition abilities. These training programmes have been shown to enhance not only the immediate capacity for recognising speech but also broader cognitive functions that support communication in everyday life. The ability to discern speech in noisy environments is particularly critical, as many social situations involve background noise that can hinder understanding. The findings suggest that individuals who engage in structured auditory training programmes may experience significant gains in their ability to process and understand speech, thereby improving their interactions with others. Moreover, the review underscores the critical role of timing in cochlear implantation, especially for children. Evidence indicates that early intervention through cochlear implants can lead to more favorable long-term outcomes in speech and language development. This early engagement with auditory stimuli appears to be essential for maximizing the effectiveness of the cochlear device, as it allows for a more robust integration of auditory input during crucial developmental periods. The data point to a clear correlation between the age at which cochlear implantation occurs and the success of subsequent language acquisition, emphasizing the importance of timely diagnosis and intervention in cases of hearing loss. Despite the compelling evidence supporting the benefits of auditory training and cochlear implantation, the review also identifies several limitations inherent in the existing body of research. One significant concern is the variability in study methodologies, which includes differences in sample sizes, participant demographics, and assessment measures. This inconsistency raises questions about the generalisability of findings across diverse populations. For instance, studies with small sample sizes may yield results that are not representative of the larger population, leading to potential biases in the conclusions drawn. Additionally, the predominance of positive outcome reporting in the literature may obscure the existence of negative results or inconclusive evidence. Many studies tend to emphasize successful interventions, which can create an overly optimistic view of the effectiveness of auditory training and cochlear implantation. As a result, there is a critical need for more balanced reporting that includes a wider range of outcomes, allowing for a more nuanced understanding of the interventions' effectiveness. Furthermore, the review highlights the need for a more comprehensive approach that incorporates psychological and socioeconomic factors influencing the effectiveness of auditory interventions. These elements can

significantly impact individual experiences and outcomes, yet they are often underrepresented in the literature. By considering these factors, researchers can gain deeper insights into how contextual variables affect intervention success and develop more tailored approaches to meet the diverse needs of individuals with hearing impairments. Overall, the findings of this review advocate for a multifaceted approach to supporting individuals with hearing loss. Structured auditory training programs and timely cochlear implantation are essential strategies that can significantly enhance communication abilities and improve the overall quality of life. As the field continues to evolve, it is crucial to refine these strategies and ensure they are effectively implemented, allowing individuals to achieve optimal communication outcomes.

REFERENCES

Abdel-Latif, K. H., & Meister, H. (2022). Speech recognition and listening effort in cochlear implant recipients and normal-hearing listeners. *Frontiers in Neuroscience*, *15*, 725412. https://www.frontiersin.org/journals/neuroscience/articles/10.3389/fnins.2021.725412/full

Bieber, R. E., & Gordon-Salant, S. (2021). Improving older adults' understanding of challenging speech: Auditory training, rapid adaptation and perceptual learning. *Hearing Research*, *402*, 108054. https://www.sciencedirect.com/science/article/pii/S0378595520303257

Carneiro, C. F., Queiroz, V. G., Moulin, T. C., Carvalho, C. A., Haas, C. B., Rayêe, D., ... & Amaral, O. B. (2020). Comparing quality of reporting between preprints & peer-reviewed articles in the biomedical literature. *Research Integrity & Peer Review*, *5*, 1-19. https://doi.org/10.2139/ssrn.3557504

Chae, S. R., Bahng, J., Chae, S. R., & Bahng, J. (2023). Effective Duration of Auditory Training for Speech Perception in Hearing-Impaired Listeners: A Systematic Review and Meta-Analysis. *Clinical Archives of Communication Disorders*, *8*(3), 192-210. http://e-cacd.org/journal/view.php?doi=10.21849/cacd.2023.01004

Dissanayake, P. I., Colicchio, T. K., & Cimino, J. J. (2020). Using clinical reasoning ontologies to make smarter clinical decision support systems: a systematic review & data synthesis. *Journal of the American Medical Informatics Association*, *27*(1), 159-174. https://doi.org/10.1093/jamia/ocz169

