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Editor-in-Chief
Prof. Henryk Skarzynski, M.D., Ph.D., Dr. h.c. multi

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Dear Colleagues,

It is my pleasure to invite you to read the second issue of the *Journal of Hearing Science* for 2025, an issue bringing you a wide selection of studies spanning tinnitus care, pharmacological vigilance, hormonal influences on hearing, safe listening, and childhood auditory development.

We begin with key insights from the 2025 World Tinnitus Congress and XIV International Tinnitus Seminar, held this year in Warsaw. This landmark gathering of researchers and clinicians revealed fresh possibilities for tinnitus and hyperacusis therapy, integrating cognitive behavioral approaches, somatosensory modulation, emerging drug treatments, and tele-audiology tools. From validated assessment methods for children to precision surgery for pulsatile tinnitus, the event highlighted a move toward care that is more tailored towards each patient's needs.

Other papers in this issue also offer valuable perspectives. A systematic review of adverse drug reactions provides clinicians with practical guidance in identifying medication-related effects on hearing, balance, and vocal health. A study on natural versus surgical menopause reveals how sudden hormonal changes can disrupt the brain's timing in sound processing, suggesting new avenues for intervention. Research into the acoustic outputs of headphones show that there are differences between combinations of devices and earbuds – sometimes above safe volume limits – and point to the need for stronger standards and safer listening habits. Finally, an assessment of Polish infants and toddlers using the LittlEARS® Auditory Questionnaire uncovers delays in some older children, reinforcing the importance of regular auditory development checks at 12 and 24 months.

Together, these contributions offer both inspiration and practical tools for improving hearing health at every stage of life. I encourage you to explore these articles and apply their insights to your own field of work.

With kind regards and greetings,

Prof. Henryk Skarzynski, M.D., Ph.D., Dr. h.c. multi

Hypothesis papers

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KEY INSIGHTS FROM THE III WORLD TINNITUS CONGRESS AND XIV INTERNATIONAL TINNITUS SEMINAR: TOWARD STRATIFIED AND MULTIMODAL TINNITUS CARE

Contributions:
A Study design/planning
B Data collection/entry
C Data analysis/statistics
D Data interpretation
E Preparation of manuscript
F Literature analysis/search
G Funds collection

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Abstract

The 2025 World Tinnitus Congress (WTC) and XIV International Tinnitus Seminar (ITS), held in Warsaw, Poland, brought together leading researchers and clinicians to share the latest advances in tinnitus and hyperacusis care. This article reviews key developments presented at the conference and explores the implications for research and clinical practice. Major themes included progress in cognitive behavioural therapy (CBT), neurophysiological mechanisms, somatosensory modulation, pharmacology, and digital health interventions. Highlights included validated paediatric assessment tools, stratified pharmacotherapy, and precision surgery for pulsatile tinnitus. Presentations underscored the expanding role of tele-audiology and digital self-help platforms, reflecting a shift toward decentralised and personalised care. The need for biomarker-guided trials, improved patient stratification, and wider access to psychological therapies are priorities for both research and clinical delivery.

Keywords: neuromodulation • cognitive behavioural therapy • hyperacusis • tinnitus

NAJWAŻNIEJSZE WNIOSKI Z III WORLD TINNITUS CONGRESS I XIV INTERNATIONAL TINNITUS SEMINAR – W KIERUNKU ZRÓŻNICOWANEJ I WIELOKIERUNKOWEJ OPIEKI NAD PACJENTAMI CIERPIĄCYMI NA SZUMY USZNE

Streszczenie

World Tinnitus Congress (WTC) 2025 i XIV International Tinnitus Seminar (ITS), które odbyły się w Warszawie (Polska), zgromadziły czołowych naukowców i klinicystów, którzy podzielili się najnowszymi osiągnięciami w zakresie leczenia szumów usznych i nadwrażliwości słuchowej. Niniejszy artykuł zawiera przegląd kluczowych osiągnięć przedstawionych podczas ww. wydarzeń oraz ich implikacje dla badań naukowych i praktyki klinicznej. Główne tematy obejmowały: postępy w terapii poznawczo-behawioralnej (CBT), mechanizmy neurofizjologiczne, modulację somatosensoryczną, farmakoterapię oraz cyfrowe interwencje zdrowotne. Najważniejsze zagadnienia dotyczyły sprawdzonych narzędzi służących do oceny szumów usznych u pacjentów pediatrycznych, farmakoterapii wyodrębnionych grup pacjentów oraz leczenia operacyjnego pulsujących szumów usznych. Prezentacje podkreślały rosnącą rolę teleaudiologii i cyfrowych narzędzi do samopomocy, odzwierciedlając przejście w kierunku zdecentralizowanych i spersonalizowanych modeli opieki. Podczas sesji jako priorytety – zarówno dla badań naukowych, jak i praktyki klinicznej – wskazano potrzebę przeprowadzania badań opartych na biomarkerach, lepszej stratyfikacji pacjentów oraz szerszego dostępu do psychoterapii.

Słowa kluczowe: neuromodulacja • terapia poznawczo-behawioralna • nadwrażliwość słuchowa, szumy uszne

Key to abbreviations	
ACT	acceptance and commitment therapy
AI	artificial intelligence
BBs	binaural beats
BOLD fMRI	blood oxygenation level dependent functional magnetic resonance imaging
CBT	cognitive behavioural therapy
CT	computed tomography
CTQ	Children's Tinnitus Questionnaire

Key to abbreviations	
DAVF	dural arteriovenous fistula
EMG	electromyography
high-SR	high-spontaneous-rate
iSHUSH	internet Self-Help, Understanding, and Support for Hyperacusis
ITS	International Tinnitus Seminar
MEG-OPM	magnetoencephalography with optically pumped magnetometers

Key to abbreviations (continued)	
MRA	magnetic resonance angiography
OAEs	otoacoustic emissions
PT	pulsatile tinnitus
SOAEs	spontaneous otoacoustic emissions
ST	somatosensory tinnitus
SSWAs	sigmoid sinus wall anomalies

Key to abbreviations (continued)	
tDCS	transcranial direct current stimulation
THI	Tinnitus Handicap Inventory
TMD	temporomandibular disorder
U-VNS	ultrasound vagus nerve stimulation
UCL	uncomfortable loudness level
WTC	World Tinnitus Congress

Introduction

Tinnitus is the perception of sound without an identifiable external or internal acoustic source – commonly experienced as ringing, buzzing, or hissing – and is often linked to distress, sleep disruption, difficulty concentrating, and a reduced quality of life. When accompanied by hyperacusis – the perception of certain everyday sounds as being too loud or painful – the impact on daily functioning can be even more severe [1]. The 3rd World Tinnitus Congress and XIV International Tinnitus Seminar brought together clinicians and researchers from around the world in Warsaw, Poland, from 13 to 15 April, 2025. This report summarises the key scientific presentations and emerging themes discussed during the meeting and highlights their implications for future research and clinical innovation [2].

We survey all oral presentations from the congress, along with selected poster presentations that reflected the core scientific themes. Highlights were chosen based on their relevance to emerging trends in tinnitus and hyperacusis research, clinical developments, and future directions in the field.

The topics discussed at the 2025 Congress covered seven main areas, as follows.

1) Cognitive-behavioural therapy (CBT) and psychological factors related to tinnitus, with a focus on diverse delivery models, mechanisms such as cognitive fusion, and the role of mindfulness and personality traits.

2) Neurophysiological mechanisms and emerging interventions, including brain imaging, non-invasive neuromodulation, and electrophysiological tools for refining treatment and diagnosis.

3) Somatosensory and sleep-related modulation of tinnitus, highlighting the influence of musculoskeletal dysfunctions and infradian sleep rhythms on tinnitus perception and the potential for personalised care pathways.

4) Psychologically and aetiologically guided drug therapy, presenting evidence for precision pharmacology based on psychological profiling, targeted drug delivery, and rigorous diagnostic processes.

5) Precision diagnosis and surgical advances in pulsatile tinnitus, introducing improved imaging techniques, new diagnostic markers, and minimally invasive surgical strategies with high resolution rates.

6) Paediatric and population-level innovations, including the development of validated assessment tools like the Children's Tinnitus Questionnaire and calls for more coordinated multidisciplinary care.

7) Digital therapies and accessibility, showcasing mobile apps, internet-based self-help platforms, and tele-audiology as scalable approaches to enhance tinnitus and hyperacusis care, especially in underserved regions.

Summary **Tables 1–7** outlining key presentations, findings, and clinical or research implications.

Conference sections

CBT and Psychological Factors

CBT is an evidence-based intervention for managing distress associated with tinnitus, hyperacusis, and misophonia. The 2025 Tonndorf Lecture, presented by Aazh (UK) [3], discussed three aspects of CBT for auditory conditions comprising the theoretical foundations; clinical evidence on CBT delivered by psychologists, audiologists, and digital platforms; and the estimated proportion of patients who may benefit from CBT. The lecture underlined that CBT is effective in reducing distress for patients experiencing tinnitus, hyperacusis, and misophonia. Both psychologist- and audiologist-delivered CBT protocols have demonstrated significant clinical improvements, while guided internet-based CBT has also yielded promising results [4–6]. Unguided internet-based CBT, though effective, is associated with higher dropout rates and variable engagement [7,8].

The lecture emphasized that not all patients benefit equally – some continue to experience significant distress even after completing CBT [9,10]. This underlines the importance of developing alternative or adjunctive therapies, as well as offering long-term follow-up and support. A key takeaway was the estimation that approximately 1 in 52 individuals with tinnitus requires CBT. This suggests that while tinnitus is a common condition, the need for intensive therapy is more targeted. To advance care, future research should compare the effectiveness of psychologist- and audiologist-delivered CBT, test hybrid delivery models, and explore improvements in digital platforms, especially for managing hyperacusis and misophonia. The lecture further advocated for the inclusion of neuroimaging and physiological markers in future clinical trials to understand neural mechanisms of improvement, and for characterizing non-responders to guide the development of tailored interventions.

Table 1. Summary of presentations on CBT and psychological mechanisms. This table summarises presentations exploring the effectiveness, delivery models, and underlying psychological mechanisms of CBT for tinnitus, hyperacusis, and misophonia. Included are cognitive-behavioural, mindfulness-based, and psychodynamic perspectives, as well as patient stratification and mechanisms of non-response

Presenter/ Author	Topic/ Study	Main Findings/ Perspective	Clinical or Research Implications
Aazh (UK)	CBT for tinnitus, hyperacusis, misophonia (Tonndorf Lecture)	CBT effective across delivery models; some patients require adjunctive therapies	compare psychologist- and audiologist-delivered CBT; integrate biomarkers and support long-term care
Fludra (Poland)	cognitive fusion and tinnitus distress	cognitive fusion correlated with higher distress, especially in men	supports ACT-based techniques in CBT
Gos (Poland)	trait mindfulness and tinnitus distress	higher mindfulness linked to lower distress	encourages inclusion of mindfulness strategies in CBT
Bastos (Brazil)	psychodynamic model of tinnitus	personality traits and unconscious processes influence distress	psychodynamic insights may enhance therapeutic models

Note: CBT = cognitive behavioural therapy; ACT = acceptance and commitment therapy

Complementing the cognitive framework presented in the Tonndorf Lecture, Fludra (Poland) investigated the role of cognitive fusion – the tendency to over-identify with distressing thoughts – as a psychological mechanism contributing to tinnitus-related distress. In a clinical sample of 105 patients, higher levels of cognitive fusion were significantly correlated with increased tinnitus severity, with particularly strong associations observed among male participants. These findings support core principles of CBT, which emphasise identifying and restructuring rigid, maladaptive thought patterns. They also resonate with third-wave CBT approaches such as Acceptance and Commitment Therapy (ACT), which target cognitive fusion through processes like mindfulness and cognitive diffusion) [11].

Adding further nuance, Gos (Poland) presented data linking trait mindfulness to reduced tinnitus distress. Higher scores on dimensions such as "acting with awareness" and "non-reactivity to inner experience" were associated with lower scores on the Tinnitus Handicap Inventory (THI) [12], suggesting that dispositional mindfulness may serve as a protective psychological resource.

Bastos (Brazil) introduced a psychodynamic tinnitus model that emphasises the role of personality traits and unconscious processes, including psychological trauma, in the development and exacerbation of tinnitus-related distress.

Together, these presentations reinforce CBT's role as a foundational approach in managing tinnitus and sound intolerance. They also underscore the value of diversifying delivery models, integrating new technologies, and refining patient stratification strategies to maximise therapeutic impact across varied populations. Key presentations on CBT, cognitive fusion, mindfulness, and psychodynamic models are summarised in **Table 1**.

Neurophysiological Mechanisms and Emerging Interventions

Advancing the understanding of tinnitus at the neural systems level, several presentations at the 2025 Congress provided compelling insights into both the neurobiology of tinnitus and hyperacusis, and the development of non-invasive therapeutic approaches.

Knipper (Germany) focused on the critical distinction between tinnitus with and without hyperacusis, arguing that failure to differentiate these subtypes has hindered the identification of reliable neuronal correlates. Her research – supported by data from audiometry – makes it possible to identify an auditory transfer function from the stimulus-onset, evoked, and resting state BOLD fMRI. The newest findings from MEG-OPM imaging technology (magnetoencephalography with optically pumped magnetometers) point to impaired fast auditory processing (specifically involving high spontaneous rate auditory fibres and subsequent loss of tonic inhibition in cortical protein parvalbumin interneuron networks) as a possible mechanism for persistent auditory phantom percepts [13].

In tinnitus patients with hyperacusis, such disinhibition might further increase attention to internal noise in certain frequency-specific cortical regions (through central hyperexcitability possibly driven by impaired efferent/afferent outer hair cell fibres) which would steepen the dynamic range of loudness perception up to painful sensation of loudness [14]. In this model, the intracortical response to elevated internal noise (tinnitus) and elevated loudness (hyperacusis) might lead to more or less strong emotional burdens and stress responses, depending on the individual. Such corticofugal feedback circuits could be a promising target for cognitive therapies.

In addition to Knipper's focus on distinguishing subtypes of tinnitus and hyperacusis through baseline neural differences, Sereda (UK) presented work from the NIHR Nottingham Biomedical Research Centre examining how non-invasive brain stimulation can modulate tinnitus-associated brain activity. This program has investigated interventions such as transcranial direct current stimulation (tDCS) and ultrasound vagus nerve stimulation (U-VNS), with the aim of altering atypical activity patterns and reducing the tinnitus percept. She explained that systematic reviews have identified tDCS as the most promising approach, with MEG revealing stimulation-induced changes in both frontal and temporal regions [15]. Variability in current delivery across individuals highlights the potential for developing personalised protocols. These findings mark a step toward a targeted, non-invasive therapy informed by a mechanistic insight.

Extending the focus on neuro-modulatory approaches, Szczepek (Germany) reported on a clinical study evaluating the immediate effects of non-invasive electrical stimulation of the ear canal on tinnitus loudness and distress [16]. Over 3 days, 66 chronic tinnitus patients received short-duration stimulation, and nearly half reported reduced loudness and more than one-third experienced less distress. Women and patients with bilateral or compensated tinnitus responded more positively, while age was not a factor. The findings suggest that non-invasive electrical stimulation via the ear canal may support both symptom management and patient stratification for advanced therapeutic options, such as extracochlear implants.

Waraczewski (Poland) evaluated the efficacy of bimodal stimulation using the Lenire device, which pairs sound stimulation with electrical stimulation of somatosensory pathways. In a cohort of 30 patients, 76% showed significant reductions in THI scores, with mean improvements of 17 to 21 points over two follow-up visits. The results are consistent with findings reported from other centres [17].

