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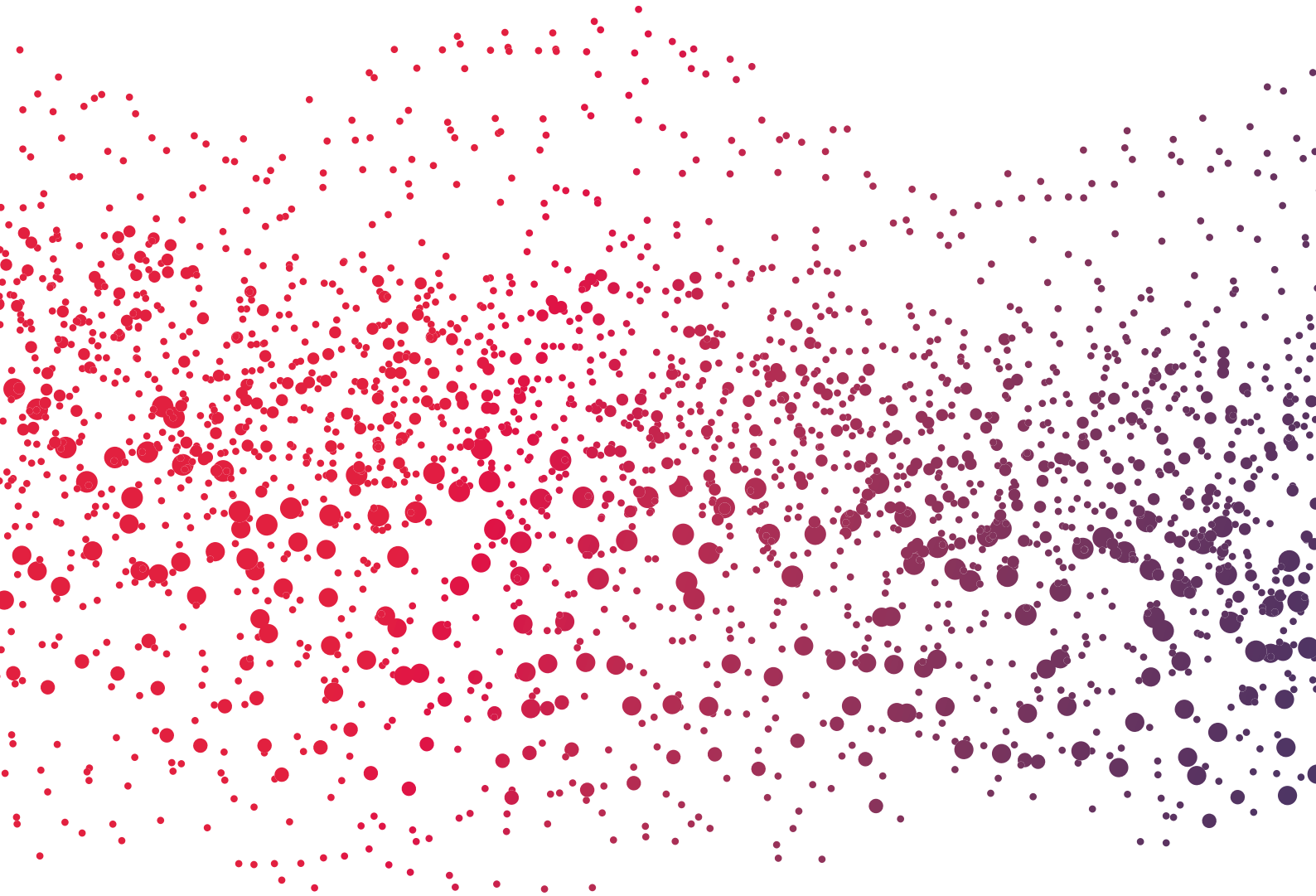

Hearing Loss and Annual Earnings Over a 20-Year Period

Cardiovascular Diseases and Sensorineural Hearing Loss

Predicting Hearing Aid Outcomes Using Machine Learning

CONTENT

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EDITORIAL

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Dear Reader, the Amplifon Centre for Research and Studies, CRS, houses one of the finest private libraries in the field of audiology and otorhinolaryngology, offering the sector's most important international journals. Every quarter, a team of Amplifon Audiologists from around the globe select the most relevant publications in the field of Otology and Audiology and make a comprehensive review. The Amplifon Centre for Research and Studies coordinates the development of this quarterly review. We are happy to share these new reviews with you. For this issue, our team reviewed 9 interesting articles published in the first quarter of 2025.

Three of the featured publications examine the role of working memory in various aspects of auditory function. One study focuses on its involvement in auditory processing. Another investigates how working memory interacts with hearing aid (HA) signal processing strategies, such as compression and beamforming, potentially affecting user outcomes. A third review compares speech understanding in noise between monolingual and bilingual adults to assess whether differences in working memory capacity may influence performance under challenging listening conditions.

In a separate line of research, the longitudinal study titled 'Hearing Loss and Annual Earnings Over a 20-Year Period' uses data from the HUNT Cohort Study in Norway to explore the economic impact of hearing loss (HL). The findings indicate that participants with normal hearing experienced an average annual income increase that was 13.2% higher than that of individuals with HL.

Further insights come from a systematic review investigating the relationship between cardiovascular disease and sensorineural hearing loss. The evidence points to a complex interaction, with HL most commonly occurring after the onset of cardiovascular conditions.

Accessibility in hearing care, a nationwide survey conducted in the U.S. on over-the-counter HAs concludes that while these devices have the potential to broaden access to treatment, their effectiveness will depend largely on closing persistent knowledge gaps among users and healthcare professionals alike.

In the realm of data-driven innovation, we are proud to showcase the groundbreaking work of our French Amplifon team, which has garnered significant attention for their work employing big data and machine learning to predict HA outcomes. This research provides valuable practice-based evidence and supports the integration of predictive analytics to advance personalised hearing care.

Advancements in audiometric testing are also noted in a Dutch study evaluating the use of synthetic speech in speech-in-noise testing. The results demonstrate that synthetic speech lists offer improved equivalence and robustness, paving the way for more standardised and reliable speech audiometry.

Finally, a pupillometry-based review on the effects of auditory training on listening effort in HA users reveals that contrary to expectations, while such training has a positive effect on speech intelligibility at soft input levels (50 dBA), it also leads to increased listening effort and cognitive load. This increase is interpreted positively, as the authors attribute it to greater confidence and motivation to invest greater effort in completing auditory tasks following training.

We hope you enjoy this issue of our CRS Scientific Journal

Mark Laureyns
Global International CRS & Medical Scientific Research Manager

ARTICLE REVIEW: A COMPARATIVE STUDY IN AUDITORY PROCESSING AND WORKING MEMORY PROFILES

IN YOUNG AND OLDER ADULTS

Ramadas V., Vaidyanath R., Uppunda AK., et al.

Am J Audiol. (2025): 34(1), 72–83

doi: 10.1044/2024_AJA-24-00069. Epub 2024 Nov 26. PMID: 39589285.

by Angela Ryall, Canada

Researchers found an increase in performance in the right ear during monaural presentation, providing empirical support for the right ear advantage (REA) theory. Due to the cognitive load associated with both the temporal patterning and the speech perception in noise tasks, the findings suggest that temporal processing plays a critical role in understanding speech under noisy conditions.

CRITICAL NOTE

The findings of this study were not unexpected, as prior research has examined age-related differences in speech perception in noise. However, this study offers a novel contribution by directly comparing these abilities across age groups within a specific linguistic and cultural context. It is particularly encouraging to observe parallels in auditory processing outcomes across languages and geographic regions. As a practitioner based in North America, I would highlight that previous studies conducted in this region have yielded results consistent with those reported in this article. These cross-linguistic similarities support the researchers' proposition that the current findings may serve as normative data for Tamil-speaking populations. The addition of Tamil-language benchmarks is particularly valuable and enhances the inclusivity and applicability of auditory assessment tools across diverse linguistic profiles.

The researchers acknowledged the cross-sectional design of the study as a limitation, noting that it does not account for intra-individual changes in auditory processing skills or working memory over time. Despite this, I believe the study provides a valuable foundation for age-based comparisons in auditory and cognitive performance. Future research could build upon these findings, notably through longitudinal designs that track the same cohort over time.

Several findings from this study resonate with clinical observations, particularly regarding auditory fatigue during speech perception tasks in older adults (in quiet and in noise). This is something I experience in my clinical practice, and is something to consider when completing hearing assessments, particularly as older patients might become more fatigued during speech-in-noise assessments, such as the QuickSIN, relative to younger individuals. This underscores the importance of considering cognitive and auditory processing capacities when designing assessment protocols. Specifically, the sequence in which tasks are administered may influence performance outcomes, particularly in individuals with reduced working memory or auditory processing abilities. Future research could usefully explore the impact of test order on performance and fatigue to inform more effective and patient-sensitive assessment strategies.

The study investigated auditory processing and working memory performance in young and older adults with near-normal hearing thresholds to determine the potential effects of ageing on these skills. The young adult group (n = 25) ranged in age from 18 to 35 years of age; the older adult group (n = 35) ranged from 56 to 79 years. All participants were native Tamil speakers with a minimum educational attainment of Grade 10. The study was conducted in Tamil, and inclusion criteria required participants to have normal hearing (<25 dB HL), complete a baseline pure tone audiometry (PTA), achieve a minimum of 80% accuracy in sentence recognition in quiet, and score >26 on the Montreal Cognitive Assessment (MoCA).

