Review Article

Mechanisms of Listening Effort in Individuals with Hearing Loss

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Article info:
Received: 10 Mar 2025
Accepted: 27 Apr 2025

Citation: Iran Pour Mobarakeh Z, Amiri M, Tavanai E, Rahimi V. Mechanisms of Listening Effort in Individuals with Hearing Loss. Journal of Modern Rehabilitation. 2025;19(3):?-?

Running Title: Listening effort mechanisms in hearing loss

Abstract

Background and Aim: Listening effort refers to the cognitive resources required to understand speech, particularly in challenging listening environments. Individuals with hearing loss experience increased listening effort due to auditory deficits, affecting their communication and cognitive load. Understanding the mechanisms behind listening effort is essential for developing effective hearing interventions. This study aims to explore the mechanisms of listening effort in individuals with hearing impairments.

Material and Methods: A narrative review was conducted using specific keywords in Google Scholar (as a search engine) and the research databases Web of Science, Scopus, and PubMed. Relevant articles were selected based on their alignment with the focus on the mechanisms of listening effort in individuals with hearing loss.

Results: Hearing loss triggers compensatory cognitive strategies, engaging prefrontal regions and working memory to process degraded auditory signals. Neural adaptations, including cross-modal plasticity and reliance on top-down processing, further elevate mental workload. Degraded temporal processing and attentional demands in noisy environments exacerbate effort, often leading to fatigue.

Conclusion: Understanding these mechanisms informs interventions such as adaptive hearing technologies, cognitive training to optimize resource allocation, and personalized communication strategies. Integrating neurophysiological insights into clinical practice can reduce cognitive fatigue and enhance real-world communication outcomes.
Keywords: Listening effort, hearing loss, cognitive load, mechanisms

Introduction

Hearing and speech comprehension are among the important issues related to human social life (1). In clinical settings, speech audiometry is one of the main audiological tests that is typically measured by calculating the proportion of identified keywords correctly in quiet or in noise to determine the perceptual abilities of people in real life conditions (1,2). Listening effort is one aspect of speech understanding that is under-evaluated. The Framework for Understanding Effortful Listening defines listening effort as the deliberate allocation of mental resources to overcome obstacles in goal pursuit when carrying out a [listening] task (3). Although listening to speech is relatively effortless under ideal listening conditions, processing speech may become more effortful due to the degradation of the signal quality, use of the complex language structure, or the message with less familiar content (2,4,5). Also, a complex interaction between factors such as working memory, attention, motivation, and cognitive capacity are related to listening effort experience (3).

Hearing impairment is one of the most prevalent disabilities in the population and poses significant challenges in daily life, particularly in areas such as speech recognition and communication (6). So, in this context, hearing-impaired individuals may experience effortful listening in their daily lives (2). The internal representation of acoustic stimuli is often degraded in individuals with hearing impairment, leading to difficulties in processing sounds. For effective speech recognition, the acoustic signal must be accurately decoded, a task that becomes particularly challenging for hearing-impaired individuals (7). Furthermore, in everyday situations, speech is frequently surrounded by background noise and other sounds, which complicates communication further (8). Researches indicate that hearing-impaired individuals experience greater difficulties in speech perception under these conditions compared to individuals with normal hearing (9–11). It is suggested that the effort to continuously process auditory input contributes to increased cognitive load during listening. (12). As a result, hearing-impaired individuals must exert additional effort to achieve successful speech perception (5,7). The decreased access to auditory information and the need for compensatory cognitive resources cause the hearing-impaired patients to exert more listening effort (2). Sensory degradation due to hearing loss increases the cognitive demands on the central auditory processing system, especially for speech comprehension. This compensatory effort engages various regions of the brain, suggesting the presence of underlying mechanisms that contribute to listening effort (3). Hearing impairment can profoundly impact an individual's social interactions and quality of life, frequently resulting in withdrawal from leisure activities and social roles (13–15). This could be partly explained by the greater effort required for successful listening (16).