Yaman (Turkey) conducted a 6-week trial in tinnitus patients of theta-band binaural beats (BBs). Some 18 participants received 20 minutes of daily BB stimulation designed to entrain neural oscillations. The THI scores dropped significantly – from an average of approximately 53 to 34. These findings support the use of BBs as a non-invasive neuro-modulatory tool, particularly in patients with comorbid depressive symptoms.

As a general point, interventions for tinnitus would benefit from more rigorous research designs, such as randomised controlled trials, to minimise the risk of various forms of bias.

Hatzopoulos (Italy) reviewed many years of efforts to identify the mechanisms underlying tinnitus through the use of evoked and spontaneous otoacoustic emissions (OAEs) [18]. His presentation outlined several key challenges. First, pinpointing the precise origin and location of tinnitus within the auditory pathway remains inherently difficult on a case-by-case basis. Second, the recording of spontaneous otoacoustic emissions (SOAEs) – which are most frequently investigated in this context – becomes increasingly unreliable with age, particularly beyond the second decade of life. Hatzopoulos provided a comprehensive review of both historical and contemporary research, presenting a balanced perspective on the ongoing debate: whether or not a meaningful relationship between OAEs and tinnitus can be reliably established.

Azevedo (Brazil) reviewed research on the use of objective measures such as event-related potentials in the assessment of tinnitus, highlighting the potential of electrophysiological techniques to inform both diagnosis and treatment [19,20]. She presented examples where such measures have helped clarify underlying aetiologies, reinforcing the clinical value of integrating objective assessments into tinnitus care. Emphasising a key gap in the field, Azevedo called for future research to prioritise the development of reliable objective examinations, noting that such tools are urgently needed to advance understanding and management.

To conclude, this section highlighted significant advances in our understanding of tinnitus neurophysiology and the development of novel non-invasive interventions. From efforts to differentiate tinnitus subtypes to emerging evidence on neuro-modulatory techniques (such as tDCS, bimodal stimulation, and electrical stimulation of the ear canal), the field is steadily progressing toward more precise and personalised treatment approaches.

Moving forward, a key question is whether these interventions can benefit individuals who continue to experience significant tinnitus-related distress even after having completed established treatments such as CBT or sound therapy. Future research should specifically investigate the potential of these techniques as adjuncts for this subpopulation of non-responders, which would help to close an important gap in current tinnitus care pathways.

Table 2 is an overview of presentations on the neurobiology of tinnitus and non-invasive neuromodulatory techniques.

Somatosensory and Sleep-Related Modulation of Tinnitus: Towards Personalised, Mechanism-Based Care

In some individuals, tinnitus can be modulated by a range of factors, including somatosensory inputs, sound, stress, physical activity, sleep, and diet. When input from the head and neck region affects the tinnitus percept, this is referred to as somatosensory tinnitus (ST). Michiels (Belgium) presented recent advances in the diagnosis and treatment of ST, introducing a validated clinical decision tree based on four diagnostic criteria [21]. Her model demonstrated a sensitivity of 82% and specificity of 79%, offering a promising framework for differential diagnosis. Treatment strategies centred on musculoskeletal physiotherapy addressing dysfunctions in the cervical spine and temporomandibular joint, with interventions including manual therapy, targeted exercises, and patient education – together forming a structured and non-invasive management pathway for ST.

Expanding on this theme, van der Wal (Netherlands) provided a critical overview of temporomandibular disorder (TMD)-related somatic tinnitus, advocating for diagnostic and therapeutic approaches grounded in evidence. She highlighted the neural connectivity between the dorsal cochlear nucleus and somatosensory systems, which helps explain how somatic dysfunctions can affect tinnitus perception [22]. She emphasised the importance of coordinated, interdisciplinary care to ensure such patients receive timely and effective support.

Krasnodębska (Poland) proposed palatal electromyography (EMG) as a novel tool for assessing somatosensory modulation in tinnitus. In a case study of a patient with unilateral tinnitus, EMG revealed abnormal activity in

Table 2. Summary of neurophysiological mechanisms and emerging interventions. This table presents studies on the neural basis of tinnitus and hyperacusis, including advances in imaging, electrophysiology, and neuromodulation techniques such as tDCS, U-VNS, bimodal stimulation, and binaural beats. Findings also address diagnostic challenges and subgroup differentiation based on neural markers

Presenter/ Author	Topic/ Study	Main Findings/ Perspective	Clinical or Research Implications
Knipper (Germany)	tinnitus with/without hyperacusis	high-SR fibre loss and disinhibition in cortex	subtype-specific neural pathways to guide personalised care
Sereda (UK)	tDCS and U-VNS	tDCS alters activity in frontal/ temporal regions	personalised brain stimulation protocols needed
Szczepek (Germany)	ear canal electrical stimulation	nearly half showed loudness reduction	supports short-term symptom relief and stratification
Waraczewski (Poland)	Lenire bimodal stimulation	76% improved on THI	reinforces bimodal treatment protocols
Yaman (Turkey)	binaural beats	significant improvement in THI	binaural beats may help patients with depression
Hatzopoulos (Italy)	otoacoustic emissions	diagnostic value limited by age and variability	highlights limitations and future refinement needs
Azevedo (Brazil)	event-related potentials	useful in clarifying tinnitus aetiology	supports use of electrophysiological markers in clinics

Note: tDCS = transcranial direct current stimulation; U-VNS = ultrasound vagus nerve stimulation; THI = Tinnitus Handicap Inventory; SR = spontaneous rate

the tensor palatini muscle. These preliminary findings invite further research into the diagnostic potential of palatal EMG in ST.

Sleep difficulties are among the most common complaints reported by individuals with tinnitus, with approximately 70% of those seeking help also experiencing symptoms of insomnia [23–26]. Compared to those without sleep problems, tinnitus patients with insomnia tend to report greater overall distress, reduced quality of life, and increased pain-related comorbidities [27], along with a heightened risk of depression [24] and hyperacusis [28]. Against this background, Guillard (France) presented novel findings on the interplay between sleep and tinnitus, with a particular focus on a subgroup of patients whose tinnitus fluctuates in relation to sleep patterns [29–31]. In one study, 17 individuals reported periods of complete remission or increased tinnitus loudness following sleep. Longitudinal data revealed infradian rhythms – typically 2.5 to 4.5 days – suggesting these fluctuations may be governed by underlying physiological cycles such as sleep pressure or sleep debt.

In another study, Guillard [32] examined patients whose tinnitus worsens following naps – a phenomenon frequently observed in clinical settings and reported by approximately 1 in 5 individuals with tinnitus. His findings confirmed the reliability of these post-nap exacerbations. He proposed that the mechanism may involve covert somatosensory influences, such as dysfunction of the tensor veli palatini muscle – often implicated in snoring or sleep apnoea – or broader autonomic or central nervous system processes. This last study is particularly relevant to the field of somatosensory tinnitus, as it suggests that sleep-related musculoskeletal and autonomic factors may rhythmically modulate tinnitus perception in a subset of patients. Both studies point to the need for further research exploring the interaction between sleep physiology, somatosensory pathways, and tinnitus modulation – potentially opening up new diagnostic and therapeutic approaches for sleep-sensitive and somatically influenced tinnitus.

Together, these presentations underscore the growing recognition of physiotherapy as a way to manage ST [33]. This work highlights a shift toward a structured, interdisciplinary approach that integrates musculoskeletal, neurological, and sleep-related factors. **Table 3** summarises studies exploring somatosensory modulation and sleep-related effects on tinnitus.

Psychologically and Aetiologically Guided Drug Therapy for Tinnitus

Pharmacological treatment of tinnitus remains an area of cautious exploration, with numerous agents trialled and few demonstrating consistent effectiveness. At the 2025 Congress, new insights were presented that bridged clinical pharmacology, psychological profiling, and drug delivery innovation.

Azevedo (Brazil) presented results from a double-blind, placebo-controlled trial examining the efficacy of olanzapine, an antipsychotic medication, in individuals with chronic tinnitus. The study included 50 participants and used the THI to assess tinnitus-related distress. Findings revealed that individuals with higher levels of neuroticism and conscientiousness experienced greater improvements with olanzapine, suggesting that personality traits may moderate treatment outcomes. These results highlight the potential of psychologically stratified pharmacotherapy, where individual psychological profiles inform medication selection. Future research should further explore the differential effects of psychotropic medication on tinnitus distress, particularly by distinguishing between patients whose distress is directly driven by the tinnitus percept itself and those whose distress stems from broader psychological comorbidities.

Table 3. Summary of work on somatosensory and sleep-related modulation of tinnitus. Topics cover somatosensory tinnitus diagnosis, physiotherapy, temporomandibular involvement, palatal muscle activity, and infradian sleep rhythms. Emphasis is on personalised care and interdisciplinary approaches

Presenter/ Author	Topic/ Study	Main Findings/ Perspective	Clinical or Research Implications
Michiels (Belgium)	somatosensory tinnitus (ST)	validated decision tree; physiotherapy effective	ST screening and treatment should be standard
van der Wal (Netherlands)	TMD-related tinnitus	emphasised neural links and interdisciplinary care	supports evidence-based diagnosis and treatment
Krasnodębska (Poland)	palatal EMG	abnormal tensor palatini activity	EMG may support somatic tinnitus diagnosis
Guillard (France)	sleep-related modulation	tinnitus fluctuates with infradian rhythms or naps	supports exploring sleep–tinnitus interactions and physiology

Note: T = somatosensory tinnitus; TMD = temporomandibular disorder; EMG = electromyography

Table 4. Summary of presentations on psychologically and aetiologically guided pharmacotherapy. Topics include psychotropic trials, intratympanic therapy, and systematic reviews of efficacy across commonly used agents, with calls for better stratification and trial design

Presenter/ Author	Topic/ Study	Main Findings/ Perspective	Clinical or Research Implications
Azevedo (Brazil)	olanzapine and personality	neuroticism and conscientiousness predicted better outcomes	psychological profiling to guide pharmacotherapy
Skarzynska (Poland)	systematic review of drugs	support for amitriptyline, gabapentin, dexamethasone	need stratified and biomarker-driven trials
Figueiredo (Brazil)	aetiologically informed prescribing	medication only after ruling out medical causes	emphasises diagnostics-first approach
Elzayat (Egypt)	intratympanic steroid trials	mild-to-moderate improvement in some cases	consider local/ systemic combinations for selected patients

Skarzynska (Poland) led a systematic review examining the efficacy and safety of various pharmacological agents used in tinnitus management. They reviewed randomized controlled trials on antidepressants (e.g. amitriptyline), anticonvulsants (e.g. gabapentin), corticosteroids (e.g. dexamethasone), melatonin, *Ginkgo biloba*, and several nootropic compounds. The strongest support was found for amitriptyline, gabapentin, or topically applied steroid (dexamethasone) with the simultaneous use of oral melatonin. However, heterogeneity in trial design and tinnitus subtypes makes generalization difficult. The review concluded with a call for better patient phenotyping and biomarker-driven clinical trials to enhance future research validity.

Figueiredo (Brazil) stressed that tinnitus is inherently multifactorial, and pharmacological treatment should only be considered after ruling out (or managing) contributory medical causes such as metabolic conditions, tumours, or noise trauma. His talk highlighted the limitations of off-label medication use and recommended aetiologically guided prescribing supported by robust diagnostic processes.

Addressing direct drug delivery, Elzayat (Egypt) reported on intratympanic injection trials using corticosteroids in patients with treatment-resistant tinnitus. Results from two small-scale studies suggested mild-to-moderate improvement in tinnitus loudness and annoyance, but variability in outcomes indicated that stratification by tinnitus subtype is essential. Elzayat further advocated for combining local drug application with systemic treatment in selected cases, particularly when inner ear pathology or inflammation is suspected.

Together, these presentations point to a more refined role for pharmacotherapy in tinnitus care – one that emphasises precision over generalisation. Psychological profiling, aetiological clarity, and targeted drug delivery are shaping a future where medications support, rather than replace, personalised and multidisciplinary treatment. For selected patients, especially those with well-defined subtypes, pharmacological approaches may offer meaningful benefit when integrated thoughtfully into a broader care framework. **Table 4** outlines pharmacological approaches to tinnitus, including stratified prescribing and drug delivery methods.

Precision Diagnosis and Surgical Advances in Pulsatile Tinnitus

Pulsatile tinnitus (PT), often caused by vascular anomalies, represents a clinically distinct subtype of tinnitus with specific diagnostic and surgical considerations. At the 2025 Congress, Hsieh (China) presented extensive work on sigmoid sinus wall anomalies (SSWAs), one of the most common causes of venous PT [34–39]. Their

Table 5. Summary of presentations on diagnostic and surgical innovations in pulsatile tinnitus, with emphasis on venous causes, radiological markers, and surgical precision. It includes new intraoperative techniques, longitudinal imaging data, and the potential use of spontaneous otoacoustic emissions as a diagnostic tool

Presenter/ Author	Topic/ Study	Main Findings/ Perspective	Clinical or Research Implications
Hsieh (China)	surgical innovations and radiology	cement thickness optimisation, "moth-eaten" marker	multimodal diagnostics and precise surgery required
Hsieh (China)	SOAEs in PT diagnosis	elevated SOAEs reduced with jugular compression	SOAEs may aid non-invasive PT diagnosis

Note: PT = pulsatile tinnitus; SOAE = spontaneous otoacoustic emission

research challenged the assumption that SSWA is always congenital, showing through serial CT imaging in 42 patients that 29% had progressive bony erosion or diverticulum expansion – emphasising the value of longitudinal radiologic monitoring in suspected cases.

Hsieh also detailed a refined surgical approach using bone cement to dampen vascular sound transmission. Impedance tube testing revealed an optimal cement thickness of 5.0–7.5 mm, balancing effective sound attenuation with surgical safety. Thinner applications were insufficient, while thicker ones added risk without further benefit. These findings now inform surgical standards for minimally invasive resurfacing.

The team introduced a new radiological marker (termed the "moth-eaten sigmoid plate") observed in over 78% of patients with dural arteriovenous fistula (DAVF)-related PT. They advocated for multimodal diagnostics, including CT, MRA, and retro-auricular compression testing, noting that a sigmoid sinus anomaly alone is not diagnostic. Coexisting structural anomalies, such as DAVFs or jugular bulb defects, are necessary to distinguish treatable from benign variants.

In a surgical cohort of 253 patients, Hsieh's team reported a 90% resolution rate for PT following transtemporal resurfacing. Most recurrences stemmed from incomplete coverage, underscoring the critical need for comprehensive anatomical correction.

A novel diagnostic addition was the use of spontaneous otoacoustic emissions (SOAEs), which were elevated in affected ears and reduced with jugular vein compression. This suggests SOAE testing may serve as a non-invasive diagnostic tool for vascular involvement in PT.

Taken together, these advances illustrate the emergence of a precision framework for pulsatile tinnitus – one that combines targeted imaging, functional acoustic diagnostics, and evidence-based surgical techniques. As anatomical and pathophysiological understanding deepens, outcomes for this challenging tinnitus subtype are poised to improve substantially. Diagnostic and surgical innovations for pulsatile tinnitus are detailed in **Table 5**.

Paediatric and Population-Level Innovations

Once considered rare, paediatric tinnitus and hyperacusis are now recognised as more prevalent than previously thought, affecting an estimated 3–6% of children. Data presented at the 2025 Congress highlighted the significant impact of these conditions on emotional wellbeing, academic performance, and social participation [40,41]. Yet, despite their prevalence, diagnostic and treatment pathways for children remain underdeveloped and inconsistently applied.