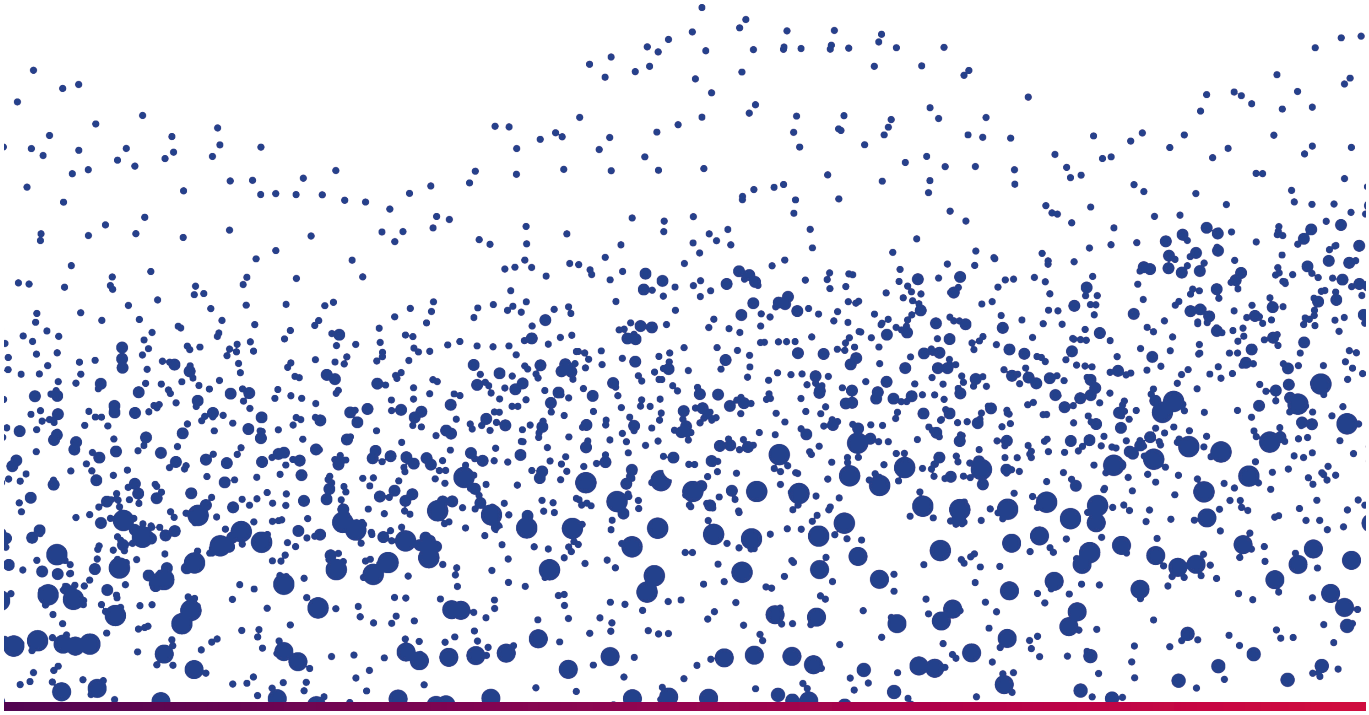
Participants underwent a number of tasks designed to compare binaural integration, auditory separation and closure, temporal resolution, temporal pattern perception, and temporal fine structure (TFS) sensitivity between groups. More specifically, these included: the Dichotic Digit Test in

Tamil (DDT-T); Duration Pattern Test (DPT); Gaps-in-Noise (GIN) test; Pitch Pattern Test (PPT); Temporal Fine Structure (TFS) test; and the Tamil Matrix Sentence Test (TMST) in noise at three signal-to-noise ratios (-5, 0, +5 dB). All stimuli were delivered at 70 dB SPL, and practice trials preceded formal testing. Task order was randomised across participants.

The young adult group consistently outperformed the older adult group across a range of auditory and cognitive tasks. Significant group differences were observed in PTAs and speech perception in quiet, with younger adults demonstrating superior hearing thresholds and recognition performance. This performance advantage extended to the speech perception in noise task across all three SNR conditions (-5, 0, +5 dB), where the young adult group showed significantly better outcomes. In the GIN test, younger participants again demonstrated superior temporal resolution, with only one failing to meet the normative threshold, as compared to 32 older adults who failed to reach this normative benchmark. This trend continued for the temporal patterning and TFS tasks, as well as in working memory tasks. Notably, a large proportion of the participants of the older adult group were unable to perceive the tonal stimuli in the TFS task. The researchers attributed this to elevated hearing thresholds in the higher frequencies commonly observed in the older cohort.

An increase in performance was observed in the right ear during monaural presentation, which supports the right ear advantage (REA) theory. This, the authors argue, may be due to the cognitive demands associated with the temporal patterning and speech-perception-in-noise tasks, which would suggest that temporal processing is a key mechanism in speech comprehension in adverse listening conditions. This hypothesis was based on performance differences between both groups. The performance of older adults suggests that they were unable to isolate speech cues from fluctuations in background noises and speech patterns; whereas younger adults demonstrated greater efficacy in this domain. Findings also indicate that younger adults appeared to utilise working memory consistently across all auditory processing tasks, whereas older adults were able to leverage it in only two of the tasks. This pattern indicates that younger individuals may recruit cognitive resources to support auditory processing with greater flexibility. Despite comparable outcomes on the working memory tasks themselves, older participants required more frequent breaks, which the researchers attributed to auditory fatigue. This fatigue was posited to arise from the increased cognitive load required to engage multiple cognitive resources during task performance.

Overall, the young adult group demonstrated significantly superior performance across the majority of auditory and cognitive tasks, indicating a more efficient utilisation of cognitive resources for task completion compared to the older adult group. The researchers propose that the performance data obtained from the young adult cohort may serve as normative benchmarks for clinical assessments involving native Tamil speakers. Conversely, the performance patterns observed in the older adult group may inform clinicians when evaluating and managing auditory processing and cognitive function in aging populations. These findings have practical clinical implications for the development of targeted rehabilitation recommendations for older adults exhibiting any type of deficit in auditory processing and working memory. The researchers further hypothesise the existence of a reciprocal relationship between auditory processing and working memory, whereby improvements in auditory function may contribute to enhancements in working memory function. •



HEARING LOSS AND ANNUAL EARNINGS OVER A 20-YEAR PERIOD:

THE HUNT COHORT STUDY

Jørgensen AY, Engdahl B et al.

Ear Hear. 2025 Jan-Feb 01;46(1):121–127

doi: 10.1097/AUD.0000000000001554. Epub 2024 Aug 14. PMID: 39138599; PMCID: PMC11637570.

By Carrie Meyer, United States

Using a population-based hearing study, Norwegian researchers analysed the impact of hearing loss (HL) on annual earnings among study participants with and without this condition. Annual earnings were tracked from 1997 to 2017. Linear mixed models adjusted for age, sex, and education were applied for longitudinal analysis. Study findings indicate that workers with HL had, on average, lower levels of education, earned less annually, and were more likely to rely on disability benefits. Additional research is recommended to more comprehensively assess the long-term occupational and economic consequences of HL .

INTRODUCTION

It is well established that hearing loss (HL) is among the most prevalent chronic health conditions globally. While research has focused on the health conditions and comorbidities associated with HL, fewer studies have explored the relationship between long-term income trajectories and HL. Existing income-related research is largely made up of cross-sectional studies which suggest there is an association between adult-onset HL and earnings but fail to indicate the directionality of the relationship. Drawing on a population study of Norwegian citizens, the researchers evaluated the changes in annual income among people with and without HL thanks to a longitudinal assessment covering a period of over 20 years. The statistical analysis was further refined to determine whether earnings varied according to factors such as sex, age and education level, in addition to hearing status.

CRITICAL NOTE

Hearing loss (HL) negatively impacts both health outcomes and quality of life. This Norwegian study examines the long-term impact of HL on annual earnings over a 20-year period by comparing the income and earnings of individuals with and without HL. Introducing an additional layer of analysis, the researchers analysed the effects of HL on income along with other influencers, such as sex, age, and education level. Unlike previous cross-sectional studies and analyses, this population-based study indicates that people with HL have lower long-term earnings growth compared to their normal hearing counterparts. The authors conclude that further research is needed and that intervention efforts should be implemented in the workplace to support workers with hearing loss.

METHODOLOGY

This research consisted of a population-based hearing study in Norway using participants ranging in age from 20 to 40 years at baseline. The collection of health data occurred across four waves, conducted between 1984 and 2019. The final sample included 14,825 subjects.

Hearing assessments included otoscopy, automated pure tone audiometry (PTA), and a hearing questionnaire. Subsequently, HL was categorised as follows:

- >20 dB: reference group/normal hearing (NH)
- 20–34 dB: mild HL
- >35 dB: disabling HL

Income was defined as yearly income or earnings from 1993 to 2017, i.e. the annual sum of wages and private business income as defined by the national statistics agency (SSB). Of particular note, this income measure also covered sick leave and parental leave wages.