Fox, M. P., MacLehose, R. F., & Lash, T. L. (2021). Applying quantitative bias analysis to epidemiologic data (pp. 105-39). New York: Springer. https://doi.org/10.1007/978-3-030-82673-4

Gao, X., Yan, T., Huang, T., Li, X., & Zhang, Y. X. (2020). Speech in noise perception improved by training fine auditory discrimination: far and applicable transfer of perceptual learning. *Scientific reports*, *10*(1),

19320. https://doi.org/10.1038/s41598-020-76295-9

Gohari, N., Dastgerdi, Z. H., Rouhbakhsh, N., Afshar, S., & Mobini, R. (2023). Training programs for improving speech perception in noise: A review. *Journal of Audiology & Otology*, *27*(1), 1. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9884994/

Grandon, B., & Vilain, A. (2020). Development of fricative production in French-speaking school-aged children using cochlear implants and children with normal hearing. *Journal of Communication Disorders*, *86*, 105996. https://doi.org/10.1016/j.jcomdis.2020.105996

Hassanzadeh, S., Ajalloueyan, M., Mirdeharbab, A., Arjmandnia, A. A., Hasanalifard, M., Saeedi, M., & Aghaz, A. (2021). Long-term effects of cochlear implantation on language skills-and speech intelligibility in early-implanted versus late implanted deaf children. *Journal of Pediatric Perspectives*, *9*(10), 14663-14671. https://doi.org/10.22038/ijp.2021.57919.4546

Henshaw, H., & Ferguson, M. A. (2013). Efficacy of individual computer-based auditory training for people with hearing loss: a systematic review of the evidence. *PloS one*, *8*(5), e62836. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0062836

Hilviu, D., Parola, A., Vivaldo, S., Di Lisi, D., Consolino, P., & Bosco, F. M. (2021). Children with hearing impairment and early cochlear implant: A pragmatic assessment. *Heliyon*, *7*(7). https://www.cell.com/heliyon/pdf/S2405-8440(21)01531-0.pdf

Kang, E., & Hwang, H. J. (2021). Ethical conducts in qualitative research methodology: Participant observation & interview process. *Journal of Research & Publication Ethics*, *2*(2), 5-10. https://doi.org/10.15722/jrpe.2.2.202109.5

Karawani, H., Bitan, T., Attias, J., & Banai, K. (2016). Auditory perceptual learning in adults with and without age-related hearing loss. *Frontiers in psychology*, *6*, 2066. https://www.frontiersin.org/articles/10.3389/fpsyg.2015.02066/full

Kronenberger, W. G., Xu, H., & Pisoni, D. B. (2020). Longitudinal development of executive functioning and spoken language skills in preschool-aged children with cochlear implants. *Journal of Speech, Language, and Hearing Research*, *63*(4), 1128-1147. https://pubs.asha.org/doi/abs/10.1044/2019_JSLHR-19-00247

Lo, C. Y., Looi, V., Thompson, W. F., & McMahon, C. M. (2020). Music training for children with sensorineural hearing loss improves speech-in-noise perception. *Journal of Speech, Language, and Hearing Research*, *63*(6), 1990-2015. https://research.bond.edu.au/files/19

0368159/AM_Music_training_for_children_with_sensorineural_hearing.pdf

Lynas, M., Houlton, B. Z., & Perry, S. (2021). Greater than 99% consensus on human caused climate change in the peer-reviewed scientific literature. *Environmental Research Letters*, *16*(11), 114005. https://iopscience.iop.org/article/10.1088/1748-9326/ac2966

Mastromarino, S. (2022). *Brain Walking Green: a pilot study on a preventive protocol of combined physical activity and cognitive stimulation in a group of older adults coming from Marche* (Master's thesis, Università di Parma. Dipartimento di Medicina e Chirurgia). https://www.repository.unipr.it/handle/1889/5164

Mateus, A. R. S. (2021). *Long-term effectiveness of cochlear implants in prelingually deaf children* (Master's thesis). https://estudogeral.uc.pt/bitstream/10316/98382/1/Tese_Mestrado_Rita Mateus.pdf