Raj-Koziak (Poland) introduced the Children's Tinnitus Questionnaire (CTQ), an 11-item instrument developed through a rigorous multi-phase validation study involving nearly 200 children [42]. The CTQ demonstrated high internal consistency ($\alpha = 0.82$) and strong correlations with visual analogue scales measuring tinnitus loudness, annoyance, and coping. As the first fully validated, tinnitus-specific questionnaire for paediatric populations, the CTQ represents a critical step forward in improving assessment and guiding tailored interventions. Further research is needed to validate its use in English-speaking contexts. In addition, Aazh (UK), during a pre-conference workshop, suggested that the use of uncomfortable loudness levels [43] and parent questionnaires for assessment of tinnitus and hyperacusis distress for children should be explored [44].

The overarching message from these sessions was unequivocal: children with tinnitus and hyperacusis urgently need developmentally appropriate assessment tools and access to specialist, multidisciplinary care. Systemic gaps remain widespread – not only in mental health provision but also in coordinated services involving speech and language therapists, specialist audiologists, and child-focused psychological support [45]. Addressing these deficits will require scaling up access to evidence-based audiological and psychological therapies, embedding validated tools like the CTQ into routine practice, and integrating child-friendly digital and mindfulness-based interventions within public healthcare systems. **Table 6** summarises paediatric-focused presentations, including validated tools and population-level service needs.

Digital Therapies and Accessibility

Digital health interventions for tinnitus and hyperacusis were highlighted at the 2025 Congress as scalable, cost-effective tools for reaching underserved populations. Several contributions outlined promising platforms that blend self-help strategies, app-based diagnostics, and remote therapeutic support.

Table 6. Summary of presentations on paediatric and population-level innovations in the diagnosis and management of tinnitus and hyperacusis in children. Key developments include validated questionnaires, parent-reported outcome measures, and the need for multidisciplinary care pathways and age-appropriate tools

Presenter/ Author	Topic/ Study	Main Findings/ Perspective	Clinical or Research Implications
Raj-Koziak (Poland)	Children's Tinnitus Questionnaire (CTQ)	validated 11-item instrument	enables standardised assessment in children
Aazh (UK)	UCL and parent-reported tools	proposed use in assessing distress	further development and validation needed

Note: UCL = uncomfortable loudness level

Table 7. Summary of work on digital therapies and remote care innovations for tinnitus and hyperacusis. It includes mobile apps, internet-based self-help tools, and tele-audiology. Presentations explored technological feasibility, user engagement, and the role of digital tools in expanding access to care in underserved populations

Presenter/ Author	Topic/ Study	Main Findings/ Perspective	Clinical or Research Implications
Fackrell (UK)	iSHUSH for hyperacusis	co-developed digital platform	supports low-intensity access to hyperacusis support
Siller & de la Cruz Avila (Mexico)	AI mobile app for tinnitus	reduced symptoms with personalisation	supports AI and mobile tools for underserved areas
Nizamuddin (Malaysia)	tele-audiology in Malaysia	high perceived usefulness; reliability concerns	investment needed in infrastructure and policy support

Note: iSHUSH = Internet Self-Help, Understanding, and Support for Hyperacusis; AI = artificial intelligence

Siller and de la Cruz Avila (Mexico) introduced an innovative mobile app that combines AI-driven diagnostics, interactive hearing tests, and a user-centred treatment program featuring sound therapy, nutritional guidance, and use of hearing aids. Following an AI-based tinnitus classification, the app offers personalised sound masking using a dynamic therapeutic sound library and tracks the patient's progress via THI and other self-report measures. Preliminary data indicate significant reductions in symptom burden, particularly when the app's sound therapy matched the tinnitus pitch and was complemented by appropriate amplification.

Fackrell (UK) presented remotely on the development of iSHUSH – internet Self-Help, Understanding, and Support for Hyperacusis – an unguided digital intervention designed to support individuals living with hyperacusis [46]. The program was developed using qualitative interviews, meta-ethnographic evidence, and iterative patient feedback. iSHUSH provides psychoeducational content, practical coping tools, and behavioural strategies targeting avoidance, safety behaviours, and emotional regulation [47,48]. Particular emphasis is placed on validating patients' experiences and addressing common fears related to sound exposure, with input from both patients and clinicians informing the design and usability of the platform. A parallel remote counselling program for hyperacusis is also under development in the United States [49]. Future studies should evaluate the comparative effectiveness of these digital interventions against targeted CBT for hyperacusis delivered by trained audiologists [9] and psychologists [50].

From a systems-level perspective, Nizamuddin (Malaysia) evaluated the acceptance of tele-audiology in tinnitus care across Malaysia. Surveying 42 audiologists and 84 patients, the study found high levels of perceived usefulness but moderate concern around reliability. While tele-audiology is gaining momentum, particularly for initial consultations and counselling, infrastructure gaps and digital literacy remain barriers. Nonetheless, both groups viewed tele-audiology as a viable complement to in-person care, particularly in rural or resource-limited settings.

These digital innovations reflect a growing shift toward decentralised, accessible tinnitus and hyperacusis care – enabling support regardless of geographical location or socioeconomic status. Yet important challenges remain. User engagement with unguided platforms like iSHUSH can be inconsistent, and long-term adherence is not yet well understood. In parallel, regulatory and reimbursement systems must adapt to support the wider adoption of tele-audiology. Crucially, digital health interventions are no longer peripheral; they are becoming central to the future of tinnitus management. As these tools continue to evolve, the integration of neurophysiological data, behavioural analytics, and personalised feedback mechanisms may significantly enhance their effectiveness – paving the way for more adaptive, scalable, and responsive care for individuals with sound intolerance disorders. Digital health and tele-audiology innovations are summarised in **Table 7**.

Conclusion and Implications for Research and Clinical Practice

The 2025 World Tinnitus Congress and International Tinnitus Seminar revealed a field undergoing rapid transformation – moving toward precision, personalisation, and integration across disciplines. Across diverse presentations, a consistent message emerged: effective tinnitus and hyperacusis care must be stratified, multimodal, and guided by both clinical evidence and patient-centred insight. Clinically, CBT remains a foundational approach, with growing support for delivery by audiologists and through digital platforms. However, variability in response – particularly among individuals with comorbid conditions – underscores the need for enhanced stratification and alternative pathways.

Neurophysiological findings are beginning to clarify subtypes and mechanisms, opening doors to targeted interventions like brain stimulation, bimodal therapies, and somatosensory modulation. Innovations in pharmacology highlight the potential of psychologically and aetiologically guided prescribing, while surgical techniques for pulsatile tinnitus are becoming more refined and evidence-based. From a systems perspective, paediatric tinnitus and hyperacusis remain under-recognised and under-treated, calling for greater investment in age-appropriate tools and services. Meanwhile, digital and tele-audiological solutions are redefining accessibility, especially for underserved populations – but sustained engagement, regulatory support, and clinical integration remain critical challenges.

Implications for research include the need for:

- Stratified trials that differentiate subtypes and assess personalised treatment combinations;
- Biomarker and neuroimaging validation to clarify mechanisms and track treatment response;
- Longitudinal studies to assess durability of treatment effects, particularly for digital and neuro-modulatory interventions;
- Comparative effectiveness research to evaluate psychologist-, audiologist-, and internet-delivered therapies across populations;
- Adaptation of tools for children and other underrepresented groups.

Implications for clinical practice centre on:
- Expanding CBT access through audiologist training and digital scaling;
- Embedding diagnostic innovations (e.g. EMG, OAEs, neurophysiology) into routine workups;
- Recognising and treating somatosensory and sleep-modulated tinnitus subtypes;
- Systematically incorporating psychological profiling into treatment planning;
- Building integrated care pathways that align with patient needs across age, geography, and health systems.

As tinnitus science and care continue to evolve, the integration of multidisciplinary knowledge, patient-specific insights, and digital innovation will be essential in delivering more effective, equitable, and sustainable solutions for individuals living with sound intolerance disorders.

Looking ahead, it was announced that, following a competitive bidding process, the IV World Tinnitus Congress and XV International Tinnitus Seminar will be held in London in 2027. There is growing momentum and international collaboration driving tinnitus research and care.

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ADVERSE DRUG REACTIONS IN AUDIOLOGY, PHONIATRICS, AND OTORHINOLARYNGOLOGY

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Abstract

Introduction: Due to the growing number of registered medicinal products, it is important to know about their mechanisms of action and adverse side effects. This also applies when diagnosing an otorhinolaryngology patient. The aim of this study was to review the literature and summarise various active substances and their relevant adverse effects.

Material and methods: Available literature data and summary of product characteristics were analysed. The following adverse reactions were studied: dizziness, hoarseness, oral candidiasis, pharyngitis, ototoxicity, painful swelling of the salivary glands, nasal congestion, dysgeusia, nosebleeds, tinnitus, dry nose, and difficulty swallowing. To classify adverse reactions the MeDRA classification was used.

Results: A list of individual adverse reactions and active substances that may cause them was prepared, along with the mechanism of causing a given adverse reaction. Dizziness was found to be caused by the largest number of drugs analyzed. The most severe adverse effects were irreversible ototoxicity (e.g., caused by intravenous aminoglycoside antibiotics) and embryotoxicity.

Conclusions: Adverse effects of medicinal substances important in otorhinolaryngology, audiology, and phoniatrics are multifactorial, but knowledge of them is necessary to make a correct diagnosis.

Keywords: adverse drug reactions • ototoxicity • tinnitus • vertigo • ENT diagnosis

DZIAŁANIA NIEPOŻĄDANE LEKÓW W AUDIOLOGII, FONIATRII I OTORYNOLARYNGOLOGII

Streszczenie

Wprowadzenie: Wraz ze wzrastającą liczbą zarejestrowanych produktów leczniczych rośnie potrzeba znajomości ich mechanizmów działania oraz możliwych działań niepożądanych – szczególnie w procesie diagnostyczno-terapeutycznym w otorynolaryngologii, audiologii i foniatrii. Celem niniejszego badania była analiza aktualnych danych dotyczących działań niepożądanych istotnych w ww. specjalizacjach.

Materiał i metody: Przeprowadzono przegląd dostępnych danych literaturowych oraz charakterystyk produktów leczniczych (ChPL). Analizie poddano działania niepożądane, takie jak: zawroty głowy, chrypka, kandydoza jamy ustnej, zapalenie gardła, ototoksyczność, bolesny obrzęk ślinianek, niedrożność nosa, zaburzenia czucia smaku, krwawienia z nosa, szumy uszne, suchość nosa oraz trudności z przełykaniem. Do klasyfikacji działań niepożądanych zastosowano system MedDRA.

Wyniki: Opracowano szczegółową listę konkretnych działań niepożądanych oraz substancji czynnych, które mogą je wywoływać, wraz z opisem mechanizmów ich powstawania. Najczęściej raportowanymi działaniami niepożądanymi ważnymi dla diagnostyki otorynolaryngologicznej, audiologicznej i foniatrycznej były zawroty głowy. Najcięższym działaniem niepożądanymi okazała się nieodwracalna ototoksyczność (np. wywoływana przez dożylne antybiotyki aminoglikozydowe).

Wnioski: Działania niepożądane substancji leczniczych istotnych w otorynolaryngologii, audiologii i foniatrii mają charakter wielokierunkowy, a ich znajomość jest niezbędna do postawienia trafnej diagnozy.

Słowa kluczowe: działania niepożądane leków • ototoksyczność • szumy uszne • zawroty głowy • diagnostyka otorynolaryngologiczna

Introduction

Because of the growing number of registered medicinal products, it is important to know the mechanisms of action of each product and its possible adverse effects. When diagnosing a patient with otorhinolaryngological or audiological conditions, the practitioner needs to be aware of the potential adverse effects that medicinal products may be having. According to national and international classifications, adverse reactions of medicinal products can be divided according to their seriousness. Serious adverse reactions are those that may result in: (1) death or life-threatening; (2) teratogenicity and embryotoxicity, associated with the occurrence of congenital defects or perinatal damage; (3) the need for hospitalization or prolongation of the patient's hospitalization; (4) permanent damage, thereby leading to disability; and (5) other serious side effects. The last classification categorizes side effects based on their frequency. This type of classification is primarily used in materials related to medicinal products – package leaflets, summary of product characteristics, and the classification of adverse reactions during clinical trials. They are then divided according to the classification of systems and organs – MedDRA dictionary (*Medical Glossary of Side Effects*). According to this classification, the frequency of adverse reactions is classified as follows:

1. Very common (≥ 1/10), i.e., more than 1 in 10 patients treated.
2. Common (≥ 1/100 to < 1/10), i.e., less than in 10 patients but more often than 1 in 100 patients treated.
3. Uncommon (≥ 1/1000 to < 1/100), i.e., less than 100 patients but more than 1000 patients treated.
4. Rare (≥ 1/10,000 to < 1/1000), i.e., less than 1000 patients but more than 10,000 patients treated.
5. Very rare (< 1/10,000), i.e., less than in 1 in 10,000 patients treated.
6. Not known [1,2].

Subsequent classification of adverse reactions to medicinal products encompasses those involving patient-dependent factors, as well as those dependent on the medicinal product (active substance) and environmental factors. Drug-related factors include:

1. Occurrence of adverse reactions despite the correct dose and method of administration.
2. The occurrence of overdose adverse reactions associated with a single high dose or another route of administration other than indicated.
3. Occurrence of adverse reactions related to chronic use of the active substance.
4. Risk of interactions. There are three types of interactions:
   - drug–drug interaction
   - drug–food ingredient interaction (including dietary supplements)
   - drug–stimulant interaction (tobacco smoke, alcohol, psychoactive substances, narcotics).

Risk factors for patient-related adverse drug reactions include:

1. Clinical characteristics of the patient (e.g., age, gender, race, BMI, renal failure, liver failure).
2. Immune reactions (e.g., allergic, most often antigen–antibody, sometimes late-cell hypersensitivity).
3. Genetically determined (e.g., characteristics of the patient in terms of drug metabolism rate).

Another classification of side effects divides them according to the type of reaction they cause. Type A side effects (*Augmented*) are dose-dependent and predictable side effects related to the mechanism of action of a drug; they usually cause low mortality. Type B side effects (*Bizarre*) are an adverse reaction which is independent of the dose used (the dose may be consistent with the characteristics of the medicinal product but cause a type B side effect). Type B side effects are rare and unpredictable; they are not related to the mechanism of action of the drug, and usually have a high mortality rate. Type C side effects (*Protect*) are adverse reactions depending on the duration of use of the drug and are related to the dose used. Type D side effects (*Delayed*) involve side effects observed during long-term treatment, although they do not always depend on the duration of drug use. Type E side effects (*End of use*) are side effects associated with the discontinuation of a drug. Type F side effects (*Therapy failure*) are adverse effects associated with failure of the therapy.

Due to intensive development and the introduction of new active substances to the market, the European Medical Agency obliges drug manufacturers to introduce an inverted black triangle marking for some of them, which means that the medicinal product needs to be monitored even more closely for adverse effects.

The aim of the study is to review the literature and summarize product characteristics, and in this way develop a list of various active substances and their adverse effects that may occur in patients, which might be important in forming a diagnosis within the fields of otorhinolaryngology and audiology.

Material and methods

This list is for reference only. Available literature and the summary of product characteristics were used to analyse the material. The following adverse reactions, which are important from the otorhinolaryngological point of view, were studied: dizziness, hoarseness, oral candidiasis, pharyngitis, ototoxicity, painful swelling of the salivary glands, nasal congestion, dysgeusia, nosebleeds, tinnitus, dry nose, and difficulty swallowing. For the classification of adverse reactions and their nomenclature, the MeDRA (*Medical Dictionary for Regulatory Activities*) classification was utilized.

Results

Based on the analyzed material, a list of individual adverse reactions and active substances that may cause them, along with the mechanisms behind each adverse reaction, was prepared. They are presented in **Table 1**.