A narrative review of the existing evidence is essential to deepen our understanding of the current knowledge regarding the mechanisms underlying listening effort following hearing loss. To date, researchers have explored various aspects of listening effort in numerous studies, including the analysis of its mechanisms (3,5,17), with the aim of providing a scientific basis for optimal management in the rehabilitation process of individuals with hearing loss (3,18). However, based on the existing literature, the neural and cognitive mechanisms underlying this increased effort remain an area of ongoing investigation. Understanding these mechanisms is important because it can help improve auditory rehabilitation strategies. By studying how the brain processes sound and the effort involved, this research can lead to improved clinical interventions, ultimately helping individuals with hearing loss communicate more easily and reduce mental fatigue (3). Therefore, the aim of the present study is to review current literature on the mechanisms of listening effort in individuals with hearing loss.

Materials and Methods

Study Design

This study is a narrative review that aims to explore the mechanisms of listening effort in individuals with hearing loss by reviewing and analyzing relevant research studies.

Eligibility Criteria

In this narrative review study, only English-language studies with available full text that assessed the mechanisms of listening effort in hearing impaired individuals were included. Inclusion criteria were the articles relevant to the topic, including those that examined the mechanisms underlying listening effort in individuals with hearing loss. No systematic inclusion or exclusion criteria were applied, allowing for a broad exploration of the field.

Sources of research

In this narrative review, the search was conducted for the related studies in different databases such as Google Scholar, Web of Science, Scopus, and PubMed, published from 1980 to 2025.

Search Strategy

In this review study, the search was carried out in January 2025 using the MeSH terms: "listening effort," "hearing loss," "cognitive load," and "mechanisms,". Boolean operators (AND, OR) were used to combine these terms, ensuring a broad but relevant search. A total of 876 articles were initially reviewed, and 45 articles were selected for final analysis and inclusion in the review.

Results

The findings of this study are shown in graphical abstract (Figure 1). The underlying mechanisms are classified in 6 categories:

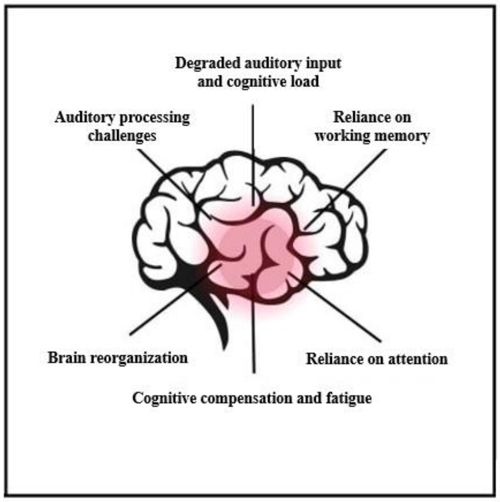

Fig1. The mechanisms of listening effort in individuals with hearing loss are plotted, using Adobe Photoshop.

Mechanisms and Important Factors

Hearing loss often leads to an increase in "listening effort," a phenomenon where individuals expend more cognitive resources to understand speech and sounds (19). This increase in effort has been a focal point of auditory research, as it affects cognitive load, fatigue, and overall communication efficiency for individuals with hearing impairment (19,20). Here's a comprehensive look at the mechanisms behind increased listening effort in hearing loss, with references to key studies.

Auditory Processing challenges and Listening Effort

Central auditory processing disorder is typically characterized as a distinct impairment in the processing and interpretation of auditory signals within the central auditory nervous system, encompassing both bottom-up and top-down neural connectivity (21). According to the bottom-up theory, hearing loss reduces auditory input fidelity requiring the brain to compensate for missing information (22), thereby increasing cognitive load (3).

Pichora-Fuller et al. in 2016, explored how listening effort increases the cognitive demands. This compensatory effort often involves regions outside of primary auditory processing areas, such as working memory and attention (3).