Study data was adjusted for covariates including age, sex and education. Education attainment was categorised as follows:

- Primary education
- Secondary education
- University <4 years
- University >4 years

STATISTICAL METHOD

Linear mixed model analysis was used to assess differences in earnings for study participants with HL compared to those with NH. Statistical significance was determined using 95% confidence intervals. Three analysis models were used to better evaluate the impact of covariates on study outcomes:

- Model A: Hearing loss x Time (crude)
- Model B: Sex x Time and Age x Time(HL adjusted for age and sex)
- Model C: Sex x Time and Age x Time and Education x Time (HL adjusted for age, sex and education)

RESULTS

Researchers found that, compared to participants with NH, those with HL were slightly older (32.3 vs. 30.6 years), more likely to be male (55% male vs. 45% female), and had a lower annual income baseline (€23,342 vs. €25,555). After adjusting for age and sex, those with NH experienced an income growth 13.2% higher per year compared to those with HL.

The authors highlight several potential confounders which may influence the study results. One primary confounder noted by the authors was occupational noise exposure. Because lower-paying jobs are often associated with greater occupational noise exposure and these same jobs may be lower paying.

Education was found to be both a confounder and a potential mediator. Specifically, higher education was consistently linked with higher earnings thereby acting as a potential mediator in the relationship between HL and income. Conversely, lower education can be an indicator of lower socioeconomic status which, in turn, may act, as a confounder because it increases both the chances of having a lower income and a HL due to occupational noise exposure.

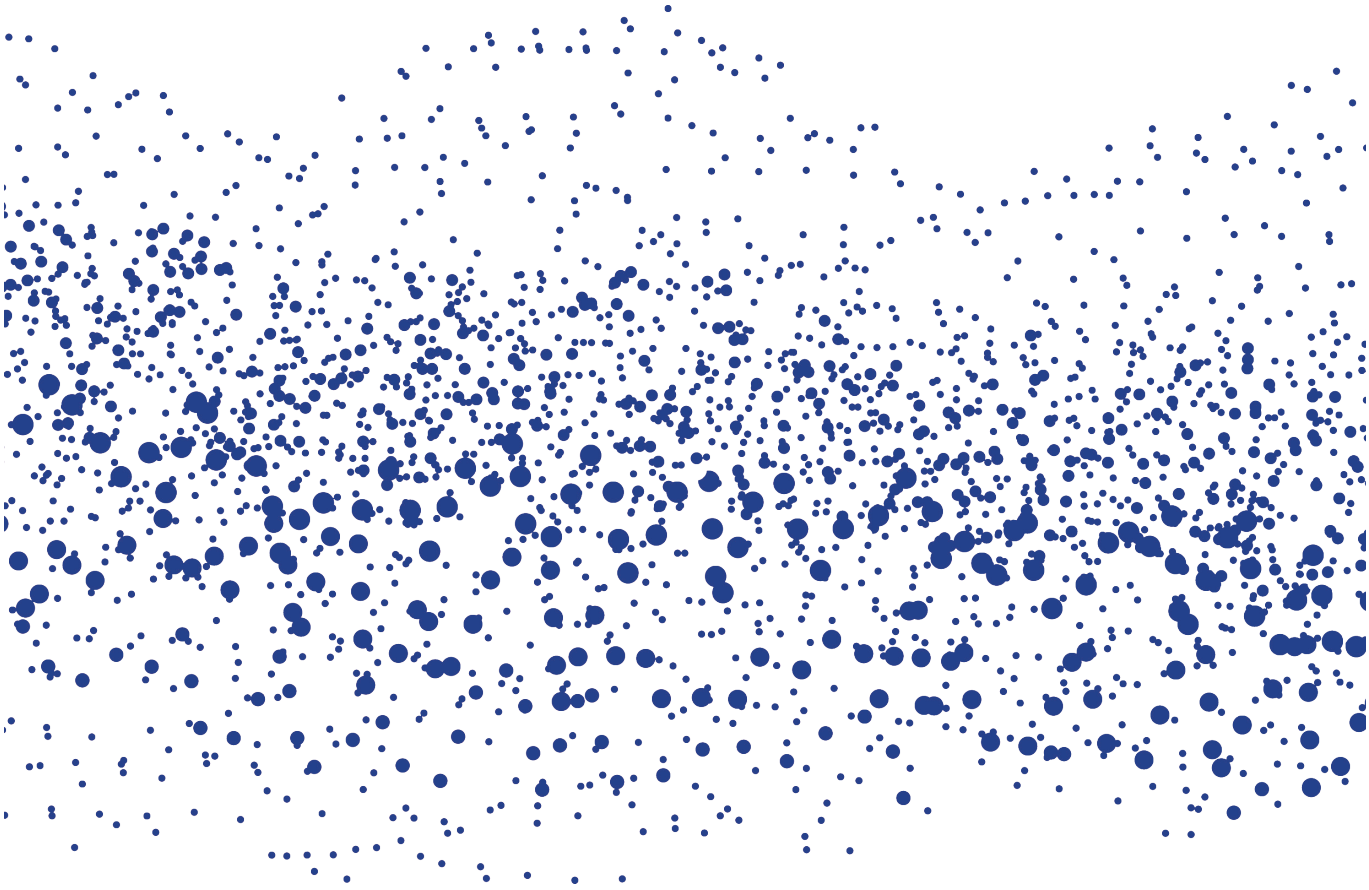
STUDY LIMITATIONS

A notable strength of this research is its large, population-based design. The study was performed in a single county in Norway which is considered representative of the national population in terms of 'geography, industry, economy, income sources, age distribution, morbidity, and mortality.' However, the absence of large urban centres in this region may limit the generalisability of the study's findings. In addition, as with much health-based research, participation in studies and health surveys was likely lower among subgroups such as those from lower socioeconomic backgrounds, with poorer mental or physical health.

CONCLUSIONS

This large, population-based study demonstrates that adults with HL that occurred before age 40 had smaller increases in income over time compared to those with NH. These income disparities were noted to be more pronounced among women than men, among younger individuals compared to older adults and greatest among individuals with lower levels of education.

The authors conclude that inclusive and accessible workplace policies are needed to provide more effective accommodations for workers with HL. •



RELATIONSHIP BETWEEN WORKING MEMORY, COMPRESSION, AND BEAMFORMERS IN IDEAL CONDITIONS

Rallapalli V., Freyman R. & Souza P.

Ear Hear. (2025): 46(2), 523–36

doi: 10.1097/AUD.0000000000001605. Epub 2024 Nov 6. PMID: 39620655.

By Jan De Sutter, Belgium

This study investigates how distortion introduced by wide dynamic range compression (WDRC) is modulated by the interaction between compression speed and directionality. In addition, the research evaluates differences in expected outcomes for speech understanding across varying signal-to-noise ratios (SNR).

Wide dynamic range compression (WDRC) has long been established as an effective technology to enhance speech intelligibility and help restore loudness perception in people with hearing loss (HL). However, using compression in amplification requires making a choice between slow and fast compression, each of which introduces various forms of distortion affecting critical speech cues in noisy environments. In parallel, directional microphone technologies have proved essential in improving signal-to-noise ratio (SNR) in noisy environments, with binaural beamformers – relying on input from four microphones – offering substantial SNR gains beyond those provided by conventional directional settings. This study aims to assess how different combinations of compression speed (fast vs. slow) and microphone settings (omnidirectional vs. binaural beamformer) influence the relationship between working memory and speech recognition performance.

DESIGN

A total of 23 participants, aged 61 to 86 years of age, with pure-tone averages (PTA) of 41.43 dB HL (left ear) and 42.26 dB HL (right ear), were exposed to sentences presented in four-speaker babble noise at SNRs ranging from 0 to 10 dB. Speech was consistently presented at a distance of 1 metre from the participant and at 0° azimuth; while babble noise was presented either at 0° (collocated condition) or 180° (spatially separated condition). Commercially available behind-the-ear (BTE) hearing aids (HAs), individually fitted using the NAL-NL2 fitting formula, were configured to provide both fast vs. slow WDRC and omnidirectional vs. beamformer microphone settings.

In order to assess working memory, participants completed a short version of the Reading Span test.

Additionally, a KEMAR (Knowles Electronic Mannequin for Acoustic Research) recording was conducted for each participant using the same HA settings to provide signal distortion measurements.

CRITICAL NOTE:

This study was performed in a controlled environment with a reverberation time (RT60) of 0.23 seconds. However, it would be valuable to assess the influence of varying reverberation time (RT) on the outcomes of this study. RT has a proportional effect on the perceived signal-to-noise ratio (SNR) and contributes to a reduction in critical distance. As the physical reality of critical distance is an important factor in the effectiveness of directionality, including beamformers, changes in RT could influence the performance of these features. An interesting hearing aid (HA) feature to investigate within a variable reverberation time (RT) study design is the suite of echo reduction technologies currently available on the hearing aid (HA) market

This study compellingly underscores the importance of considering the interactions between various HA technologies and their impact on the psychoacoustic experience of the patient. The craft of audiology lies in selecting the optimal combination of available tools and technologies, and fine-tuning their settings and interactions.

At the same time, it is crucial to take into account the central auditory processing abilities of each individual patient to accurately assess their potential and identify opportunities for improvement. A comprehensive approach that combines counselling, fitting, and testing appears to be the most effective way to support this consideration. Successful intervention involves not only optimising HA settings, but also empowering patients to maximise the benefits of their hearing solution through education and guidance.

RESULTS

Signal distortion was found to be influenced positively – i.e. less present, as evidenced by a better SNR – with beamforming and slow compression. A significant interaction between SNR and microphone mode was identified, however, no significant three-way interaction was found between compression speed, microphone mode, and SNR.