Discussion

Significant adverse drug reactions relevant to the diagnosis of diseases in the fields of otorhinolaryngology, audiology,

Table 1. Adverse reactions associated with otorhinolaryngology (adverse reactions affecting hearing, balance, throat, larynx, and nose) and mechanisms of their formation [1–20]

No.	Type of side effect	Active substance that may cause the side effect
1.	Difficulty in swallowing	tetracycline
		clindamycin
		iron preparations
		bisphosphonates
		non-steroidal anti-inflammatory drugs (NSAIDs)
		antipsychotics (e.g., haloperidol, chlorpromazine)
2.	Dry oral mucous membranes	lithium
		tricyclic antidepressants
		anticholinergic drugs
		H_1 receptor blockers
		opioid analgesics
3.	Embryotoxicity (caused by the use of medications during pregnancy)	isotretinoin
		aminoglycoside antibiotics
		warfarin
4.	Hoarseness	inhaled glucocorticoids
5.	Nasal congestion	mepolizumab
6.	Nose bleeds	clopidogrel
		new generation oral anticoagulants (NOAK)
		vitamin K antagonists
7.	Oral candidiasis	glucocorticoids
8.	Ototoxicity	chemicals used in industry: toluene, styrene
		salicylates
		aminoglycosides antibiotics
		diuretics (loop diuretics)
		topical preparations containing neomycin/polymyxin B
		quinine, chloroquine
		macrolides
		vincristine
		chemotherapy drugs: cisplatin, fluorouracil, bleomycin
		phosphodiesterase type 5 inhibitor: sildenafil
		glycopeptide antibiotics: vancomycin
		oral contraceptives
		iodine-containing agents
9.	Painful swelling of the salivary glands	iodine compounds
10.	Pharyngitis	mepolizumab
		sulfonamides
		eptinezumab

Table 1 continued. Adverse reactions associated with otorhinolaryngology (adverse reactions affecting hearing, balance, throat, larynx, and nose) and mechanisms of their formation [1–20]

No.	Type of side effect	Active substance that may cause the side effect
11.	Taste disturbances	angiotensin-converting enzyme (ACEI) inhibitors
		terbinafine
		lithium
		calcium antagonists
		metronidazole (bitter-metallic taste)
		levodopa
		carbamazepine
		metformin
		some cytostatics, e.g., cisplatin, carboplatin
		zaleplon, zolpidem, zopiclone, eszopiclone
		iodine
		maribavir
12.	Tinnitus	isoniazid
		quinine
		salicylates
		doksazosin
		beta-blockers
		amlodipine
		ramipril
		tadalfil, sildenafil
		paroxetine, sertraline, escitalopram, fluoxetine (SSRI)
		sofosbuvir, ledipasavir
		etoposide
		abatacerpt
13.	Vertigo	hypnotics
		aminoglycoside antibiotics
		gyrase inhibitors
		beta-blockers
		opioid analgesics
		angiotensin-converting enzyme inhibitors
		antiarrhythmics
		anticonvulsants
		psychotropic drugs
		proton pump inhibitors
		bupropion
		varenicline
		trazodone

Table 1 continued. Adverse reactions associated with otorhinolaryngology (adverse reactions affecting hearing, balance, throat, larynx, and nose) and mechanisms of their formation [1–20]

No.	Type of side effect	Active substance that may cause the side effect
13.	Vertigo	agomelatine
		triptans
		nitrates
		buspiron
		gabapentin
		pregabalin
		brivaracetam
		macrolides
		tolperizone
		tizanidine
		baclofen
		dantrolene
		mefloquine
		H_2 blockers
		fexinidazole
		acyclovir
		aprepitant
		galcanezumab (common)
		antiarrhythmic drugs

and phoniatrics should be reported to the manufacturer or the Office for Registration of Medicinal Products, Medical Devices and Biocidal Products. Depending on the severity of the adverse reaction, the time-frame of its reporting extends from the moment of becoming aware of its occurrence to later times.

Dizziness is often classified as a neurological side effect, and can have different origins. It is often seen at the beginning of therapy in patients suffering from hypertension or taking antiarrhythmics or cardiac glycosides, which can cause cardiac arrhythmias and dizziness. Dizziness can also be caused by a hypoglycemic episode. This is particularly important in patients with diabetes who are using drugs to treat the condition (e.g., insulin, sulfonylureas).

Hoarseness and candidiasis of the oral cavity are complications resulting from the negative effects of oral-inhaled glucocorticoids in patients suffering from asthma or chronic obstructive pulmonary disease. Oral candidiasis is mainly associated with immunosuppressive glucocorticoid activity; reducing the likelihood of side effects can be achieved by taking drugs from this group before a meal. In addition, after using these medications it is worth brushing the teeth and rinsing the mouth with water.

Taste disturbances, or complete loss of taste, were reported to physicians during and after the COVID-19 pandemic. Some of the side effects can be a complete loss of taste, unpleasant sensations of specific tastes, and lowering the taste threshold. They can be temporary, although they can also accompany the patient throughout the therapy. In some cases, switching to another drug may be considered (e.g., in the case of long-term treatment, switching from one drug from the group of angiotensin-converting enzyme inhibitors to another drug from this group or to one from the so-called spartan group).

Ototoxicity is a dangerous side effect of medications because some of them can cause irreversible damage to the hearing organ. Factors that may increase the toxicity of drugs include: renal failure; age of the patient (geriatric and pediatric populations are particularly vulnerable); history of inner ear diseases; use of the drug for a long time or in high doses; individual sensitivity of the patient; dehydration; fever; and concomitant use of other ototoxic agents (e.g., aminoglycosides and loop diuretics).

Some drugs cause reversible hearing disorders, while others are irreversible (e.g., aminoglycoside antibiotics). To reduce the ototoxicity of cisplatin, in recent years a medicinal product with INN-sodium thiosulfate has been approved. It is indicated for the prevention of cisplatin chemotherapy-induced ototoxicity in patients 1 month to < 18 years of age who have local, non-metastatic solid tumors. The mechanism of action of sodium thiosulfate to protect against ototoxicity is not fully understood. However, it probably includes an increase in endogenous antioxidant levels, inhibition of intracellular oxidative stress, and a direct interaction between cisplatin and the thiol group to produce inactive platinum species. Concomitant incubation of sodium thiosulfate with cisplatin has resulted in a reduction in cisplatin cytotoxicity to cancer cells in vitro, and delayed addition of sodium thiosulfate to these cultures has prevented the achievement of a protective effect (based on the summary of product characteristics).

Difficulty swallowing can also be part of the diagnosis of patients by otorhinolaryngologists and phoniatricians. Swallowing disorders can be reduced by recommending that the patient use plenty of water while taking solid forms of the drug. In this way, it is possible to reduce the contact of the drug with the esophageal mucosa.

Tinnitus can be a side effect of medication and may go away on its own once the medication is discontinued. It is divided into objective and subjective tinnitus, as well as primary and secondary tinnitus (as in the case of tinnitus caused by drugs). The appearance of tinnitus in a patient who has started pharmacotherapy with a drug that can cause such an effect requires contact with a doctor and further diagnostics to confirm the cause.

In Poland, the obligation to report adverse reactions applies to healthcare professionals (e.g., doctors, dentists, pharmacists, nurses). Patients who have had an adverse reaction to a medicine can also report it themselves, or through their legal representative or guardian. The notification is made via a form on the website of the Office for Registration of Medicinal Products, Medical Devices and Biocidal Products. Such a notification can also be made directly to the manufacturer of the medicinal product in question.

Conclusions

The adverse effects of medicinal substances important in otorhinolaryngology, audiology, and phoniatric diagnostics are multidimensional; however, knowing them is essential for making an accurate diagnosis for the patient.

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THE EFFECTS OF NATURAL AND SURGICAL MENOPAUSE ON AUDITORY AND COGNITIVE PROCESSING

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A Study design/planning
B Data collection/entry
C Data analysis/statistics
D Data interpretation
E Preparation of manuscript
F Literature analysis/search
G Funds collection

Abstract

Introduction: Estrogen plays a vital role in various physiological processes. While its impact on peripheral hearing sensitivity has been explored, limited attention has been given to its effect on central auditory processes, particularly during menopause. The present study examines the effects of both natural and surgical menopause on temporal processing of sound, speech perception in noise (SPIN), and working memory.

Material and methods: Three groups of women aged 49–60 years were recruited: 20 women with natural menopause, 20 with surgical menopause, and 20 premenopausal women. Temporal processing was assessed using the modulation detection threshold (MDT) and gap detection threshold (GDT) tests, SPIN abilities were evaluated using the Speech Perception in Noise Test in Kannada (SPIN-K), and working memory was assessed through digit span and sequencing tasks.

Results: The group of women with surgical menopause had significantly poorer temporal processing abilities, as reflected in higher MDT and GDT thresholds than the other two groups. No significant differences in SPIN or working memory were observed among the groups.

Conclusions: The findings highlight the adverse effects of surgical menopause on auditory temporal processing, likely due to an abrupt decline in estrogen levels. These results underscore the importance of estrogen in auditory health and call for targeted interventions and further research to confirm and expand these findings.

Keywords: menopause • cognition • audition

WPŁYW MENOPAUZY NATURALNEJ I CHIRURGICZNEJ NA PRZETWARZANIE SŁUCHOWE I POZNAWCZE

Streszczenie

Wprowadzenie: Estrogen odgrywa istotną rolę w różnych procesach fizjologicznych. Chociaż zbadano jego wpływ na czułość słuchu obwodowego, niewiele uwagi poświęcono jego oddziaływaniu na centralne procesy słuchowe, szczególnie w okresie menopauzy. Niniejsze badanie analizuje wpływ zarówno menopauzy naturalnej, jak i chirurgicznej na przetwarzanie czasowe dźwięku, percepcję mowy w hałasie (SPIN) oraz pamięć roboczą.

Materiały i metody: Do badania włączono trzy grupy kobiet w wieku 49–60 lat: 20 kobiet z menopauzą naturalną, 20 z menopauzą chirurgiczną i 20 kobiet przed menopauzą. Przetwarzanie czasowe oceniano za pomocą testów wykrywania progu modulacji (MDT) i wykrywania przerw w szumie (GDT), zdolności SPIN oceniano za pomocą testu percepcji mowy w hałasie w języku kannada (SPIN-K), a pamięć roboczą – za pomocą zadań sprawdzających zapamiętywanie zakresu cyfr i sekwencjonowanie.

Wyniki: Grupa kobiet z chirurgiczną menopauzą wykazywała znacznie mniejszą zdolność przetwarzania czasowego, co znalazło odzwierciedlenie w wyższych progach MDT i GDT w porównaniu do pozostałych dwóch grup. Nie zaobserwowano istotnych różnic w zakresie SPIN ani pamięci roboczej między grupami.

Wnioski: Wyniki badań wskazują na niekorzystny wpływ menopauzy chirurgicznej na słuchowe przetwarzanie czasowe, prawdopodobnie spowodowane gwałtownym spadkiem poziomu estrogenu. Wyniki te podkreślają znaczenie wpływu poziomu estrogenu na stan słuchu i wskazują na potrzebę podjęcia ukierunkowanych działań oraz dalszych badań w celu potwierdzenia i rozszerzenia tych wyników.

Słowa kluczowe: menopauza • funkcje poznawcze • słuch

Key to abbreviations	
GDT	gap detection thresholds
MDT	modulation detection threshold
MLP	maximum likelihood procedure
NM	natural menopause
OAE	otoacoustic emission
PM	premenopausal women
SD	standard deviation
SM	surgical menopause
SNR	signal-to-noise ratio
SPIN	speech perception in noise
SPIN-K	Speech Perception in Noise Test in Kannada

Introduction

Menopause is characterized by the permanent discontinuation of menstruation resulting from a decline in ovarian follicular activity. The average age of menopause is around 51 years and is officially diagnosed when a woman has experienced 12 consecutive months of amenorrhea (absence of menstrual cycles) due to the permanent cessation of ovarian function. Perimenopause, characterized by fluctuating ovarian function, typically precedes a woman's last menstrual cycle by several years, marking the transition into full menopause [1]. Common symptoms include hot flashes, night sweats, mood swings, sleep disturbances, and vaginal dryness, affecting both physical and emotional well-being.

Many women experience symptoms during the first few months after menopause, and for most, these symptoms last 1–2 years. However, in some cases, they may continue for 3–5 years and are referred to as early menopausal complications. Underlying mechanisms of early menopausal complications include estrogen deficiency and its impact on neurotransmitters such as serotonin and endorphins [2].

In addition to natural aging, menopause can be induced by surgical procedures such as hysterectomy with bilateral oophorectomy (removal of the uterus and both ovaries). It can also be triggered by medical treatments for conditions like endometriosis and breast cancer, where antioestrogen medications or chemotherapy may be used [3]. The treatment and management of menopause focuses on alleviating bothersome symptoms and preventing long-term complications. Treatment for menopause involves a range of hormonal and non-hormonal options tailored to address specific symptoms and health considerations. Hormone therapy can be effective in relieving menopause symptoms, but it requires careful consideration of its potential risks. Non-prescription remedies should be used with caution due to limited scientific evidence supporting their safety and effectiveness [4].

Studies have shown that estrogen is important in numerous physiological functions. Estrogen regulates the auditory processing of acoustic signals in the brain [5,6]. It is therefore involved in interpreting auditory information and how it is represented in the auditory cortex before it is transmitted to sensory-motor parts of the brain [7,8]. Estrogen also affects neurotransmission and biochemistry in the brain [9]. Studies have shown that temporal resolution and speech perception in noise are better during the ovulation phase of the menstrual cycle [10] and that estrogen plays a role in maintaining verbal and visual memory [11]. Estrogen may also influence peripheral hearing sensitivity, suggesting that menopause should be recognized as a significant risk factor for the onset of hearing loss in women, possibly due to endocrinological effects on auditory function [12].

Since estrogen plays an important role in auditory processing, there are effects on temporal processing and speech perception in noise [13]. Temporal processing involves resolving fine details in a speech signal's spectrum or temporal envelope [14–16]. Several studies have established a link between temporal processing and speech perception in adverse listening conditions [17–20]. While hormonal effects on central auditory processing have been investigated in women during the menstrual cycle and under hormone therapy, research exploring the specific effects of natural and surgical menopause on auditory processing remains limited.

Cognitive complaints are also common near menopause [21]. There is a reduction in memory in women during the transition to menopause. There are symptoms such as difficulties learning, recalling new information, and having impaired episodic memory, which are early signs of Alzheimer's disease [22]. Thus, in women experiencing natural menopause, the levels of estrogen, progesterone, and androgens gradually decline for 5–10 years as the ovarian stroma continues to produce these hormones [23].

The impact of menopause on cognition is complex, and more research is needed to understand these relationships. Evidence from a clinical trial emphasizes the limited effectiveness of hormone initiation in improving cognitive function in older post-menopausal women (mean age > 60 years) [24]. This study is designed to study the effect of ovarian hormones as a result of natural menopause and surgical menopause on temporal processing, speech perception in noise, and working memory.

Material and methods

Research design

A between-group cross-sectional study design was used to compare auditory temporal processing, speech perception in noise, and auditory working memory across three distinct groups of women based on menopausal status. The participants were three groups ($n = 20$ per group) of right-handed women, aged 49–60 years, who were recruited for the study based on their menopausal status. Participants were recruited from gynaecology clinics as well as through community health programs and local women's groups.

Group 1: Natural menopause group. These were women who had experienced cessation of menstruation within the last 3 years, without any other major medical conditions (mean age: 54.7 ± 1.3 years).

Group 2: Surgical menopause group. These were women who had undergone bilateral oophorectomy (surgical removal of ovaries) within the past 3 years before the study and had not reached natural menopause (mean age 54.1 ± 1.1 years).