Olson, A. D. (2015). Options for auditory training for adults with hearing loss. In *Seminars in hearing*, *36*(4), 284-295. Thieme Medical Publishers. https://www.thieme-connect.com/products/ejournals/html/10.1055/s-0035-1564461

Pesnot Lerousseau, J. P., Hidalgo, C., & Schön, D. (2020). Musical training for auditory rehabilitation in hearing loss. *Journal of Clinical Medicine*, *9*(4), 1058. https://www.mdpi.com/2077-0383/9/4/1058/pdf

Purcell, P. L., Deep, N. L., Waltzman, S. B., Roland Jr, J. T., Cushing, S. L., Papsin, B. C., & Gordon, K. A. (2021). Cochlear implantation in infants: why and how. *Trends in hearing*, *25*, 23312165211031751. https://journals.sagepub.com/doi/pdf/10.1177/23312165211031751

Rasmussen, K. M. B., West, N. C., Bille, M., Sandvej, M. G., & Cayé-Thomasen, P. (2022). Cochlear implantation improves both speech perception and patient-reported outcomes: a prospective follow-up study of treatment benefits among adult cochlear implant recipients. *Journal of Clinical Medicine*, *11*(8), 2257. https://doi.org/10.3390/jcm11082257

Saharan, V. A., Kulhari, H., Jadhav, H., Pooja, D., Banerjee, S., & Singh, A. (2020). Introduction to research methodology. In *Principles of Research Methodology & Ethics in Pharmaceutical Sciences* (pp. 1-46). CRC Press. https://doi.org/10.34021/ve.2022.05.01(5)

Scarabello, E. M., Lamônica, D. A. C., Morettin-Zupelari, M., Tanamati, L. F., Campos, P. D., Alvarenga, K. D. F., & Moret, A. L. M. (2020). Language evaluation in children with pre-lingual hearing loss and cochlear implant. *Brazilian journal of otorhinolaryngology*, *86*(1), 91-98. https://www.scielo.br/j/bjorl/a/GPQtFT67L5Qf4LLqJ5RppSm/?lang=en

Scells, H., Zuccon, G., & Koopman, B. (2021). A comparison of automatic Boolean query formulation for systematic reviews. *Information Retrieval Journal*, *24*, 3-28. https://doi.org/10.1002/9780470689646.ch1

Schneider, P., Groß, C., Bernhofs, V., Christiner, M., Benner, J., Turker, S., ... & Seither-Preisler, A. (2022). Short-term plasticity of neuro-auditory processing induced by musical active listening training. *Annals of the New York Academy of Sciences*, *1517*(1), 176-190. https://nyaspubs.onlinelibrary.wiley.com/doi/full/10.1111/nyas.14899

Tuz, D., Isikhan, S. Y., & Yücel, E. (2021). Developing the computer-based auditory training program for adults with hearing impairment. *Medical & biological engineering & computing*, *59*, 175-186. https://doi.org/10.1007/s11517-020-02298-3

Tye-Murray, N., Spehar, B., Sommers, M., Mauzé, E., Barcroft, J., & Grantham, H. (2022). Teaching children with hearing loss to recognize speech: Gains made with computer-based auditory and/or speechreading training. *Ear and hearing*, *43*(1), 181-191. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8712342/

Whitton, J. P., Hancock, K. E., Shannon, J. M., & Polley, D. B. (2017). Audiomotor perceptual training enhances speech intelligibility in background noise. *Current Biology*, *27*(21), 3237-3247. https://www.cell.com/current-biology/fulltext/S0960-9822(17)31178-8

Woods, D. L., Doss, Z., Herron, T. J., Arbogast, T., Younus, M., Ettlinger, M., & Yund, E. W. (2015). Speech perception in older hearing impaired listeners: Benefits of perceptual training. *PloS one*, *10*(3), e0113965. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0113965

APPENDIX

Table 2.