As anticipated, speech recognition was positively influenced by a better SNR and the use of beamforming. Slow compression yielded better results in the omnidirectional mode. Furthermore, the performance gap between compression speeds in beamformer mode was reduced as SNR increased. Subjects with better working memory demonstrated a greater improvement in speech understanding as a function of reduced signal distortion.

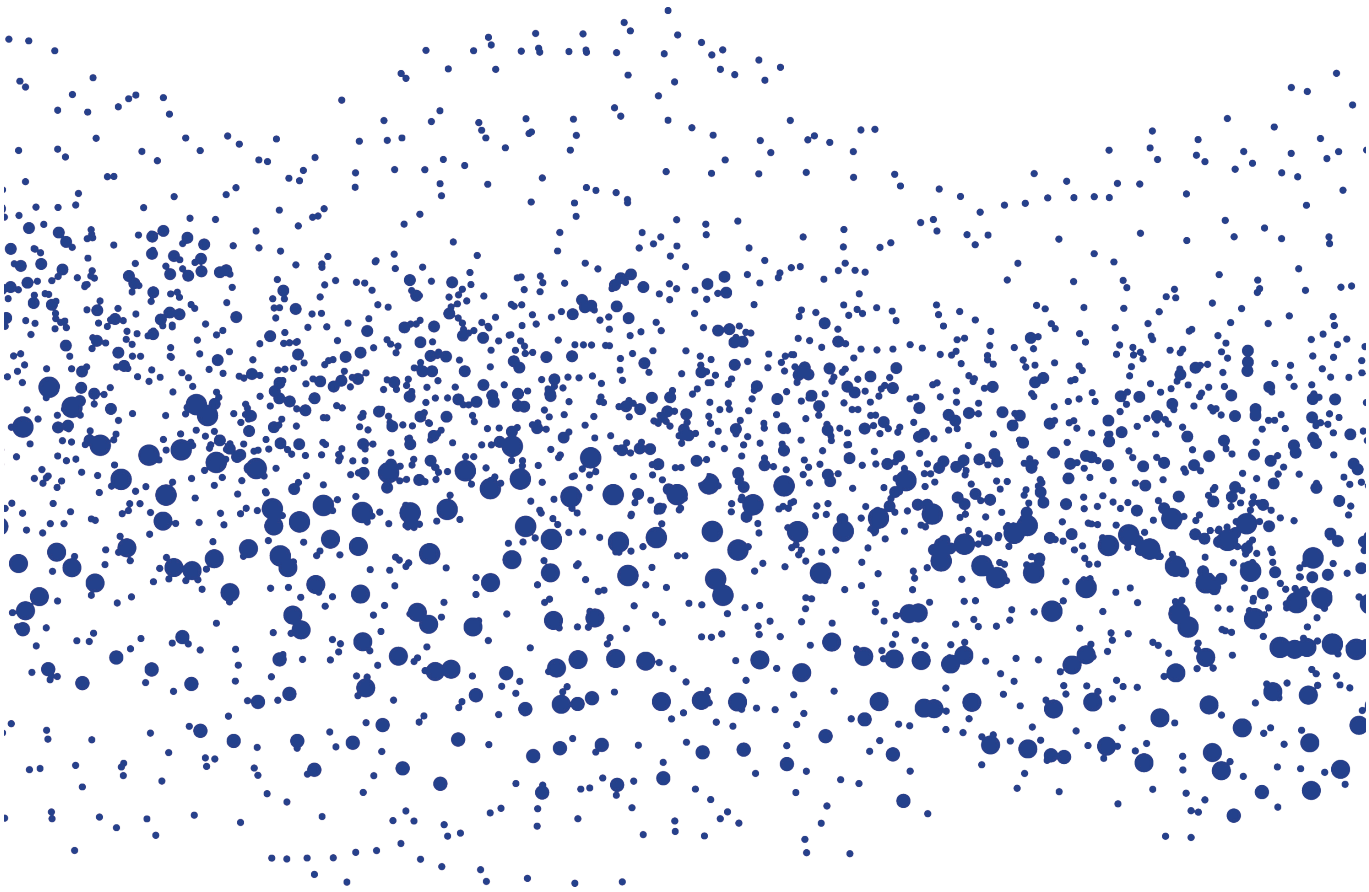
Spatial conditions also influenced speech understanding: conditions with spatially separated noise resulted in better scores. Similarly, at higher SNR levels, participants exhibited better speech understanding.

DISCUSSION AND CONCLUSION:

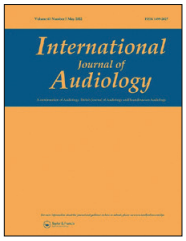
The use of a beamformer resulted in less signal distortion compared to the omnidirectional mode. However, in contrast to findings from prior studies with classic directionality, the combination of beamforming with fast-acting WDRC did not lead to a reduction in signal distortion.

The researchers found that working memory was not a defining factor in speech recognition in noise, regardless of whether the microphone was set to omnidirectional mode or beamformer, or when different consonant durations were tested. Individual differences in working memory did, however, affect listeners' sensitivity to distortion, particularly in conditions with less favourable SNRs. This suggests that the results of the combination of fast or slow act and release time in combination with microphone directionality are subject to interindividual variability.

The authors conclude that the findings of this study support the need or possibility to optimise HA features for improved performance. Specifically, they suggest that the preference for fast or slow-acting WDRC should be minimised at higher SNR, while the use of beamforming should be considered a key tool in combination with WDRC. Lastly, the authors advocate for a more comprehensive approach to hearing rehabilitation, with a greater emphasis on incorporating auditory training and counselling into therapeutic interventions. •



THE RELATIONSHIP BETWEEN SPEECH IN NOISE PERCEPTION AND AUDITORY WORKING MEMORY CAPACITY IN MONOLINGUAL AND BILINGUAL ADULTS



Shokuhifar G., Javanbakht M., Vahedi M., et al.

Int. J. Audiol. (2025): 64(2), 131–8

doi: 10.1080/14992027.2024.2328556. Epub 2024 Apr 1. PMID: 38557258.

By Connie Loi, New Zealand

The authors aim to determine the relationship between speech comprehension in noise and auditory working memory in Kurdish-Persian bilingual adults compared to Persian monolingual adults.

Hearing speech in background noise presents a complex auditory-cognitive challenge, as it relies on the integration of sensory input with higher-order functions (e.g. attention and memory).This task can be especially taxing for bilingual individuals, who must simultaneously navigate two distinct types of processing, i.e. auditory and language-specific cognitive demands.The Ease of Language Understanding (ELU) model suggests that successful speech understanding draws on specific processing resources, such as working memory. It follows that working memory appears to be a critical factor in speech perception in noise.

In parallel, bilingualism, a rapidly growing phenomenon, is one of several factors which influence cognitive processing. Considering the significant role cognitive processes play in speech perception in noise, it is reasonable to hypothesise that differences in working memory capacity between monolingual and bilingual individuals may affect their ability to understand speech in noise.

Consequently, the authors of the study propose that working memory capacity would be positively correlated with speech-in-noise performance among bilingual participants, suggesting that working memory plays a more significant role in speech comprehension in noise for bilinguals than for monolinguals.

PARTICIPANTS & INCLUSION CRITERIA

- 96 participants, including 48 Kurdish-Persian bilinguals and 48 Persian monolinguals.
- 18–28 years old individuals with normal hearing
- No history of otological or neurological disorders
- Right-handed (determined by the Edinburgh questionnaire)
- No history of long-time musical training or activity (due to proven effects on auditory processing)

CRITICAL NOTE

This study contributes to the understanding of speech-in-noise perception in bilingual individuals. The observed disadvantage in speech perception in noise among that population may be explained by limited language exposure and the phenomenon of co-activation. It has been suggested that bilinguals, when processing language, must manage additional competing distractors, as both of their languages are co-activated, even when only one language is required for a given task.This co-activation therefore leaves fewer cognitive resources available for speech processing, thereby increasing listening effort and perceptual difficulty.

Auditory working memory rehabilitation through behavioural tasks or specially designed games may offer potential benefits for improving speech perception in noise. However, further research is needed to substantiate this approach.

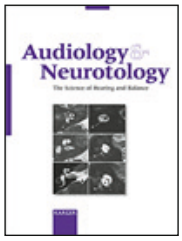
PROCEDURES

- The Persian version of Quick speech in noise (Q-SIN): assess speech perception in noise at sentence level.
- The Persian consonant-vowel (CV) in noise test: at different SNRs.
- Auditory working memory assessments: the forward digit span test; the backward digit span test; and the n-back test.

RESULTS

- Both monolingual and bilingual participants performed within normal limits for auditory working memory assessments and the SIN test.
- A significant statistical difference was observed between the groups across all SIN and auditory working memory tests, with bilinguals performing significantly worse than monolinguals on the SIN test.
- When meaningful speech stimuli were presented, a statistical significant correlation was found between auditory working memory and speech perception in noise in both monolingual and bilingual participants.
- No such correlation was observed when meaningless speech stimuli were used.
- These findings suggest that the ability to understand speech in noise is directly influenced by both the auditory working memory capacity and by the nature of the speech stimuli. •

CARDIOVASCULAR DISEASES AND SENSORINEURAL HEARING LOSS-A SYSTEMATIC REVIEW OF THE LITERATURE



Berezovsky AN., Espahbodi M., LaPrade SL., et al.