Group 3: Premenopausal group. This group consisted of age-matched women (mean age 53.9 ± 1.2 years) who reported having regular menstrual cycles (typically 25–35 days) for at least 3 consecutive months before enrollment. To verify the regularity of their cycles, participants kept a menstrual diary for 2–3 months before they participated in the study. The first day of menstruation was considered day 1 of the cycle. To minimize hormonal variability all tests were scheduled during the mid-follicular phase (days 7–10 of their menstrual cycle), a time when estrogen levels are rising but have not yet peaked.

All participants had normal hearing thresholds, with pure-tone averages within 15 dB HL at octave frequencies ranging from 0.25 to 8 kHz. They were native speakers of Kannada and had completed at least a primary school level of education. None of the participants were using hormonal therapy, including oral contraceptives or hormone replacement therapy. Individuals with a history of otological conditions, neurological or psychiatric disorders, cardiovascular or endocrine diseases, or other metabolic disorders were excluded from the study based on their self-reports during the initial screening interview. Additionally, participants who were employed in industrially noisy environments or who had a history of steroid use were not included. Prior to participation, written informed consent was obtained from all individuals. The study protocol was reviewed and approved by the institutional ethics committee.

All tests were conducted in a quiet room using a calibrated laptop and Sennheiser HD 559 headphones. The output was calibrated using a sound level meter to ensure stimuli were presented at 60 dB SPL. Tasks were counterbalanced across participants to control for order effects and fatigue. Temporal processing and speech perception in noise were assessed monaurally (both ears separately), and working memory tasks were assessed binaurally.

Temporal processing evaluation

Temporal processing was assessed using gap detection thresholds (GDT) and modulation detection thresholds (MDT). These tests were done using the maximum likelihood toolbox (MLP), implemented in Matlab (2014 version). MLP offers a user-friendly graphical interface and includes pre-built psychoacoustic experiments. MLP utilizes numerous candidate psychometric functions, assessing the probability of the listener's response to all presented stimuli after each trial. The function with the highest probability guides stimulus selection for the subsequent trial, typically converging toward the most probable psychometric function and thereby facilitating more accurate threshold estimation. A three-interval alternative forced-choice method was used to estimate the thresholds of both ears.

Gap detection threshold: Temporal resolution ability was assessed using GDT where the goal was to determine the shortest detectable gap. Subjects performed a gap detection task with 750 ms Gaussian noise, where the gap duration varied adaptively based on performance. Both standard (continuous noise) and variable (noise with a gap) stimuli lasted 750 ms, with 0.5 ms cosine ramps. A three-interval, alternative forced-choice paradigm was used: on each trial of three blocks, two blocks consisted of a 750 ms broadband noise with no gap, and the other block had a variable stimulus with a gap inside it. The participant's task was to identify the variable block. The minimum and maximum duration of the gap used was 0.1 and 64 ms. The gap detection corresponding to the 79.4% point of the psychometric function was calculated using MLP.

Modulation detection threshold: A 1000 ms Gaussian noise was sinusoidally amplitude modulated at 8, 20, 60, and 200 Hz. In each trial, three stimulus intervals were presented: two contained standard (unmodulated) stimuli, while the third, selected at random, contained a modulated stimulus. Participants were asked to identify which interval contained the modulation. The modulated and unmodulated stimuli had equal root-mean-square (rms) power. The depth of modulation was adjusted based on the participant's responses until the 79.4% criterion level was reached.

Speech perception in noise assessment

The Speech Perception in Noise Test in Kannada (SPIN-K), a test developed by Yathiraj and Vijayalakshmi [25], was used to assess participants' ability to perceive speech in the presence of noise. The test stimuli comprised phonemically balanced words presented with ipsilateral speech noise at 0 dB signal-to-noise ratio (SNR). The task of the participants was to repeat the words presented to them. During the assessment, two lists of 25 words each were presented to each ear. The percent correct scores were calculated for both ears.

Auditory working memory assessment

Auditory working memory was assessed using digit span (forward and backward digit span) and digit sequencing (ascending and descending digit sequencing) using Smriti Shravan software [26]. The digits were presented with increasing test difficulty, using a 250 ms inter-stimulus interval and a 5000 ms response window for each stimulus during which participants were required to provide their response. The testing was done using Kannada digits from 1 to 9, and participants were asked to repeat the digit according to the digit span and digit sequence task. The scoring was based on the number of correct digits the participants reported concerning the task. The midpoint of the digit span and digit sequencing task was noted. The tests were done at 60 dB SPL binaurally [27].

Data analysis

All analyses were performed using IBM SPSS version 20.0, and descriptive statistics were computed. Shapiro–Wilk tests were used to assess data normality. For non-parametric data, a Kruskal–Wallis test was used to compare group

Table 1. Results of tests on auditory and cognitive processing in women with natural menopause (NM), surgical menopause (SM), and premenopause (PM). There were multiple tests involving temporal perception (MDT and GDT), speech perception in noise (SPIN), and working memory (FR, BK, AS, and DS). A key to the tests is given below the table

Auditory test		Mean	Median	*SD*	Range	
					minimum	maximum
MDT 8 Hz R [dB]	NM	–30.91	–32.60	3.41	–34.25	–24.25
	SM	–27.39	–28.22	4.17	–34.25	–20.45
	PM	–33.13	–33.47	1.34	–34.86	–30.25
MDT 8 Hz L [dB]	NM	–31.41	–32.45	3.86	–37.85	–24.25
	SM	–27.54	–28.22	4.18	–36.45	–21.65
	PM	–33.22	–33.00	1.79	–37.85	–30.55
MDT 20 Hz R [dB]	NM	–33.03	–35.22	6.26	–39.25	–21.40
	SM	–26.42	–26.60	3.69	–34.20	–19.65
	PM	–31.96	–32.25	2.92	–37.70	–22.80
MDT 20 Hz L [dB]	NM	–34.95	–36.67	5.15	–39.25	–24.35
	SM	–25.03	–24.37	4.05	–32.30	–17.55
	PM	–31.27	–31.00	2.37	–36.48	–24.55
MDT 60 Hz R [dB]	NM	–34.31	–34.82	2.19	–36.80	–29.45
	SM	–22.49	–22.63	4.99	–34.25	–14.35
	PM	–29.46	–30.27	2.97	–32.75	–20.15
MDT 60 Hz L [dB]	NM	–33.28	–33.00	2.22	–36.80	–29.45
	SM	–22.14	–22.45	4.73	–32.25	–13.35
	PM	–28.63	–29.62	3.67	–34.42	–22.45
MDT 200 Hz R [dB]	NM	–25.72	–27.15	4.94	–34.25	–13.65
	SM	–12.59	–13.20	3.54	–19.25	–6.15
	PM	–23.54	–24.00	3.18	–30.25	–18.45
MDT 200 Hz L [dB]	NM	–23.37	–25.65	3.17	–34.25	–20.40
	SM	–12.62	–13.65	3.57	–19.35	–5.85
	PM	–24.68	–24.82	4.04	–33.30	–15.85
GDT R [ms]	NM	3.77	3.52	1.84	1.26	7.43
	SM	6.01	5.96	1.87	2.27	10.79
	PM	4.95	4.57	1.61	2.80	8.96
GDT L [ms]	NM	3.99	3.52	1.99	1.95	7.93
	SM	5.61	5.70	2.20	2.16	10.14
	PM	4.49	4.72	1.20	2.16	7.23
SPIN R [%]	NM	57.90	56.00	9.39	44.00	72.00
	SM	56.00	56.00	8.99	36.00	68.00
	PM	61.60	62.00	8.64	44.00	80.00

Table 1 continued. Results of tests on auditory and cognitive processing in women with natural menopause (NM), surgical menopause (SM), and premenopause (PM). There were multiple tests involving temporal perception (MDT and GDT), speech perception in noise (SPIN), and working memory (FR, BK, AS, and DS). A key to the tests is given below the table

Auditory test		Mean	Median	*SD*	Range	
					minimum	maximum
SPIN L [%]	NM	54.80	56.00	8.31	44.00	68.00
	SM	57.00	58.00	10.69	36.00	72.00
	PM	60.80	62.00	8.39	44.00	76.00
FR (No. of digits repeated)	NM	3.11	3.00	0.62	2.10	4.25
	SM	2.98	3.00	0.59	2.10	4.25
	PM	3.62	3.10	1.03	2.00	5.73
BK (No. of digits repeated)	NM	2.70	2.72	0.55	1.80	3.60
	SM	3.60	2.75	4.13	2.00	5.00
	PM	2.97	2.90	0.92	2.00	4.75
AS (No. of digits repeated)	NM	3.03	3.00	0.91	1.50	4.37
	SM	3.30	3.05	1.14	1.50	5.75
	PM	3.67	3.45	1.22	1.50	5.73
DS (No. of digits repeated)	NM	2.71	2.10	0.98	1.60	5.50
	SM	3.10	3.05	1.01	1.60	5.50
	PM	3.31	2.10	0.82	2.00	4.75

NM – Natural menopause women, SM – Surgical menopause women, PM – Premenopause women, MDT 8Hz R – Modulation detection threshold of 8 Hz in the right ear, MDT 8Hz L – Modulation detection threshold of 8 Hz in the left ear, MDT 20Hz R – Modulation detection threshold of 20 Hz in the right ear, MDT 20Hz L – Modulation detection threshold of 20 Hz in the left ear, MDT 60Hz R – Modulation detection threshold of 60 Hz in the right ear, MDT 60Hz L – Modulation detection threshold of 60 Hz in the left ear, MDT 200Hz R – Modulation detection threshold of 200 Hz in the right ear, MDT 200Hz L – Modulation detection threshold of 200 Hz in the left ear, GDT R – Gap detection threshold of the right ear, GDT L – Gap detection threshold of the left ear, SPIN R – Speech perception in noise in the right ear, SPIN L – Speech perception in noise in the left ear, FR – Forward digit span score, BK – Backward digit span score, AS – Ascending digit span score, DS – Descending digit span score

differences across outcome measures. For pairwise comparisons, Mann–Whitney *U*-test were applied.

Results

Prior to conducting inferential statistics, a Shapiro–Wilk test was applied to assess the normality of data distribution for all outcome variables. The results indicated that the data for all central auditory processing and working memory measures violated the assumptions of normality ($p < 0.05$). Consequently, nonparametric statistical tests were used for subsequent analyses. Descriptive statistics, including the mean, median, standard deviation (*SD*), and range for all measures across the three groups, are provided in **Table 1**. Overall, women in the surgical menopause group exhibited lower performance on temporal processing tasks and SPIN compared to the other two groups.

Temporal processing using MDT and GDT

Figure 1 presents the MDT scores across all modulation frequencies (8, 20, 60, and 200 Hz) and all groups. The surgical menopause group (SM) showed consistently elevated thresholds across both ears, suggesting reduced temporal resolution. A Kruskal–Wallis test confirmed that there were statistically significant group differences for all MDT frequencies In the right ear, significant effects were observed at 8 Hz ($\chi^2(2) = 18.59$, $p < 0.001$), 20 Hz ($\chi^2(2) = 18.87$, $p < 0.001$), 60 Hz ($\chi^2(2) = 41.84$, $p < 0.001$), and 200 Hz ($\chi^2(2) = 38.74$, $p < 0.001$). In the left ear, corresponding frequencies also showed significant differences: 8 Hz ($\chi^2(2) = 19.88$, $p < 0.001$), 20 Hz ($\chi^2(2) = 29.85$, $p < 0.001$), 60 Hz ($\chi^2(2) = 38.38$, $p < 0.001$), and 200 Hz ($\chi^2(2) = 39.82$, $p < 0.001$). Follow-up analyses using a Mann–Whitney *U*-test revealed that women with surgical menopause performed significantly poorer than both women with natural menopause and premenopausal women at all tested frequencies in both ears ($p < 0.001$ for most comparisons). Additional comparisons showed that premenopausal women performed significantly worse than women with natural menopause at 60 Hz and 200 Hz in both ears, suggesting a more nuanced pattern of group differences (asterisks in **Figure 1**).

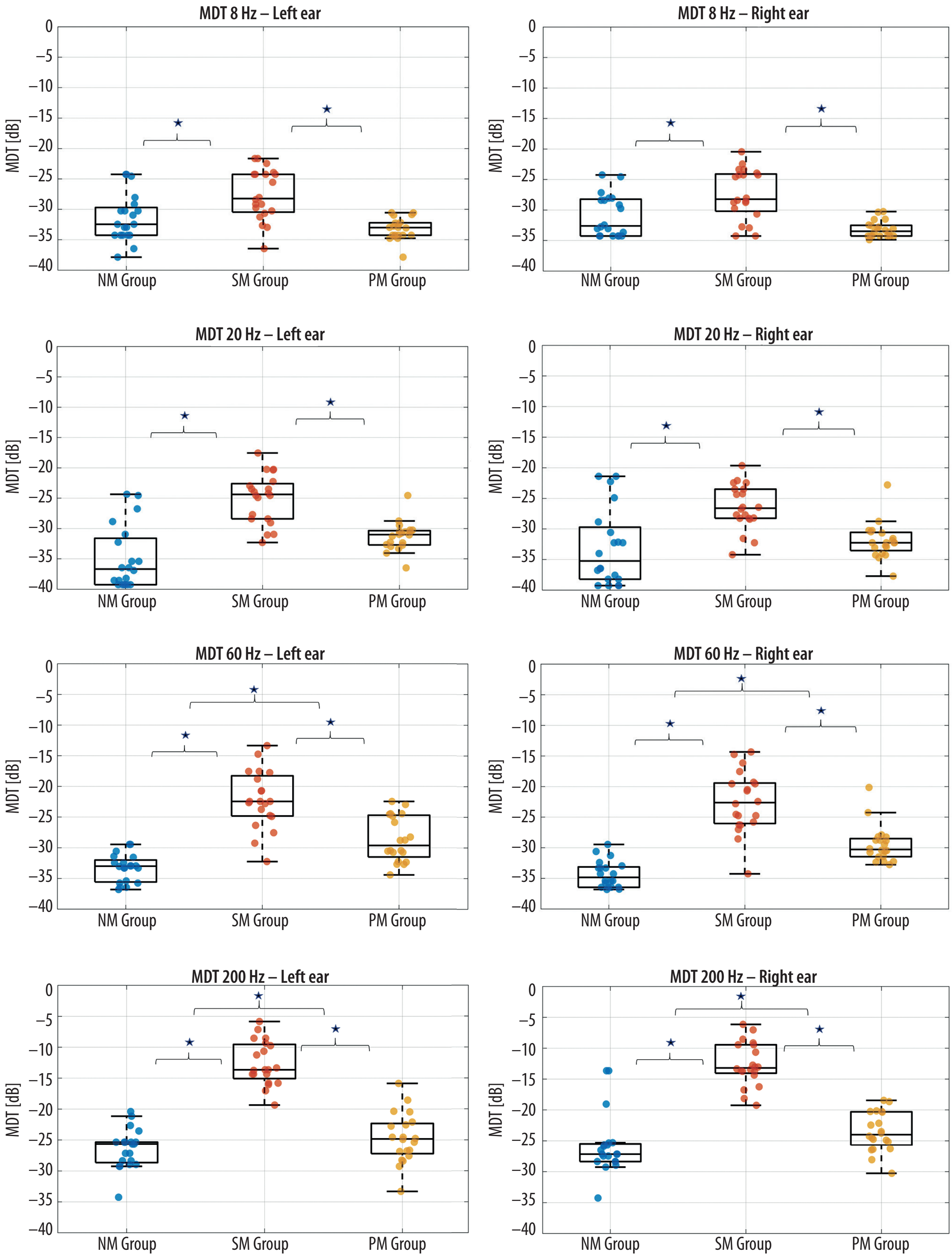

Figure 1. Comparison of MDT [dB] between groups of women with natural menopause (NM), surgical menopause (SM), and premenopausal women (PM). Boxes represent the interquartile range (25th to 75th percentiles), and the horizontal line indicates the median. The whiskers extend to the most extreme data points not considered outliers, and individual data points are shown as dots. Asterisks show significant differences ($p < 0.05$)