Degraded Auditory Input and Cognitive Load

Hearing loss degrades the quality of the auditory signal, often distorting speech sounds or making certain frequencies less audible. This degraded input means that the auditory cortex receives incomplete information, which the brain has to process and interpret. Each step of this process increases cognitive load, especially when listening in noisy environments (5,12). For example, studies reported that hearing loss typically distorts the auditory signal by selectively reducing audibility across certain frequencies, often leading to a loss of high-frequency sounds critical for speech understanding (23,24). This selective degradation following hearing loss creates incomplete auditory input, making speech recognition especially difficult in real-world listening environments (3). This degraded input quality poses additional difficulties for recognizing speech sounds in noisy environments, as the brain cannot rely solely on the auditory signal to differentiate speech from background sounds. Hearing loss individuals experience reduced speech recognition ability in noise because the degraded signal limits their ability to access essential acoustic cues (5,12). Hearing loss exacerbates challenges in separating speech from background noise, leading to greater listening effort (12). Also, some studies showed that temporal cues in speech are vital for comprehension, and hearing loss significantly impairs the processing of these cues. This disruption hinders the brain's ability to follow rapid temporal changes, which are crucial for understanding complex or fast-paced speech (17,25). Studies highlight that when these temporal cues are compromised, the brain must expend additional resources to fill in gaps or predict missing information, which contributes to increased listening effort (25).

Increased Reliance on Working Memory

Working memory is integral for holding and manipulating information in real-time tasks, such as speech comprehension, which becomes especially crucial when auditory input is unclear (26). This increased reliance on cognitive resources has been corroborated by research showing a link between degraded hearing and reduced cognitive performance, as the brain reallocates resources away from other functions (27). For individuals with hearing loss, working memory compensates by engaging in several demanding processes:

Listeners with hearing impairment must rely heavily on their working memory to hold fragmented or distorted auditory input, retaining incomplete speech signals long enough to fill in gaps (5). This process requires maintaining partial information in memory, while using context, language knowledge, and prior experiences to reconstruct the intended message. Studies show that this cognitive compensation is essential but demanding, as it draws significantly on limited working memory resources, especially in dynamic listening environments (27,28).

Furthermore, when clear auditory cues are absent, listeners with hearing loss often reconstruct meaning by piecing together words from context, memory, and prior knowledge. This process places an additional load on working memory, as it requires holding onto incomplete speech fragments, mentally replaying portions, and integrating audible segments with contextual cues to approximate the intended meaning (3). This complex reconstructive process is mentally taxing, increasing cognitive load and leading to heightened listening effort and fatigue in conversation (25). Rönnberg et al. in 2013, proposed the Ease of Language Understanding (ELU) model, which suggests that when auditory input deviates from expectations, individuals with hearing loss exert additional cognitive effort to reconstruct the message. This reconstruction process places strain on working memory, especially in dynamic or noisy environments where speech signals are harder to process accurately (5).

Increased Reliance on Attention

Attention is crucial for directing cognitive resources toward understanding speech, particularly when listening conditions are challenging (3). For individuals with hearing loss, there is an increased reliance on attentional mechanisms to compensate for degraded auditory input. For example, the ability to filter out background noise and focus on the speaker’s voice is compromised following hearing loss. This makes it harder to isolate relevant speech from other sounds, such as overlapping conversations or ambient noise, increasing the need for selective attention (12). Selective attention, the cognitive process of focusing on desired aspect of the stimulus while suppressing irrelevant aspects, becomes more demanding as it compensates for diminished auditory clarity. This need for heightened selective attention increases the cognitive load, leading to greater listening effort (3).

Neural and Cognitive Compensation in Hearing Loss

When hearing loss occurs, the brain undergoes neural reorganization to compensate for the reduced auditory input. This plasticity may involve auditory temporal regions recruitment for executive functions, particularly during switching tasks, indicating that the absence of auditory inputs allows these areas to take on cognitive roles, reflecting neural reorganization and plasticity (29). In the context of hearing loss, cross-modal plasticity occurs, where areas of the brain that are no longer receiving sufficient auditory input are recruited to process other types of information. the brain shifts processing away from auditory regions and engages other modalities, which can increase cognitive load (30).