Otol Neurotol. (2025): 46(1), 23–30

doi: 10.1097/MAO.0000000000004380.Epub 2024 Nov 21. PMID: 39627856.

By Mark Laureyns, Italy–Belgium

This systematic review leads to the conclusion that the relationship between conditions affecting the main blood vessels that supply blood to the heart and Sensorineural Hearing Loss is notably complex.

Numerous studies have established a link between cardiovascular diseases (CVD), risk factors for CVD (e.g. high blood pressure, high cholesterol, diabetes), and hearing loss (HL). The purpose of this systematic review was to assess existing evidence on the relationship between these health conditions and the potential impact of the various treatment options available.

This systematic review examined 68 studies, published between 1946 and 2023, which met the inclusion criteria, and yielded the following findings on the relationship between CVD and SNHL.

Conditions which impact the main blood vessels supplying blood to the heart (CVD)

- **Heart bypass surgery:** Among three studies investigating one found no effect after controlling for other factors; one demonstrated a significant effect on high-frequency HL; and one reported higher hearing thresholds across all frequencies (500 to 14,000 Hz).
- **Atherosclerosis (coronary artery disease, CAD):** Of three studies, two revealed a relationship with high-frequency HL, while one showed a modest yet significant increase in hearing thresholds at low frequencies.
- **Retinopathy:** One study identified a relationship with HL between 500 and 4000 Hz, but surprisingly found better hearing at 8000 Hz.
- **Carotid artery stenosis (CAS), a narrowing caused by atherosclerosis:** One study showed no significant effect on hearing.

CRITICAL NOTE:

This systematic review addresses a multifaceted and complex topic. It offers an insightful overview that prompts reflection on potential strategies for preventing or mediating the consequences of conditions which impact the main blood vessels that supply blood to the heart on hearing loss. However, the review lacks a statistical analysis that systematically presents the odds ratios for the various factors contributing to the development of sensorineural hearing loss. We look forward to a future meta-analysis on this topic.

- **Myocardial infarction (heart attack):** Three studies found, after controlling for other factors, either no significant relationship or a very weak one ($p = 0.02$).
- **Percutaneous coronary intervention, a minimally invasive procedure to open blocked coronary arteries:** One study, when controlled for other factors, found no significant effect.

Conditions that impact the blood vessels in the brain (cerebrovascular disease)

- **Cerebral small vessel disease (CSVD)**, where the small blood vessels in the brain become narrowed, blocked, or damaged: one study demonstrated a significant relationship with low-frequency HL.
- **Cerebrovascular accidents (CVA),** where blood flow to a part of the brain is obstructed due to either a blockage or the rupture of a blood vessel: A total of eight studies examined this topic, among these:
  - One study identified a relationship with low-sloping HL,
  - One study showed a correlation with both low- and high-frequency HL,
  - one study found a correlation with all frequencies, with a greater impact on high frequencies,
  - five studies found no significant correlations.
- **Transient ischaemic attack (TIA),** a temporary stroke with symptoms which resolve within 24 hours: One study showed no significant relationship when controlled for other factors.
- **Peripheral vascular disease (PVD)**, which affects the circulatory system outside the brain and heart: One study, which found a relationship with strial HL, although it was not controlled for other conditions related to PVD.

Risk factors

- **High cholesterol:** Among 20 studies on this topic:
  - 14 found no correlation with HL;
  - Four showed a relationship with low-frequency HL, mid to high-frequency HL, and HL across all frequencies;
  - One study reported improved hearing at both low and high frequencies;
  - One study found that high-frequency HL was associated with lower levels of good cholesterol (high-density lipoprotein, HDL).

- **High blood pressure:** A total of 30 studies investigated the relationship between this condition and HL, of which:
  - 15 studies found no correlation;
  - The remaining 15 indicated a relationship with HL, including high-frequency HL, low-frequency HL, mid-frequency HL, and slow-sloping HL. One study specifically found a correlation with high-frequency HL in men and low-frequency HL in women.

- **Diabetes:** With a total of 44 studies, 14 studies found no significant relationship with HL. 30 studies found significant correlations, including:
  - Two studies focused on ultra-high-frequency HL,
  - Eight studies focused on high-frequency HL,
  - Eight studies on HL across all frequencies,
  - One study on low-frequency HL,
  - Eight studies found relationships between high-frequency and low-frequency HL,
  - Three studies reported correlations specific to particular genders or racial groups.

Conclusions

The relation between conditions that impact the main blood vessels that supply blood to the heart and HL is complex. Most publications highlight a correlation HL one the one hand and heart bypass surgery or atherosclerosis or the other.

Regarding risk factors, diabetes is consistently linked with HL in the majority of studies, while high cholesterol and high blood pressure do not show a consistent correlation with HL. The authors suggest that HL may occur as a consequence of CVD, rather than being an early indicator of these conditions. •

MEASUREMENT AND OPTIMISATION OF THE PERCEPTUAL EQUIVALENCE OF THE DUTCH CONSONANT-VOWEL-CONSONANT (CVC) WORD LISTS USING SYNTHETIC SPEECH AND LIST PAIRS

Polspoel S., Holtrop FS., Bosman AJ., et al.

Int. J. Audiol. (2025): 64(1), 35–42

doi: 10.1080/14992027.2024.2306186. Epub 2024 Feb 7. PMID: 38327074.

By Gerard Ros, The Netherlands

The current consonant-vowel-consonant (CVC) lists used in the Netherlands exhibit a significant variation of up to 20% across different lists. Synthetic speech presents a promising solution to mitigate this list-effect, potentially improving consistency and reliability in auditory assessments.

A Dutch research group published results comparing the standard Dutch CVC word list for speech audiometry, recorded over 30 years ago by a 'live' female speaker, with the same words generated by a text-to-speech programme.
This study's findings led to a follow-up initiative. The original Dutch word lists for speech audiometry exhibited a 'list effect', as individual lists varied in speech recognition scores under identical conditions. This paper publishes and analyses both sets of results.

Speech material for recognition tests human versus synthetic

The potential benefits of using synthetic speech for generating speech material include increased efficiency and cost-effectiveness. A human speaker faces greater challenges in maintaining consistent articulation and speech rate compared to a text-to-speech program that generates synthetic speech. The ability to create new speech materials in a more time- and cost-efficient manner will allow for more frequent updates of the materials, ensuring they remain relevant and reducing the inclusion of obsolete words.
However, a significant downside to implementing new materials is the potential issue of backward compatibility with previous test results. A considerable variation in speech recognition scores between the new and legacy versions would limit the ability to directly compare recent test results with older ones. Previous research on synthetic speech for testing speech recognition found no significant differences in scoring or listening effort between natural and synthetic speech.

CRITICAL NOTE

As a Dutch hearing care professional, I was aware of the variation between word lists, but I was still taken aback by the 20% spread observed. Given the potential of synthetic speech as a solution, developing an 'audiometric tool' that provides stable, lasting output should be a priority in the development of ANSI and IEC standards. However, I see a practical downside with the paired word lists as used in this study. Clients/patients are typically tested at four to five different presentation levels per ear, which makes the use of longer word lists more cumbersome and challenging in routine clinical practice.

The most commonly used speech material in Dutch speech audiometry consists of consonant-vowel-consonant (CVC) word lists, with each list containing 12 words. The first word serves for conditioning, while the remaining 11 words are scored. Each word consists of three phonemes, leading to a total of 99 phonemes per list.
During the development of the Dutch speech material, efforts were made to minimise phonetic differences across lists; however, complete balance was not achieved. This approach was intended to prevent the inclusion of meaningless words, which would have been necessary to fully balance the lists, as such words might confuse elderly people.
The phonetic differences between lists are less noticeable for individuals with normal hearing (NH) compared to those

with hearing impairments or cochlear implant (CI) users. This discrepancy highlights the need for the development of new speech material to mitigate these differences, possibly including dedicated lists for each group.
The incorporation of synthetic speech could prove valuable in the development of these specialised lists.

Generating synthetic Dutch CVC lists

The CVC word lists were used to generate synthetic speech material with a synthetic female voice via the Google Cloud Text-to-Speech application. The material was produced as 16-bit WAV files with a sample rate of 44.1 kHz.
The produced synthetic material was then equalised to ensure consistency with the long-term average speech spectrum of the original natural-voice material.

Comparing the human voice Dutch CVC lists to synthetic generated lists

A total of 24 NH, native Dutch-speaking young adults were recruited for the study. The participants were tested with both the naturally recorded and synthetically generated CVC word lists at sound pressure levels (SPL) of 17; 22; 27; 32; 37; and 65 dB SPL.
All tests were performed in a sound booth using Sennheiser HDA200 headphones.
Half (n=12) of the participants began the test with the natural speech material, while the remaining half (n=12) started with the synthetic material. In order to limit fatigue, the presentation levels were mixed, alternating between more challenging (faint) and easier (more audible) stimuli. Participants were instructed to repeat all the words they heard, whether real or nonsensical. The testing procedure followed a double-blind design.
Following statistical analysis, the results showed less variation in speech recognition scores between the word list for the synthetic speech compared to the natural speech material. The list effect was smaller for the synthetic speech. Additionally, the mean speech reception threshold (SRT) scores for natural speech were 1.6 dB lower, and the slopes for the synthetic speech were steeper. All of these differences were found to be statistically significant.