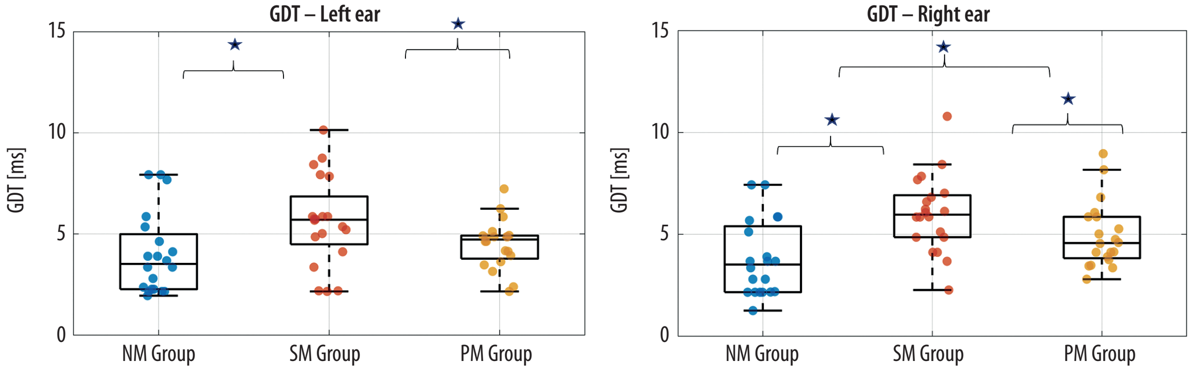

Figure 2. Boxplots of gap detection thresholds (GDT) among groups of women with natural menopause (NM), surgical menopause (SM), and premenopausal (PM). Key as per Figure 1

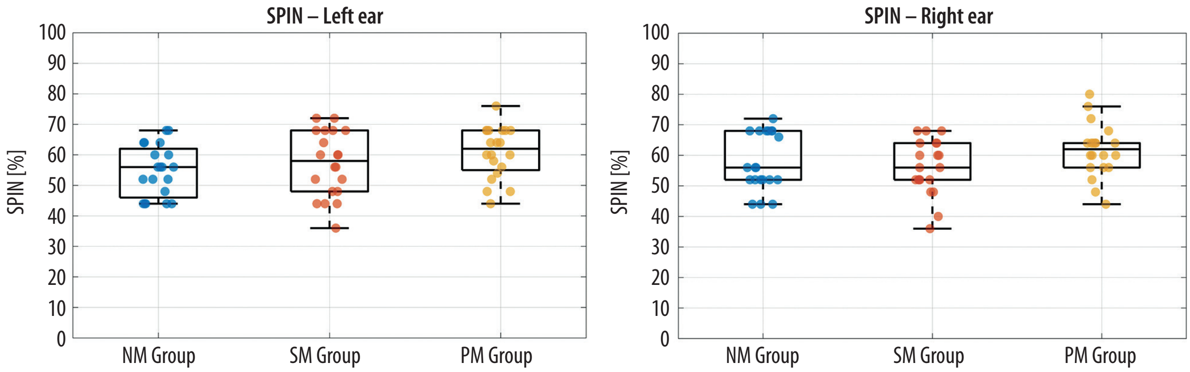

Figure 3. Boxplots of speech perception in noise (SPIN) among groups of women with natural menopause (NM), surgical menopause (SM), and premenopausal (PM). Key as per Figure 1

Figure 2 displays GDT scores for each group. Women in the surgical menopause group again demonstrated elevated thresholds, indicating reduced sensitivity to temporal gaps in noise. Kruskal–Wallis test results showed significant differences between groups for both the right ear ($\chi^2(2) = 14.17$, $p = 0.001$) and the left ear ($\chi^2(2) = 8.39$, $p = 0.015$). Post hoc comparisons revealed that the surgical menopause group performed significantly poorer than both the natural menopause and premenopausal groups in both ears ($p < 0.05$). Furthermore, premenopausal women also performed significantly poorer than those in the natural menopause group for the right ear ($U = 113.00$, $p = 0.018$), but not the left.

Comparison of SPIN across the three groups

Speech perception in noise performance was assessed using the SPIN test, and the results are illustrated in **Figure 3**. While the premenopausal group showed a trend toward better performance, Kruskal–Wallis test results indicated that the differences among groups were not statistically significant for either the right ear ($\chi^2(2) = 4.30$, $p = 0.117$) or the left ear ($\chi^2(2) = 2.96$, $p = 0.227$). Given the absence of significant group effects, pairwise comparisons were not conducted.

Comparison of working memory abilities

Working memory was assessed using digit span (forward and backward) and digit sequencing (ascending and descending) tasks. **Figure 4** illustrates the performance across the three groups. Results of a Kruskal–Wallis test indicated no statistically significant differences for any of the working memory tasks. Specifically, the forward digit span yielded a $\chi^2(2)$ value of 5.34 ($p = 0.069$), the backward digit span yielded $\chi^2(2) = 0.238$ ($p = 0.888$), ascending digit sequencing yielded $\chi^2(2) = 3.549$ ($p = 0.170$), and descending digit sequencing yielded $\chi^2(2) = 5.604$ ($p = 0.061$). Although a few comparisons approached statistical significance, none met the threshold for further post hoc testing.

In summary, women who underwent surgical menopause demonstrated significantly poorer temporal processing abilities compared to both premenopausal women and women who had undergone natural menopause. While SPIN and working memory scores did not differ significantly across groups, the clear group differences in temporal processing suggest that abrupt cessation of ovarian function may have a negative impact on certain auditory processing mechanisms.

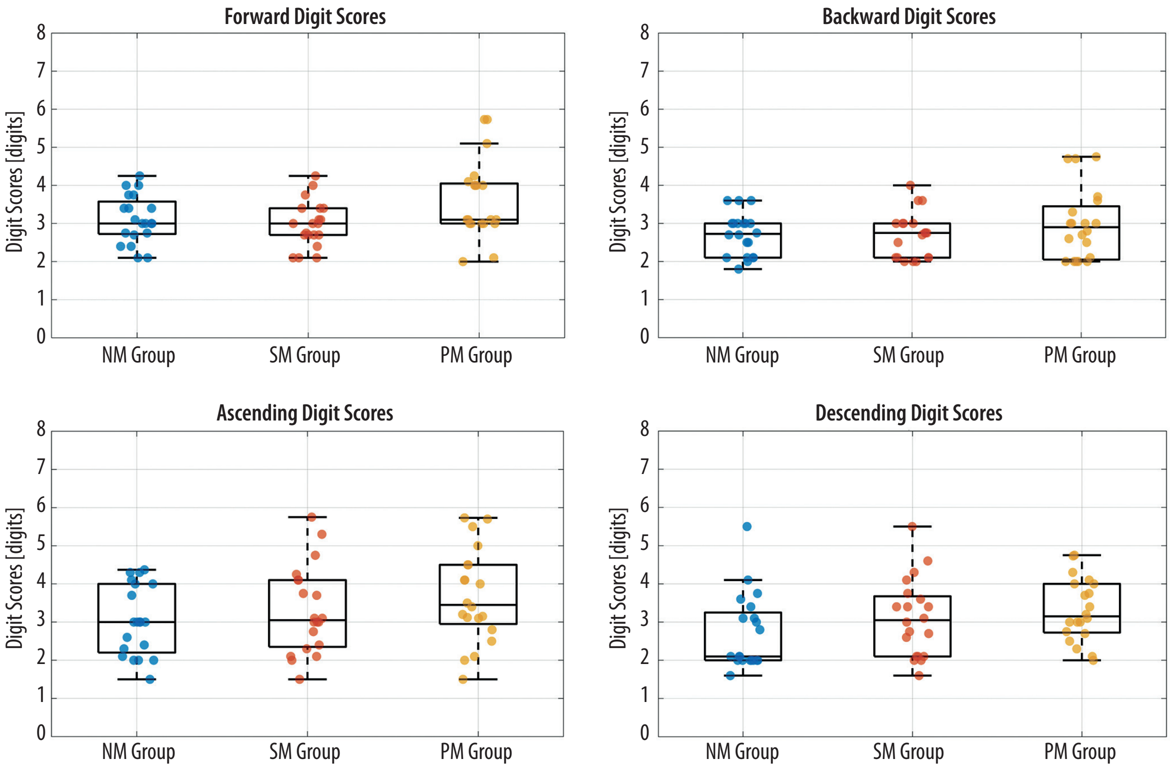

Figure 4. Boxplots of working memory abilities using digit span (forward and backward digit span) and digit sequencing (ascending and descending digit sequencing) among women with natural menopause (NM), surgical menopause SM), and premenopausal (PM). Key as per Figure 1

Discussion

The study aimed to evaluate the effect of natural and surgical menopause on temporal processing, speech perception in noise, and working memory.

Temporal processing abilities

Temporal processing refers to the auditory system's ability to process and interpret temporal aspects of sound. This includes detecting changes in sound over time, such as the duration, rhythm, and timing of auditory stimuli. Temporal perception is essential for understanding and processing speech, especially in noisy environments, as it helps distinguish between different phonemes and understand spoken language's timing and rhythm [28]. In this study, two tests were used to evaluate temporal processing abilities: MDT to detect amplitude modulation in a sound signal at different frequencies and GDT to detect silent gaps between sounds, providing insights into the temporal resolution of the auditory system.

This study found that women with surgical menopause exhibited poorer temporal processing abilities compared to those with natural menopause and premenopausal women. To the author's knowledge, this is the first study to report the impact of surgical menopause on temporal perception. Estrogen has been shown to enhance auditory sensitivity and temporal perception [29] and may influence hearing by altering blood flow within the cochlea [30]. The findings indicate that women who underwent surgical menopause may have experienced declines in various cognitive functions related to auditory processing. This decline was closely associated with a significant reduction in estradiol levels post-surgery, highlighting the critical role of estrogen in supporting cognitive and auditory health [31]. In this study, women with surgical menopause demonstrated the lowest scores, followed by women with natural menopause. These findings align with the study by Özgedik et al. [32], which reported that hearing thresholds and OAE amplitudes were significantly lower in women with surgical menopause compared to those with natural menopause. Menopause often coincides with auditory decline due to decreased estrogen levels, which play a protective role in maintaining auditory system health [33]. These results underscore the impact of surgical menopause on auditory temporal perception, emphasizing the importance of tailored auditory rehabilitation programs for this population.

Premenopausal women demonstrated poorer MDT compared to women with natural menopause. These findings are in agreement with earlier studies, which suggested that hormonal changes during menopause could impair auditory processing [34].

SPIN results

SPIN assesses auditory closure abilities, which involve filling in missing or distorted parts of speech using context and linguistic knowledge. This skill is crucial for effective communication in everyday environments where background sounds are prevalent, such as in social gatherings, public places, or work settings [35]. SPIN tests help identify specific difficulties in auditory perception, guiding the development of targeted interventions and rehabilitation programs [36].

This study administered SPIN tests to assess the auditory closure abilities of three groups. The results indicate a better speech perception in noise among premenopausal women, although the differences were not statistically significant. The results are contrary to the literature, which states that hormonal changes affect auditory processing pathways, significantly impacting auditory perception [37]. These discrepancies may be attributable to differences in sample size, participant characteristics, stimulus parameters, or testing methods used in the present study. The reduction in speech perception is linked to the loss of estrogen, which helps protect auditory and cognitive functions [38]. The abrupt loss of estrogen has been associated with increased risks of cognitive decline and reduced neural efficiency, which are critical for tasks such as speech perception in noise [39]. The small sample size may have contributed to the lack of a significant difference observed in the present study.

Working memory abilities

Working memory is a cognitive construct that temporarily stores and manipulates information essential for complex tasks such as language comprehension, learning, and reasoning [40]. It enables individuals to store and process information simultaneously, vital for activities like mental arithmetic, following multi-step instructions, and reading comprehension. Deficits in working memory can negatively impact academic performance, daily functioning, and overall cognitive health [40]. Estrogen plays a crucial role in cognitive functions, including working memory [41], and its decline following surgical or natural menopause may disrupt the neural circuits involved in working memory, leading to reduced performance in tasks such as digit span and sequencing [42].

The analysis of working memory using forward and backward digit span, as well as ascending and descending sequencing tasks, revealed no statistically significant differences across the groups. While some mean differences were observed, particularly higher variability in surgical menopause and a slight trend toward better performance in premenopausal women, these did not reach significance. These results suggest that while abrupt hormonal changes may influence basic auditory processing, their impact on verbal working memory may be limited or require a longer duration post-menopause to manifest significantly. Alternatively, the digit span tasks used in this study may not be sensitive enough to detect subtle differences in executive function or working memory capacity related to hormonal status.

Conclusions

The study highlights the effects of menopause on temporal processing abilities, emphasizing the specific challenges encountered by women with surgical menopause, likely due to the abrupt reduction in estrogen levels critical for auditory processing. These findings reinforce the role of estrogen in temporal processing and underscore the necessity for further research with larger sample sizes. Additionally, tailored rehabilitation programs and interventions are crucial to addressing the unique challenges faced by this population.

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VARIABLE EARBUD OUTPUT ACROSS VARIOUS DEVICES

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Contributions:
A Study design/planning
B Data collection/entry
C Data analysis/statistics
D Data interpretation
E Preparation of manuscript
F Literature analysis/search
G Funds collection

Abstract

Introduction: Today, many people are in the habit of listening to music, watching movies, and playing games via headphones or earbuds connected to devices such as cellphones, computers, and iPads, when studying or doing other activities. This study investigated the LAeq output of four different devices connected with two different earbud types.

Material and methods: A GRAS 45CB Acoustic Test Fixture was used to measure the output of the earbuds. All devices were purchased in a regular store to mimic the natural process and usage of the products. Both earbuds have the same cable length and are of the same design.

Results: The findings indicated that one earbud brand produced varying output levels when connected to different devices, even when the same volume setting was used. Statistical analysis confirmed that the output differences across devices were significant, as reflected in the results: [$F(3) = 805.08$, $p < 0.001$], with a partial R^2 of 89.7% for the right ear, and [$F(3) = 805.08$, $p < 0.001$], with a partial R^2 of 89.7% for the left ear, based on measurements taken at five different volume levels. Likewise, the interactions were also found to be significant in both ears. Furthermore, the discrepancies between the left and right ear outputs for each earbud–device combination were found to be potentially unsafe, raising concerns about auditory risk. Notably, at the 60% volume setting, the sound output from both ears across all tested devices exceeded the exposure limits recommended by the U.S. Environmental Protection Agency (EPA).

Conclusions: Findings showed that one size does not fit all. Findings from this study could help government intervention in headphone/earbud manufacturing policy and standards and assist long-term users of earbuds to regulate the usage of earbuds.

Keywords: earbuds • cell phones • sound pressure • generation • hazard

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ZMIANY POZIOMU DŹWIĘKU SŁUCHAWEK DOUSZNYCH W RÓŻNYCH URZĄDZENIACH

Streszczenie

Wprowadzenie: Obecnie wiele osób podczas nauki lub wykonywania innych czynności ma zwyczaj oglądania filmów, grania w gry i słuchania muzyki przez słuchawki lub wkładki douszne podłączone do takich urządzeń jak telefony komórkowe, komputery i iPady. W niniejszej pracy zbadano poziom LAeq czterech różnych urządzeń podłączonych do dwóch różnych typów słuchawek dousznych.