Lomber et al. (2010) demonstrated that in individuals with profound hearing loss, parts of the auditory cortex began processing visual and somatosensory information. While this allows the brain to adapt to sensory deprivation, it also means that these regions are no longer available for auditory processing (31). Alongside structural changes in the brain, individuals with hearing loss develop cognitive compensation strategies to maintain speech comprehension. In situations with degraded or unclear auditory input, top-down processing becomes essential. Listeners rely more heavily on stored knowledge and contextual clues to "fill in" missing auditory details, especially in noisy or complex environments where acoustic cues are limited (3, 5). This increases cognitive load as it requires greater use of memory and attentional resources. The added effort can lead to listening fatigue and may impair performance in other cognitive tasks

Pichora-Fuller and Singh in 2006, further developed the understanding of cognitive compensation in hearing loss, explaining that individuals with hearing impairment rely heavily on working memory and attentional resources to interpret degraded input. Their study shows that degraded auditory signals force listeners to retain fragments of speech in working memory while attempting to fill in gaps, which leads to increased listening effort. This work emphasizes how hearing loss reallocates cognitive resources to manage incomplete auditory information, especially in complex listening environments (33).

Discussion

The purpose of the study was to review mechanisms of listening effort in individuals with hearing loss. Listening effort refers to the amount of cognitive and perceptual resources required to understand speech, particularly in difficult listening environments such as background noise or degraded acoustics especially experienced following hearing loss (34). To better manage and provide effective counseling to individuals with hearing loss who exert significant effort to listen, it is essential for clinicians and researchers to be aware of the related mechanisms of listening effort associated with hearing loss. There are several mechanisms suggested by different studies:

Degraded speech not only makes understanding harder but also impairs memory retention, especially for distorted words and sentences. This effect is more pronounced in older adults and those with hearing loss (35). It is demonstrated that hearing-impaired listeners struggle more with recalling complex stimuli like short stories, though self-paced listening can help them perform better, indicating a higher cognitive load leading to greater degree of cognitive challenges (36). In conclusion, both auditory and cognitive resources are involved in processing degraded speech, with hearing impairments increasing the cognitive demands (35). To identify neural signatures of listening effort, researchers examine areas with increased activity for degraded but intelligible speech. Studies show increased activation in the left lateral temporal cortex, inferior frontal cortex, and premotor cortex for degraded speech, suggesting an effort-related response (37,38). Increased activity for degraded speech is also seen in the cingulo-opercular network (39–42), linked to error-monitoring and attention (35). Effort-related increases in brain activity are observed in both auditory/language and executive systems, especially within the multiple-demand system, which supports speech understanding (43,44). Therefore, listening effort following degraded speech often requires listeners to rely more heavily on the other areas in the brain including different types of cognitive resources (35). Various factors, including cognitive aspects, play a crucial role in the successful adoption and satisfaction with hearing aids (45).

Conclusion

Listening effort in individuals with hearing loss involves complex interactions between auditory and cognitive processes. Understanding these mechanisms is essential for designing targeted interventions, such as individualized auditory and cognitive training programs, that aim to improve speech perception and reduce cognitive fatigue. These insights also support the development of enhanced rehabilitation strategies that combine hearing amplification with cognitive support and real-life communication training. Furthermore, optimizing assistive listening devices, particularly auditory tools like hearing aids and cochlear implants, through improved signal processing and user-specific configurations, can help reduce listening effort. Overall, a multidimensional approach informed by behavioral and neurophysiological evidence can more effectively support individuals with hearing impairment.

Ethical Considerations

Compliance with ethical guidelines

There were no ethical considerations to be considered in this research.

Funding

There are no Funding sources in our work.

Authors' contribution

ZIPM: drafting the manuscript, and editing final version; MA: Reviewing; ET: Reviewing; VR: Editing, reviewing, providing guidance.

Conflict of interest

There is no conflict of interest.

Acknowledgments

This study was supported by Tehran University of Medical Sciences (The Ethics Committee approved this study with R.TUMS.FNM.REC.1402.134) and extracted from thesis for MSc degree in Audiology at School of Rehabilitation.

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