	SD SRT (dB)	Mean SRT (dBSPL)	Slope (% points/dB)
human lists	1,8	20,9	3,4
synthetic lists	0,7	22,5	3,8

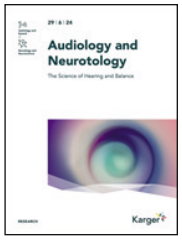
The observed variation in speech recognition scores across the original natural recorded word lists triggered the researchers to explore ways to minimise this list effect.
It is commonly assumed that these word lists are balanced and can be used interchangeably. However, this study found a significant variation of over 20% in intelligibility between the lists.
The list effect introduces uncertainty when comparing test results over time or across different conditions, such as aided vs. unaided testing or varying device settings. Since the lists are inherently more 'easy' or 'difficult', the outcome of a test is influenced not only by the presentation level and testing condition but also by the specific list selected for the test.
In order to minimise the list-effect, the natural recorded word lists were ranked according to their intelligibility score and paired accordingly: the 'lowest' intelligibility list was paired with the 'highest', the 'second lowest' with the 'second highest', and so on, creating word lists with twice the original number of words (66 phonemes).
List 6, which had the lowest intelligibility scores, was excluded due to its difficulty and inability to be paired effectively.
The seven newly created word lists were presented to 28 NH young adults at a level of 30 dB SPL, using an unscored practice list. For consistency, the researchers used the same equipment as in the first experiment.
Since the primary aim was to compare the internal balance between the combined lists, presenting them at multiple loudness levels was not deemed productive.
Statistical analysis revealed a smaller list effect for the combined 'double list', suggesting that this approach may offer higher test-to-test reliability for speech intelligibility tests.
This study demonstrates that the standard Dutch CVC word lists, commonly used in audiometry, exhibit variability in intelligibility, with average scores differing across lists. While the word lists share the same phonetic structure, this proves insufficient to prevent the occurrence of a list-effect, resulting in unequal intelligibility across the lists.
There are multiple factors that can create a list-effect in CVC speech material. In the Dutch material only the vowel composition is constant over each list, another factor is the daily use of words, more commonly used daily words could be recognised better.
Additionally, words that are acoustically similar to others may be reproduced incorrectly, and their occurrence in a word list can affect the overall recognition score.
Notably, for the original Dutch CVC word lists level corrections were not applied.
Interestingly, the list-effect observed in the natural recorded word lists was not found in the synthetic lists. This suggests that natural speech may exhibit less stability than synthetic speech, making synthetic speech a viable alternative for generating speech materials.
Similar findings have been reported in earlier studies (please refer to the original article for details).
A potential drawback in generating synthetic speech for speech audiometry lies in the ongoing innovation within text-to-speech (TTS) systems. As TTS technology advances, suppliers aiming to enhance the naturalness of synthetic speech may introduce greater variation in the sound profile.

This variability could complicate the development and long-term consistency of speech material for audiometry. Another important consideration is the comparability of recent and historical test results. If the speech material undergoes modifications over time, it introduces an additional factor that must be accounted for when interpreting test outcomes and comparing results across different periods.

CONCLUSION

The current CVC word lists in the Netherlands present significant variation, with differences of up to 20% between the lists. Synthetic speech presents a promising solution for mitigating this list-effect. Furthermore, the list-effect observed in the current natural recorded Dutch CVC word lists can be minimised by strategically pairing specific. •

PREDICTING HEARING AID OUTCOMES USING MACHINE LEARNING



Roger P., Lespargot T., Boiteux C., et al.

Audiol Neurootol (2025): 3, 1–9

doi: 10.1159/000543916. Epub ahead of print.

PMID: 39899999.

By Catherine Boiteux, France

The authors analyse the results of patients fitted with hearing aids in current practice, using a common audiological data collection protocol. They use advanced artificial intelligence techniques to analyse the available data.

INTRODUCTION

With the global prevalence of hearing loss (HL) steadily increasing – a condition the WHO estimates will affect 2.5 billion people by 2050 – hearing aids (HAs) have become an essential therapeutic solution. However, the effectiveness of HAs varies considerably from one individual to another, posing a major challenge for hearing care practitioners. The present study proposes an innovative approach: leveraging machine learning tools to identify factors which predict HA benefits, based on a retrospective dataset of over 77,000 patients.

This pioneering research not only highlights the overall effectiveness of HAs but, more importantly, uncovers the precise conditions which optimise their performance. It represents a key advancement towards personalised hearing healthcare, driven by data and informed through detailed explanatory analysis.

METHODOLOGY AND STUDY POPULATION

The study is based on a homogeneous dataset drawn from hearing centres which applied standardised protocols between 2018 and 2021. In order to reduce biases associated with audiometric asymmetry, recruited participants were all over the age of 50 and diagnosed with symmetrical HL. Audiometric outcomes were assessed using three tests:

- Pure Tone Average (PTA): mean tonal threshold (0.5; 1; 2; 4 kHz);
- Speech Recognition Threshold (SPIQ): A measurement of the minimum sound level at which speech can be recognised;
- Speech Perception in Noise (SPIN): Assessed intelligibility in noise via an adaptive signal-to-noise ratio.

The study compared patient performance with and without HAs and correlated these results with various variables: the technology level of the HAs; personalised adjustments (e.g. gain and binaural balance), and adherence to daily wear.

MAIN RESULTS AND HEARING GAINS

The results were particularly convincing, with the following key improvements:

- An average +11 dB improvement in SRT in quiet;
- An average +3.1 dB gain in the SNR in noise;
- 99% of patients regained an SRT below 60 dB (normal voice level).

The frequency bands around 2,000 Hz (15–25 dB gain) play a major role in the improvement, followed by 1,000 Hz for quiet and 4,000 Hz for noise, supported by SHAP (Shapley Additive Explanations) values.

The choice of technology level:

The study shows a strong correlation between the technology level of HAs and their clinical effectiveness,

CRITICAL NOTE

For the last two decades, inter-individual variability in the benefits of HAs has been a central focus in audiology. While numerous studies have attempted to identify factors predictive of hearing aid (HA) success, few have reached large-scale populations, and even fewer have used robust artificial intelligence (AI) tools. This article brings new insights through:

- ***An exceptionally large sample:*** *with data from more than 77,000 patients, whereas the majority of previous studies typically include 100 to 1,000 subjects.*
- ***Standardisation of clinical protocols:*** *thanks to the Amplifon network, the data is homogeneous and can be applied on a large scale.*
- ***High-level AI methodology:*** *Use of XGBoost (benchmark in supervised machine learning), paired with interpretable analysis via SHAP values, making the predictive model explicable (which few competing studies do rigorously).*
- ***Clinical predictive approach:*** *while most previous studies have been correlational, this study takes a clear, objective approach with the aim to apply predictive insights directly to clinical practice.*

LIMITATIONS

While the article offers significant insights, there are areas which recent literature covers more comprehensively:

- ***Cognitive and emotional factors:*** *The study does not incorporate data on executive functions, anxiety, or motivation, which are well known to strongly influence HA use and satisfaction.*
- ***Subjective quality-of-life tests:*** *unlike other studies that use standardised scales such as the IOI-HA or the APHAB, the study remains focused on audiometric criteria.*
- ***Prospective design:*** *although impressive in its scope, the retrospective design may introduce selection bias or missing data (which cannot be ignored).*
- ***External validation:*** *the predictive models developed in the study have not been tested on an independent dataset, limiting their generalisability to other clinical contexts or countries.*

Despite these limitations, the article represents a methodological breakthrough in the field of prosthetic prediction. By moving beyond conventional statistical approaches and integrating large-scale, explainable AI tools, the study offers a model that is immediately transferable to clinical practice. With its originality, large sample size, and clear results, it will serve as a structuring reference for years to come, especially in the field of personalised calibration of HAs. However, for it to become a complete model for predicting prosthetic success, it still fails to incorporate psycho-cognitive variables. These elements are essential for ensuring that AI, clinical audiology, and patient-centred medicine are aligned.

particularly in noisy environments. Higher-technology devices offer:

- Superior improvement in SPIN, irrespective of the degree of HL.
- A dose-response effect, with better outcomes as the technology-level increases.

Clinical implications: The findings underscore that opting for higher technology is not merely a matter of comfort or marketing, but rather a functional necessity to maximise hearing benefits, particularly in complex auditory environments.

The importance of binaural loudness balancing

The binaural loudness balancing test, frequently overlooked in clinical practice, has proved to be a decisive predictive factor, particularly for:

- Patients with losses > 50 dB HL,
- Improving SPIN, with a greater effect than on-board anti-noise systems.

Clinical Implications: Accurate adjustment of the gain between both ears improves binaural fusion and promotes the activation of the brain's unmasking mechanisms in noise. This fine-tuning should be incorporated into the initial fitting process and checked regularly.

Adherence to daily wear

Patients who consistently wear their HAs for more than nine hours per day consistently achieve better results, particularly in noisy conditions (SPIN) and for HL greater than 60 dB HL. ***Clinical Implications:*** HA professionals must actively monitor and encourage daily use of the devices through data logging and make this a criterion for prosthetic monitoring in its own right.

A new approach to results analysis

The study introduces advanced analytical methods, such as XGBoost for predictive analysis and SHAP values for individualised interpretation of impact factors. This approach allows for a deeper understanding beyond the population average, providing a personalised reading of the hearing performance profile based on clinical, technological, and behavioural variables.