Materiał i metody: Do pomiaru mocy wyjściowej słuchawek wykorzystano urządzenie do testów akustycznych GRAS 45CB. W celu odwzorowania naturalnych procesów zakupu i użytkowania produktów wszystkie urządzenia zostały zakupione w zwykłym sklepie. Obie wkładki douszne mają taką samą długość kabla i są tej samej konstrukcji.

Wyniki: Wyniki wykazały, że jedna marka słuchawek dousznych wytwarzała różne poziomy wyjściowe po podłączeniu do różnych urządzeń, nawet przy tym samym ustawieniu głośności. Analiza statystyczna potwierdziła, że różnice wyjściowe między urządzeniami były znaczące, co znalazło odzwierciedlenie w wynikach: [$F(3) = 805{,}08$, $p < 0{,}001$], z częściowym R^2 wynoszącym 89,7% dla prawego ucha i [$F(3) = 805{,}08$, $p < 0{,}001$], z częściowym R^2 wynoszącym 89,7% dla lewego ucha, na podstawie pomiarów wykonanych dla pięciu różnych poziomów głośności. Podobnie interakcje także okazały się znaczące w obojgu uszach. Co więcej, rozbieżności między wyjściami lewego i prawego ucha dla każdej kombinacji słuchawek i urządzenia okazały się potencjalnie niebezpieczne, co świadczy o występującym ryzyku słuchowym. Warto zauważyć, że przy ustawieniu głośności na 60% całego zakresu poziom dźwięku w obojgu uszach we wszystkich testowanych urządzeniach przekroczył limity ekspozycji zalecane przez amerykańską Agencję Ochrony Środowiska (EPA).

Wnioski: Wyniki pokazały, że jedno rozwiązanie nie jest uniwersalne. Wyniki tego badania mogą pomóc instytucjom rządowym w interwencji w zakresie polityki i standardów produkcji słuchawek/ wkładek dousznych oraz pomóc osobom długofalowo korzystającym z słuchawek dousznych w uregulowaniu ich stosowania.

Słowa kluczowe: słuchawki douszne • telefony komórkowe • ciśnienie akustyczne • generacja • zagrożenie

Key to abbreviations	
ASA	Acoustical Society of America
ATF	acoustic test fixture
CDC	Center for Disease Control and Prevention
EPA	(U.S.) Environmental Protection Agency
IRB	institution review board
LAeq	average sound level
Leq	average exposure level
NIDCD	National Institute on Deafness and Other Communication Disorders
NIHL	noise induced hearing loss
NIOSH	National Institute for Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
USAARL	U.S. Army Aeromedical Research Laboratory
WHO	World Health Organization

Introduction

The effects of hearing loss are not only local to the affected person, but also have global impacts. For example, the cost of lost productivity, special education, and medical treatment may exceed $30 billion per year for disorders of hearing, speech, and language [1]. According to Johns Hopkins Cochlear Center for Hearing and Public Health, as of 2019, approximately 38.2 million Americans (14.3%) report some degree of hearing loss [2]. Hearing loss is also rising among adolescents and has increased more than 30% between 1988 and 2006 [3]. In the early 20th century, health care experts, audiologists, parents, and governments expressed concerns about noise sources causing hearing loss in adolescents and young adults [4]. Recently, the World Health Organization (WHO) said that approximately 1.1 billion young people are at risk of potentially life-altering hearing loss due to loud noise exposure. In 2005, the Hearing Alliance of America reported that levels of hearing loss in 15% of college graduates are now equal to or greater than those of their parents and concluded that the significant cause is listening to loud music [5]. Various findings concluded that increasing numbers of adolescents and young adults now experience symptoms indicative of poor hearing, such as distortion, tinnitus, hyperacusis, or threshold shifts for reasons not yet affirmed [6–9].

Research has confirmed that today many youths are losing their hearing at alarming rates, presumably due to excessive noise exposure [10]. One possible explanation may be suggested by the results of Fasanya [11], who found that, of the total number of college students who participated in an audiometric experiment, 10% had their hearing thresholds shifted to such a degree that they were excluded from the study. The degree of potential hearing damage in young adults, like unselective exposure to places where there is a high level of noise, could bring irreversible damage to the auditory system and impact hearing performance. The use of earbuds has been attributed to hearing loss and hearing performance degradation. However, many have argued that various factors contribute to hearing loss and degradation associated with the daily use of earbuds. These factors include the design of the earbuds (in-ear, on-ear, or over-ear), the fit of the earbuds, their impedance, sensitivity, personal hearing sensitivity, audio processing and equalization settings, cable length, as well as the age and condition of the earphones.

Practically, the effect of these factors is relative. It depends on the connection. For example, one earbud connected with three different devices will not demonstrate any effect due to the design type, cable length, age, condition, impedance, and personal hearing sensitivity because only one type of earbud is used in the process. The electric circuitry of earbuds plays a major role in the voltage inputs. Therefore, one earbud type connected to different devices should produce the same output no matter what. Hence, if different earbuds are connected with the same devices, the possibility of producing different outputs is high due to the electric circuitry. Public understanding of earbuds is that one earbud should work perfectly in the same manner on any device. Contrary to this public opinion, the preliminary study by Fasanya et al. [12] proved otherwise. Therefore, to ensure safety and to protect users from overexposure, as well as educating users on how earbud works, it is imperative to understand how typical behavior such as earbud use may affect hearing.

Currently, the use of earbuds is rising all over the world, especially among the younger generation. In 2014, Ansari et al. [13] revealed that earbud usage is common among college students and 84% of all respondents in the preliminary survey conducted by Fasanya & Strong [14] used earbuds on a daily basis. Likewise, Świerczek et al. [15] revealed that the biggest threat causing hearing loss in children and adolescents is recreational noise, such as music on earbuds, concerts, discos, and toys. However, as useful as earbud devices may be in terms of allowing the user to listen uninterrupted, it does pose some safety risks [6,16]. The exponential increase in earbud usage began in the early 20th century and the targeted population is the younger generation [14]. Since the target population for earbuds are Generations Y and Z, these are the individuals who will be most impacted by any hazards associated with this device. In addition, many individuals within this demographic

Panasonic earbud | Samsung earbud

Figure 1. Pictures of all headphone brands used for data collection

are or will be attending college, where they are even more likely to use earbuds regularly [14]. Certainly, they will often need to study or do homework, and some believe that earbuds will allow them to eliminate many of the distractions they will encounter. Findings from Vogel et al. revealed that frequent users were 4 times more likely to listen to high-volume music than were infrequent users, and adolescents in practical prevocational schools were more than twice as likely to listen to high-volume music as were those attending pre-university education [17].

It is important to note that the absolute volume, duration of exposure to loud sound, sound character, and individual susceptibility are the ultimate risk factors for hearing loss [15]. However, it is possible that usage such as volume settings differ between listeners depending on the manner in which the earbuds function: over the ear, in the ear, and on the ear [18], and the type of device to which the earbuds are connected (laptop, phone, tablet). Users may set their different devices to "the same" level setting, but this may result in delivering different absolute sound pressure levels to their ears. For example, in preliminary work Fasanya et al. [12] found that setting the volume to 40% of the maximum level on an iPhone delivered a different decibel level when compared with the 40% volume level of an Android phone with the same earbud type and brand. Therefore, effects on users may depend on the type of device the earbud is being connected to. Research has concluded that earbuds should not be considered as one size fits all [12], but currently there is no adequate empirical study to support this statement. In 2020, Fasanya et al. [12] also found that young adults mostly use one earbud type on different devices.

As much as the connection between sound level and hearing damage is well-known, and the connection between earbud usage and distraction is likewise easy to understand, it is not clear whether typical earbud use rises to hearing damaging levels or is susceptible to hearing acuity degradation. The differences in the outputs of the earbuds connected with different devices could be a hearing hazard for consumers who frequently use one earbud type on different devices. Therefore, it is imperative to conduct an empirical study to investigate the output of one earbud type connected with different devices. The hypotheses for this study were:

H1: The dB outputs from the two earbuds will vary significantly with the same device, even when set to the same volume level.
H2: The devices will produce different dB outputs using the same earbud in the same ear at the same volume setting.
H3: There will be an interaction effect between the earbuds and the devices when used at the same volume setting and in the same ear.

This study investigated the average sound level (LAeq) output in dBA of two different earbud types connected with four different devices produced in two different scenarios.

Material and methods

Four different devices were utilized for data collection in this study: the Blackberry Android model KEYone BBB100-1, the Android Google Pixel 3 model G013A, the iPhone 6x model A1586, and the Samsung Android Galaxy S8 model SM-G950U. Additionally, two types of earbuds were employed: the Panasonic earbud model RP-HJE120-R and the Samsung earbud model EO-EG920LW. Both earbuds have the same cable length and are of the same design. Both were bought on the same day to ensure the same age and condition. We chose the in-ear earbuds because research have shown that majority of the young adult use in-ear earbuds on a daily basis [19,20]. All devices and earbuds were purchased from retail stores to mimic the natural sources, where users normally purchase their products for use. The study experiment was conducted at U.S. Army Aeromedical Research Laboratory (USAARL) in Fort Rucker, now known as Fort Novosel, Alabama.

The following methods were formulated to achieve the primary goal of the study: (1) submit protocol to the institution review board (IRB); (2) purchase devices for data collection; (3) calibrate equipment (GRAS 45CB ATF, software, computer, cell phones and earbuds) for data collection; (4) connect earbud with devices and collect data.

The study protocol was approved by the principal investigator's university IRB before being taken to the site where data was collected. The university is located in the northwest of Indiana, United States. Sound pressure level delivery by the earbuds (**Figure 1**) was measured with the

Figure 2. GRAS 45CB acoustic test fixture (ATF) and testing lab setting during data collection

GRAS 45CB acoustic test fixture (ATF) connected to a Dell desktop computer. Prior to the experiment, the GRAS 45CB was calibrated with the Nelson Acoustic Trident software for data recording on the attached desktop computer. A WAV noise file was generated using REATpro software. Thereafter, the volume adjustment on all devices was calibrated. The number of clicks for each volume adjustment on the cellphones was determined through the transposition method before the start of the experiment.

The five different volume levels (20, 40, 60, 80, and 100%) used in the study were determined from past studies. The levels were selected to mimic different volume levels reported in research findings, as the commonly used volume by typical earbud users [14].

The sensitivities for both right and left ears were normalized to 14.35 mV/Pa and 15.92 mV/Pa, with a reference microphone at 49.8 mV/Pa. The calibrated offset in dB for the right, left, and the reference mic were –1.2, –2.1, and –0.9 dB, respectively. **Figure 2** represents the GRAS 45CB (ATF) for the study and the setup when one of the cellphones was connected for data collection. **Figure 3** is a screen print of the Nelson Acoustic software used for data acquisition. Data from the left and right ears were collected independently in one-third octave bands, in accordance with the findings presented in the 2019 Honeycutt report [21].

A two-factor factorial design repeated measure was employed in this study to evaluate the variations in earbud output across different devices and ear sides. This design was appropriate because the earbud's output, measured in decibels, was the only continuous variable in the experiment and served as the primary dependent variable. The independent variables were the playback device (Blackberry Android, Android Google Pixel, iPhone, and Samsung Android Galaxy) and the ear side (left or right), each having multiple levels. Data collection was carried out using the GRAS 45CB ATF, a standardized and calibrated system designed for accurate and repeatable earbud measurements. For each combination of device, volume level, and ear side, measurements were taken only once due to the controlled and repeatable nature of the ATF system.

We employed two-way ANOVA to analyze the data. This statistical method was selected to determine whether there were significant differences in earbud outputs, any significant differences within device types using a single earbud brand, or any interaction effects between the earbud and the device. The method allowed for a comprehensive assessment of both main effects. We used both descriptive and inferential statistical methods for the analysis. In the descriptive statistics, we determined the means and standard deviations, as well as differences between the output of the earbuds at each ear and at each volume. These were used to summarize the data and assess the practical significance of any observed differences in output. The inferential statistics were used to determine whether the observed differences in average output levels across devices and between earbuds were statistically significant. This dual approach provided both a practical interpretation of the data and a rigorous test of statistical significance. We hypothesized that there would be a significant difference in the mean values of the dependent variable (dB outputs) across the various levels of each independent factor, which was device type. Likewise, the interaction between the devices and the earbud was expected to be statistically significant.

Results

Data acquisition

At the end of each run/test, all 1/3-octave band frequencies from 31.5 to 16.000 Hz for all volumes on the two devices were exported from the software onto an Excel spreadsheet. All frequencies were tested on each ear for

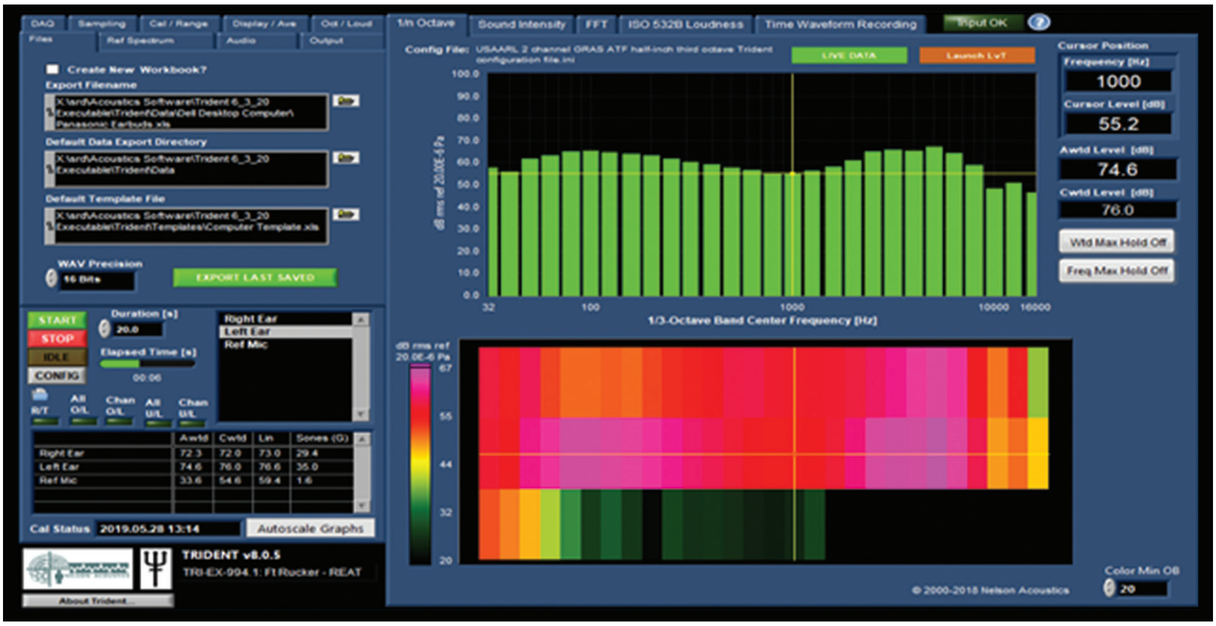

Figure 3. Nelson Acoustic Trident software that measures the third octave band center frequency sound is used for the recording. All parameters at each click and both right and left ears with the start and stop button for the software processing are included on the display box shown in the ScreenPrint

each earbud connected with the four devices at each volume level tested. The data from the report were compared with GRAS 45CB ATF manual data to ensure consistency of data recording.

After data from the Nelson Acoustic Trident software was exported to a spreadsheet, data processing and analysis were completed using MS Excel version 2020 (Microsoft, Redmond, WA, USA). Corresponding sound pressure levels with each earbud measured at each frequency and at each volume level were recorded. **Figure 4** and **Figure 5** plot outputs for the right and left ears across various volume levels, ranging from 20% to 100%, while using two different earbuds connected to four distinct devices. It is evident from both figures that different earbuds generate varying outputs in dBA when used with the same devices at identical volume levels.