Data Extraction

Author	Method	Key Findings:
Bieber & Gordon-Salant (2021)	Secondary literature review	The authors reviewed the pertinent features of stimulus, listener, and training protocol. The results demonstrated that auditory training has some overarching outcomes for the ageing population that include an intact capacity regarding auditory perceptual learning. However, limited transmission of learning to untrained stimuli has been reported by authors.
Gao et al. (2020)	Primary Longitudinal experiment with 83 adults from Beijing Normal University.	The researchers trained separate groups of normal listeners who were trained under auditory interaural level difference discrimination or ILD, fundamental frequency or F_0, and interaural time difference or ITD. No improvement was noted in the case of ITD. However, ILD and F_0 seemed to produce transfer as well as learning to the perception of speech-in-noise when differences in noise and speech existed in the trained feature.
Lo et al. (2020)	Primary pseudo-randomised, longitudinal study	The authors of this study were required to evaluate how music training can offer perceptual benefits for children who have lost their hearing. However, the paper has delivered some intricate details of adults with hearing loss as well. The adults with hearing loss have benefitted from a SIN or speech-in-noise with music training.

Gohari et al. (2023)	Systematic literature review	Within this article, it is noticed that pitch training, fundamental frequency training, localisation training, and temporal training are some auditory perceptual learning programs that help in improving speech recognition skills in noisy environments among adults who have sensorineural hearing loss.
Schneider et al. (2022)	37 Adolescents were involved in this investigation and data was collected through the primary research method.	Short-term APLPs' effectiveness is moderate in speech recognition.
Mastromarino (2022)	This article followed a primary methodology for investigation.	The key finding of this study is associated with the effectiveness of high-intensity programmes in improving speech recognition in noisy environments for adults with sensorineural hearing loss.
Rasmussen et al. (2022)	Longitudinal cohort Study 49 participants were associated.	This study generates positive findings with regards to the impact of cochlear implants on the targeted population. It was found that adults who undergo cochlear implantation have remarkably improved speech perception and communication and auditory comprehension. They remain in a stronger position to socialize, be independent and enjoy a good quality of life, thanks to this increased sense of hearing. Through this study the importance of cochlear implants in hearing impaired people is highlighted and showed how it renders speech recognition and hearing-impaired people's personal lives much better.
Grandon & Vilain (2020)	Primary research has been followed in this article and the total participants were 20 children.	The sound production among children with cochlear implants is shown to be different to those of normal hearing children, with the

		frequency of pitches in children with cochlear implants being lower. Furthermore, macronuclei vary in terms of their vowel production, with two distinct speech patterns. The findings suggest that speech development is supported by cochlear implants, but phonetics is different from those of children with normal hearing. It however indicates that overall, the results show the role that cochlear implants play in the development of speech production, improving communication skills and auditory perception of children with hearing impairment than their pre-implantation status.
Scarabello et al. (2020)	The authors investigated using primary research	Within this study, it is revealed that there is a significant improvement noticed in the understanding of oral language among people with cochlear implants. Children who have cochlear implants at an early stage have better improvement in the understanding of oral language.
Kronenberger et al. (2020)	Primary research was implicated in this investigation. The participants were 3-7 years old and annual reports were collected.	The findings highlight that compared to the NH groups, the CI groups' vocabulary growth is much higher. The PLS-4 score is much higher among people who have cochlear implants. This highlights that cochlear implants help in improving the vocabulary of prelingually deaf children over time.
Mateus (2021)	The participants were around 132 children of which 119 were prelingually deaf. Analysing this article, it is	The key finding of this investigation is one of the factors that influence the variability in long-term speech and language development

	noticed that the primary research method was followed and data was collected over 15 years.	outcomes is the duration of the device usage. Prelingually deaf children who have CI at an early stage have a direct influence on their speed production and understanding of language.
Hassanzadeh et al. (2021)	For this investigation, the researchers collected data from 31 children from a cochlear implant centre in Tehran. This indicates the following primary research methodology.	In the content of speech intelligibility, there is a significant difference noticed among early and late CI in long-term outcomes. Children who have CI at an early stage have better speech intelligibility. This is highlighted in age at implantation as the other factors that influence the variability in long-term speech and language development outcomes.