Clinical Implications: In the future, analysis by cluster and profile could, in time, lead to the development of tailored fitting protocols, customised to patients' unique audiological profile.

LIMITATIONS AND OUTLOOK

While the results are robust, they should be interpreted with caution due to the heterogeneity of the population and

the retrospective nature of the analysis. Nevertheless, this study paves the way for more refined predictive protocols, including the development of patient profiles based on audiometric results and personalised adjustments integrated into fitting software.

CONCLUSION

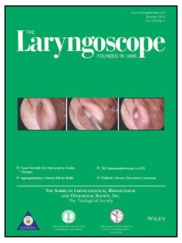
This study marks a turning point in clinical HA practice. For the first time, a very large-scale analysis (n=77,661) shows how three key factors – technology, binaural adjustment and everyday use – interact to determine the true effectiveness of HAs. By combining field data with artificial intelligence, this study makes it possible to:

- Scientifically validate empirical practices in the field,
- Objectivise technological choices for patients and prescribers,
- Optimise the customisation of hearing equipment.

The practical implications of these findings are profound: a new era is opening up, in which clinical expertise is augmented by predictive analysis, directly benefiting the patient. The future of HAs will be characterised by a human-centred, digital, and adaptive approach. •

OVER-THE-COUNTER HEARING AIDS: A NATIONWIDE SURVEY STUDY TO UNDERSTAND PERSPECTIVES

IN PRIMARY CARE



Davis RJ., Lin M., Ayo-Ajibola O., et al.

Laryngoscope. (2025): 135(1), 299–307

doi: 10.1002/lary.31689. Epub 2024 Aug 27. PMID: 3919238.

By Michael Joseph, United States

The study found that participants generally held positive attitudes towards over-the-counter (OTC) hearing aids (HAs) and expressed a desire for increased involvement and knowledge regarding the use of these devices. However, participants perceived their level of ownership of care as neutral. Additionally, there was a lack of confidence in the management of OTC HAs.

OBJECTIVE

The proliferation of over the counter (OTC) hearing aids (HAs) has raised important questions regarding awareness, attitudes, and perceived responsibilities of primary care physicians (PCPs). For this study, the researchers developed a novel national online survey to garner data on PCPs' perspectives on OTC HAs.

BACKGROUND & INTRODUCTION

Hearing loss (HL) is a common chronic condition, affecting roughly 15% of adults in the United States alone, with its incidence increasing with age. Despite its well-established consequences for cognitive, emotional, and physical health, HL often goes untreated. HA adoption remains low, with fewer than one third (30%) of adults over 70 and only a small fraction (16%) of younger individuals using them. Contributing factors include financial barriers, limited access to care, technological barriers and literacy, low public awareness, social stigma, and dissatisfaction with device effectiveness.

Until recently, HAs were primarily available through hearing care professionals. However, in a move to broaden access and encourage innovation, the FDA introduced a new class of OTC HAs in August 2022. With OTC HAs now accessible for purchase online or in retail settings – without the need for clinical evaluation or prescription – individuals must take on tasks traditionally managed by hearing care professionals. This includes recognising their own hearing difficulties, selecting appropriate devices, performing self-fitting through mobile applications, and troubleshooting technical issues independently. Such responsibilities can be daunting for many users.

In this context, primary care physicians (PCPs), who frequently serve as the initial contact in healthcare, may play a pivotal role in guiding patients through these decisions. However, there is limited understanding of how

PCPs perceive this responsibility or how confident they feel in supporting patients with OTC HAs. To explore these issues, researchers designed a specialised national survey, the first of its kind, to assess PCPs' views, knowledge, and sense of responsibility regarding this emerging aspect of hearing care.

METHODOLOGY

To ensure methodological rigour and ethical oversight, the research team obtained approval from the Institutional Review Board at the University of Southern California. An anonymous, cross-sectional survey was developed with reference to guidance from the FDA, the American Speech-Language-Hearing Association (ASHA), the American Academy of Audiology, and other authoritative sources. Input from specialists in neurotology, audiology, and primary care was used to further refine the instrument. The finalised survey was then disseminated nationwide to PCPs in the U.S. via professional email networks and digital forums.

Data were collected over a period covering September to December 2023, i.e. roughly one year following the implementation of the FDA's policy on OTC HAs. The survey captured a range of variables, including demographic characteristics their clinical experience with hearing-related issues and their typical practice behaviours.

The survey combined five-point Likert-scale items, multiple-choice questions, and knowledge-based assessments to evaluate respondents' confidence, perceived responsibility, and understanding of over-the-counter hearing aids (OTC HAs), as well as their preferred learning methods. Descriptive statistics were used to summarise responses, and regression analysis was conducted to identify factors associated with familiarity and positive attitudes towards OTC HAs. Key predictors included provider training level, clinical experience, practice setting, and prior education related to hearing loss, with significance set at $p < 0.05$. Among the 111 respondents, 90% were physicians with a mean of 16.85 years in practice, largely based in urban (50%) or academic outpatient settings (48%), and most cared for adults aged 60–79 years. Notably, approximately 21% of their patient population experienced some form of hearing difficulty.

RESULTS & DISCUSSION

This study is the first to assess PCPs' attitudes, knowledge, confidence, perceived roles, and ownership regarding OTC HAs. PCPs generally held positive attitudes towards OTC HAs and demonstrated a clear interest in becoming more engaged and informed in their clinical management. Despite this enthusiasm, 61% of PCPs felt very unfamiliar with these devices and had low confidence in providing patient guidance. However, 92% did view the devices positively and recognised the potential benefits of hearing intervention. More work is needed in improving the education and knowledge regarding OTC HAs with 65% of PCPs viewing

REVIEWER'S NOTE AND CONCLUSION

In October 2022, the U.S. hearing and audiology market underwent one of the most significant regulatory changes in recent history with the introduction of a new category: Over-the-counter (OTC) hearing aids (HAs). This shift sparked a range of responses within the industry. While some stakeholders welcomed the move to reduce barriers to access, others raised concerns about consumer safety and emphasised the continued importance of prescriptive hearing solutions for effective hearing loss (HL) treatment.

A key insight that has emerged over the past few years is that lowering barriers to access does not necessarily lead to a corresponding increase in adoption or usage. Moreover, patients experiencing hearing difficulties do not always seek help from audiologists or hearing care providers initially; instead, primary care physicians (PCPs) often serve as the first point of contact. As such, the role of PCPs can play a critical role in shaping a patient's journey towards hearing intervention.

From the reviewer's perspective, understanding how non-specialist healthcare professionals perceive their role in hearing care is particularly valuable. While PCPs generally express confidence in identifying HL and referring patients to specialists, they often feel uncertain about managing hearing concerns directly or making recommendations regarding OTC HAs.

This suggests a clear opportunity for growth through targeted education and interdisciplinary collaboration. Although many PCPs acknowledge the potential benefits of OTC devices, a lack of professional familiarity and structured knowledge around these products contributes to ongoing ambivalence towards their use.

By building on their foundational skills in screening and patient engagement, PCPs could play a more active role in the evolving OTC HA landscape–particularly if supported by formal guidelines, clinical tools, and continuing education.

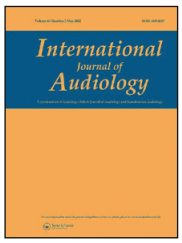
For PCPs and other healthcare providers to take a more proactive role in hearing health, especially with respect to OTC HAs, it is essential that they receive additional training and resources to bolster their confidence and competence. Future research would benefit from expanding the sample size to include a broader range of PCPs and healthcare professionals, while also integrating patient perspectives to better understand the full scope of the hearing care journey.

themselves as poor sources of information. To improve this knowledge, respondents most frequently endorsed the need for more formal guidelines and continuing education opportunities with a key focus on more structured learning approaches rather than information provided by sales representatives.

STUDY LIMITATIONS:

The study sample was small and not fully representative, with a predominance of participants from urban and academic environments. Additionally, there may have been a respondent bias, as individuals with strong opinions on the topic may have been more likely to take part in the survey. •

THE EFFECT OF AUDITORY TRAINING ON LISTENING EFFORT IN HEARING-AID USERS: INSIGHTS FROM A PUPILLOMETRY STUDY



Koprowska A., Wendt D., Serman M., et al.

Int. J. Audiol. (2025): 64(1), 59–69

doi: 10.1080/14992027.2024.2307415. Epub 2024 Jan 30. PMID: 38289621.

By Raquel Teixidor, Spain

Auditory training using phoneme-in-noise tasks has the potential to enhance listening effort in hearing-aid users, as evidenced by increased task-evoked pupil responses. This effect occurs even in the absence of marked gains in speech intelligibility, underscoring the value of pupillometry as a meaningful outcome measure in auditory rehabilitation.

CRITICAL NOTE:

While the study offers compelling evidence for the utility of pupillometry in assessing cognitive effort during auditory tasks, several limitations temper the conclusions. The small sample size (n=19 after exclusions) and imbalance in working memory capacity between groups may have influenced outcomes. Future research would benefit from replication with a larger and more cognitively matched cohort. Additionally, the absence of self-reported measures for fatigue and motivation – two variables likely crucial to understanding the observed increase in effort post-intervention – represents a notable gap, particularly given the unexpected post-training increase in pupil dilation.

Despite these caveats, this study demonstrates the potential of pupillometry as a sensitive and complementary tool alongside traditional speech intelligibility tests, especially for detecting subtle cognitive changes induced by auditory training.

OVERVIEW

This study explores the effects of auditory training on listening effort in older adults with hearing aids (HA). While speech-in-noise performance has traditionally been the main metric for assessing auditory training outcomes, the present research highlights the use of pupillometry – a physiological indicator of cognitive load – to gain deeper insight into listening effort during speech perception tasks.

BACKGROUND AND RATIONALE

Auditory training is increasingly recognised as a valuable component in auditory rehabilitation, especially for HA users. While the primary goal of such training is to improve speech recognition, particularly in noisy settings, outcome measures have predominantly relied on intelligibility scores. This approach, however, fails to account for the cognitive effort required to process speech – a factor which significantly affects the quality of life for hearing-impaired individuals.

Pupillometry, which tracks changes in pupil diameter as an indicator of cognitive load, offers an objective method for

assessing listening effort. However, despite its promise, relatively few studies have thus far used this technique to evaluate training outcomes. The present study bridges that gap by applying pupillometry to assess the impact of phoneme-in-noise training on listening effort.

STUDY DESIGN AND PARTICIPANTS

A population of 20 HA users (aged 63–79) with mild-to-moderate symmetrical HL and at least one year of experience using hearing aids were assigned to one of two groups: one received a six-session phoneme-in-noise training, while the other participated in a placebo activity involving audiobook listening and EEG monitoring. Pre- and post-intervention assessments were conducted using the Danish Hearing in Noise Test (HINT), with speech intelligibility measured at two levels: SNR50 (50% correct) and SNR80 (80% correct). Pupillometry data were recorded simultaneously.

METHODS

Two key metrics were analysed: peak pupil dilation (PPD) and the time-course of pupil response via growth curve analysis (GCA). The training group focused on identifying phonemes embedded in noise, receiving real-time feedback to facilitate improvement. The control group completed listening tasks with no phoneme-specific training, serving as a baseline to isolate the cognitive impact of the training intervention.

Pupillary responses were normalised and baseline-corrected. Rigorous pre-processing was performed to ensure data quality by controlling for potential confounds such as blink artefacts, time of day, and caffeine intake.

RESULTS

Speech Intelligibility:

- At SNR50, speech intelligibility improved significantly only in the training group, suggesting a potential benefit of training on low-context speech tasks. No significant changes were observed at SNR80 for either group, likely due to a ceiling effect.

Peak Pupil Dilation (PPD):

- Surprisingly, both groups exhibited increased PPD post-intervention, indicating heightened cognitive effort. Contrary to initial hypotheses, training did not reduce listening effort as measured by raw pupil dilation measures.

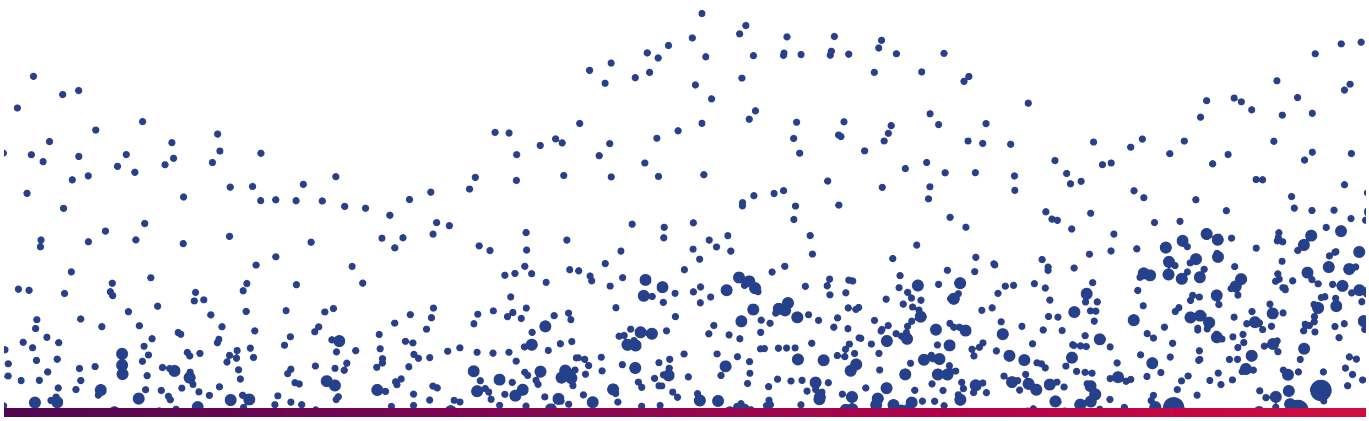
Growth Curve Analysis (GCA)

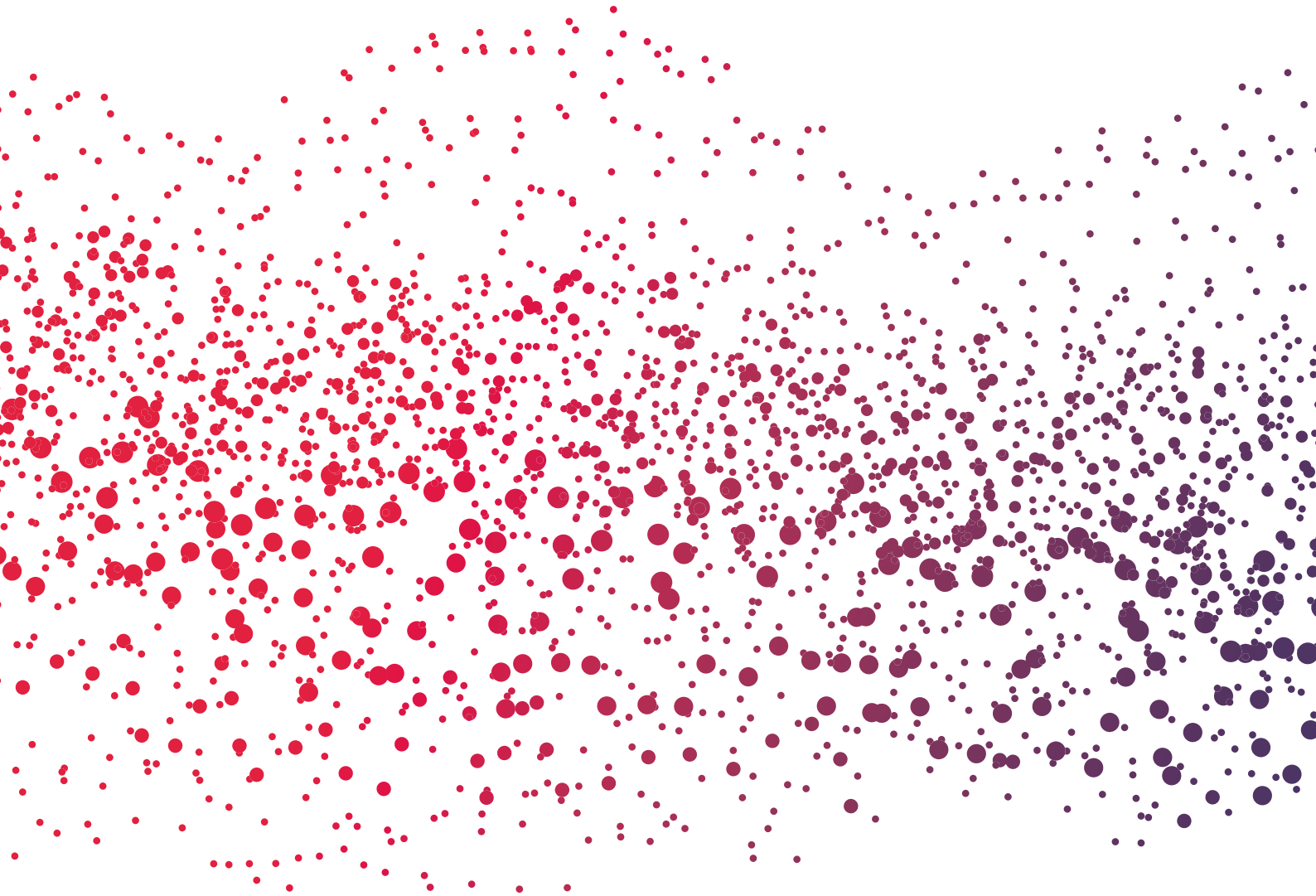
- GCA revealed a more nuanced pattern. The training group showed more pronounced and consistent changes in pupil response dynamics, particularly at SNR80. These included greater response amplitudes and steeper slopes – potentially reflecting increased task engagement or motivation post-training.
- In contrast, the control group exhibited only mild changes, largely confined to the SNR50 condition. Notably, these changes are likely attributable to placebo-like expectations rather than actual improvements in auditory processing abilities.

DISCUSSION

These findings challenge the prevailing assumption that successful auditory training always reduces cognitive load. Instead, the observed increase in listening effort following training may reflect greater motivation or a strategic shift in the allocation of cognitive resources – listeners may be more engaged and willing to invest effort when they perceive the task as manageable.

Moreover, the study underscores the limitations of conventional intelligibility metrics, especially in high-performing conditions such as SNR80. While intelligibility scores remained unchanged, pupillometric data revealed training-related effects, underscoring the value of including physiological measures in future audiological assessments. The use of an active control group in the study design further revealed that participation itself or the perception of training can alter listening effort, a factor which complicates the interpretation of pupillometry data but also highlighting the method's sensitivity to contextual variables such as motivation. •





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