Descriptive statistics

Our primary focus was to report the mean and standard deviation of the earbud output levels, and to assess their practical significance, rather than relying solely on statistical significance. To achieve this, we compared the variations in earbud output levels across different devices against the National Institute for Occupational Safety and Health (NIOSH) recommended noise exposure exchange rate (trade-off) of 3 dB. This benchmark was used as a critical threshold to assess whether the observed differences in output levels across devices could have meaningful implications for user hearing health and safety. We analyzed the differences in measured sound level output for each device–ear combination, and then calculated the range of these differences across all tested devices. Additionally, we quantified the percentage of output differences that fell below, equal to, or above the 3 dB exchange rate threshold. This comparison allowed us to determine not only the magnitude but also the potential real-world impact of using different devices with the same earbuds. The results of this comparison, including the range of output differences and the distribution of values relative to the 3 dB threshold, are summarized in **Table 1**. This table provides a clear representation of how frequently the variations in earbud output may exceed levels considered critical by occupational health standards, thereby helping to contextualize the findings in terms of practical auditory risk.

In order to facilitate a clearer understanding of the recorded measurements, we plotted the data captured from both the left and right ears, thereby enabling a pictorial representation of the observed variations. As illustrated in **Figure 4**, there are noticeable differences in the audio output levels between the left and right ears across several devices, despite using the same Samsung earbud and maintaining a consistent volume setting. This disparity suggests potential asymmetries in either the earbud design, device audio processing, or ear canal acoustics.

Table 2 presents the mean values and standard deviations of the sound output, measured in dBA, for all connected devices across the full range of volume levels tested in this study. These statistical summaries are provided separately for both the Panasonic and Samsung earbuds, and are distinguished by measurements taken at the left and right ears. This allows for a comparative analysis of the earbuds' performance in terms of consistency and output level variation across different devices and volume settings.

Figure 5 demonstrates that, for certain devices, the output at the left ear differs from that at the right ear when using the Panasonic earbud at a consistent volume level.

Inferential statistics

To further explore the differences in earbud output levels, we employed inferential statistical analysis by performing

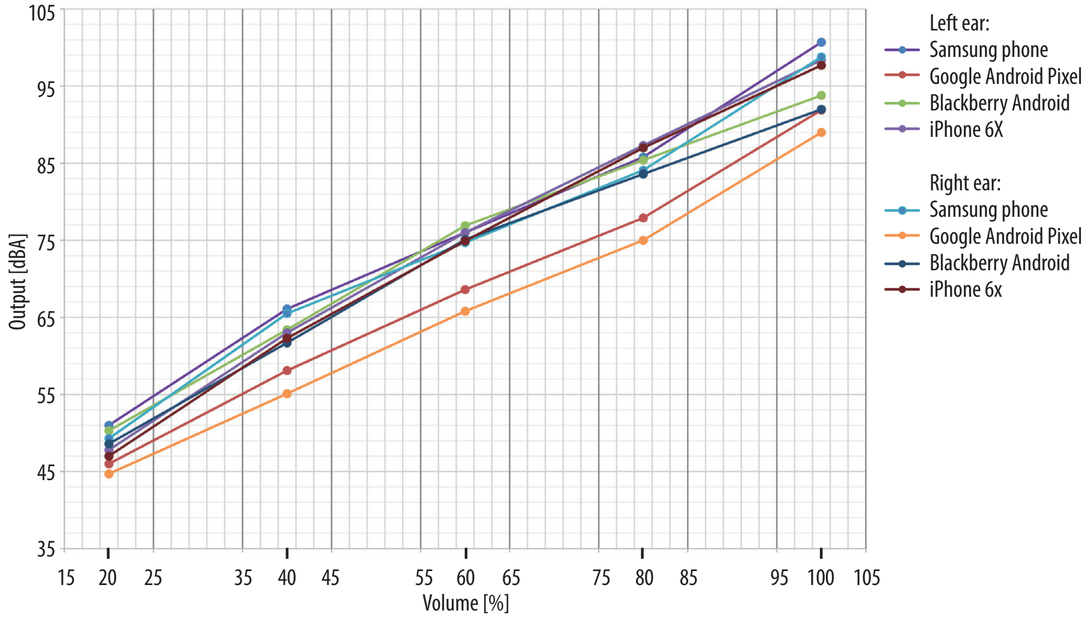

Figure 4. Output in dBA comparison of right and left ears for all four devices using Samsung headphone at the same % volume

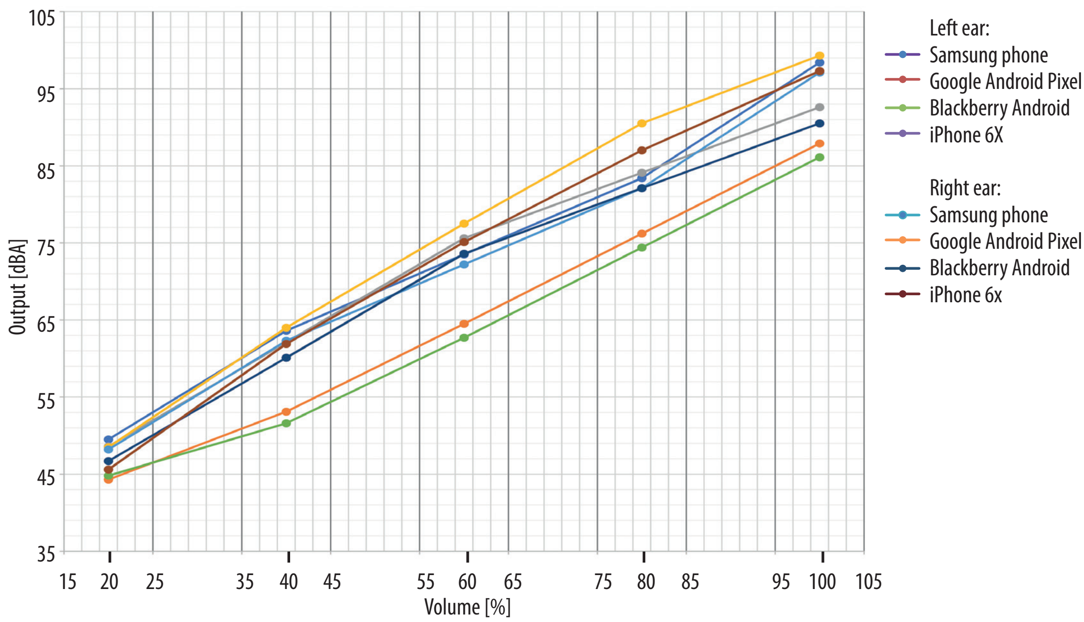

Figure 5. Output in dBA comparison of right and left ears for all four devices using Panasonic headphone at the same % volume

a two-way analysis of variance (ANOVA). This analysis was conducted on output data measured from both ear sides (left and right) across the various connected devices, with a significance level set at $\alpha = 0.05$. The primary objective was to determine whether the differences observed and summarized in **Table 3** were statistically significant. Before conducting inferential statistical tests, we assessed the assumption of normality for all datasets using the Jarque–Bera test, with a significance level of $\alpha = 0.05$. All p-values exceeded the alpha threshold, confirming that the data were normally distributed and met the assumptions required for ANOVA.

The results of the multivariate test using Wilks' lambda revealed a statistically significant effect of the device on dB output in the right ear. Specifically, the main effect of the device was significant, yielding [$F(3) = 539$, $p < 0.001$], with a partial R^2 of 85.4%. Likewise, a significant interaction effect was found between the device and the earbud, yielding [$F(3) = 18.276$, $p = < 0.001$], with a partial R^2 of 16.6%. The within-subjects effects on devices, assuming sphericity, were statistically significant [$F(3) = 346.373$, $p < 0.001$], with a partial R^2 of 55.5%. Additionally, the interaction between device and earbud was also significant [$F(3) = 377.784$, $p < 0.001$], with a partial R^2 of 10.8%.

Table 1. Output differences compared with NIOSH noise exchange rate of 3-dB

Devices	Range [dB]	% lower than 3-dB	% higher than 3-dB
Panasonic earbud			
BBA & AGP	1.9–11.1	10	90
BBA & IP	0.1–6.8	60	40
BBA & SAG	0.0–6.6	80	20
AGP & IP	1.7–14.3	10	90
AGP & SAG	3.4–11.0	0	100
IP & SAG	0.1–7.1	70	30
Samsung earbud			
BBA & AGP	1.9–9.3	10	90
BBA & IP	0.2–5.7	70	30
BBA & SAG	0.4–6.9	70	30
AGP & IP	1.8–11.7	20	80
AGP & SAG	4.6–10.4	0	100
IP & SAG	0.0–3.2	70	30

Note: BBA – Blackberry Android, AGP – Android Google Pixel, IP – iPhone, SAG – Samsung Android Galaxy

Table 2. Full data average values and standard deviation for both Panasonic and Samsung earbuds

Device type	Right ear										Left ear									
	20%		40%		60%		80%		100%		20%		40%		60%		80%		100%	
	mean	*SD*	mean	*SD*	mean	*SD*	mean	*SD*	mean	*SD*	mean	*SD*	mean	*SD*	mean	*SD*	mean	*SD*	mean	*SD*
Panasonic earbud																				
BBA	46.70	5.87	60.10	5.24	73.60	5.18	82.10	5.20	90.50	5.21	48.60	6.17	62.10	5.71	75.60	5.66	84.10	5.67	92.60	5.68
AGP	44.80	8.00	51.60	6.26	62.70	5.45	74.40	5.41	86.10	5.43	44.30	7.11	53.10	5.39	64.50	4.61	76.20	4.51	87.90	4.51
IP	46.50	5.89	62.40	5.48	74.50	5.42	86.50	5.42	97.30	5.42	48.50	5.87	64.00	4.49	77.50	5.43	90.50	5.44	99.30	5.43
SAG	48.20	6.30	62.30	6.07	72.20	6.05	82.10	6.05	97.10	6.06	49.50	5.74	63.60	5.24	73.50	5.21	83.40	5.19	98.40	5.20
Samsung earbud																				
BBA	48.60	7.53	61.70	7.33	75.10	7.29	83.60	7.23	92.00	7.15	50.30	6.77	63.50	6.86	76.90	7.32	85.40	7.46	93.80	7.36
AGP	44.70	7.44	55.10	7.24	65.80	6.86	75.00	6.75	89.00	6.69	46.00	7.33	58.10	7.48	68.60	7.21	77.90	7.44	91.90	7.48
IP	47.50	5.89	62.50	5.48	75.30	5.42	86.70	5.42	97.70	5.44	47.80	5.87	63.00	5.49	76.00	5.43	87.30	5.44	98.40	5.43
SAG	49.30	6.17	65.50	9.09	74.70	8.46	84.10	7.98	98.80	7.57	51.00	6.07	66.10	7.25	76.00	7.20	85.80	7.12	100.70	7.14

Note: BBA – Blackberry Android, AGP – Android Google Pixel, IP – iPhone, SAG – Samsung Android Galaxy

The results revealed no statistically significant difference between the earbuds, yielding [$F(1) = 0.1100$, $p = 0.9150$]. The pairwise comparison results for the device types (Blackberry Android, Android Google Pixel, iPhone, and Samsung Android Galaxy) are presented in **Table 3**. All device outputs were significantly different from one another, except for the iPhone and Samsung Android Galaxy, which did not show a significant difference for the right ear.

Figure 6 illustrates the relationship between the devices' estimated marginal means and the earbuds. However, no significant difference was found between the effects of the two earbuds (Panasonic and Samsung) on dB outputs across devices.

A similar analysis was conducted on the left ear outputs. The main effect of the device was significant, yielding [$F(3) = 805.08$, $p < 0.001$], with a partial R^2 of 89.7%. Likewise, a significant interaction effect between the device and the earbud was found, yielding [$F(3) = 31.471$, $p < 0.001$], with a partial R^2 of 25.5%. The within-subjects effects on devices, assuming sphericity, were statistically significant [$F(3) = 148.373$, $p < 0.001$], with a partial R^2 of 34.9%. Additionally, the interaction between device and earbud was also significant [$F(3) = 22.569$, $p < 0.001$], with a partial R^2 of 7.5%. The results revealed no statistically significant difference between the earbuds, yielding [$F(1) = 2.691$, $p = 0.1020$]. The pairwise comparison results for the device types (Blackberry Android, Android Google

Table 3. Pairwise comparison results of devices on the right ear

Devices	Devices	Right ear		Left ear	
		mean difference	*P*-value	mean difference	*P*-value
BBA	AGP	6.3450	<.001	10.7410	<.001
	IP	–1.0470	0.0050	1.5670	0.2460
	SAG	–1.8260	<.001	1.3720	0.5860
AGP	BBA	–6.3450	<.001	–10.7410	<.001
	IP	–7.3920	<.001	–9.1730	<.001
	SAG	–8.1710	<.001	–9.3690	<.001
IP	BBA	1.0470	0.0050	–1.5670	0.2460
	AGP	7.3920	<.001	9.1730	<.001
	SAG	–0.7790	0.2220	–0.1950	1.0000
SAG	BBA	1.8260	<.001	–1.3720	0.5860
	AGP	8.1710	<.001	9.3690	<.001
	IP	0.7790	<.222	0.1950	1.0000

Note: BBA – Blackberry Android, AGP – Android Google Pixel, IP – iPhone, SAG – Samsung Android Galaxy

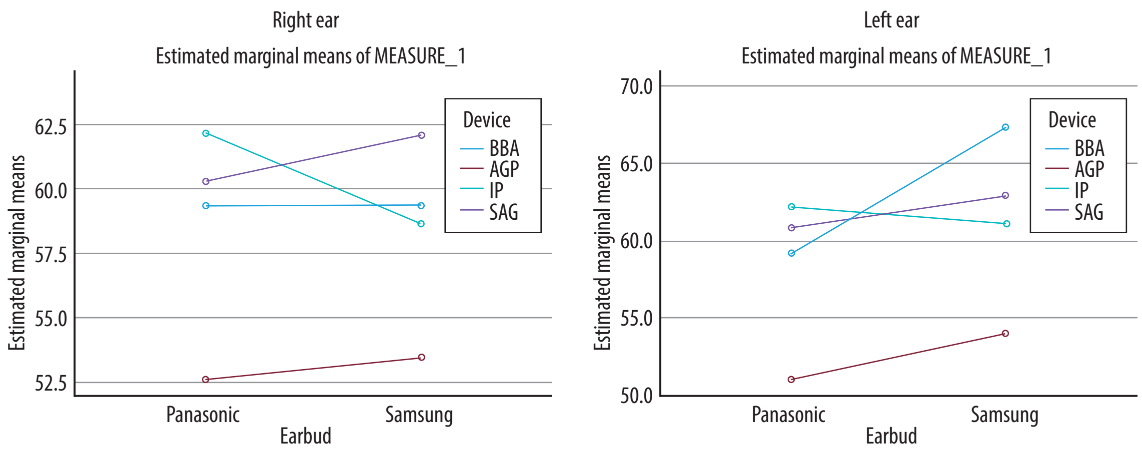

Figure 6. Relationship between the devices' estimated marginal means and the earbuds

Pixel, iPhone, and Samsung Android Galaxy) are shown in **Table 3**. All device outputs were significantly different when compared using Bonferroni, except for the following pairs: Blackberry Android and iPhone, Blackberry Android and Samsung Android Galaxy, and iPhone and Samsung Android Galaxy for the left ear. **Figure 6** (right) illustrates the relationship between the estimated marginal means and the earbuds. However, no significant difference was found between the effects of the two earbuds (Panasonic and Samsung) on dB outputs across devices.

To supplement the dBA analysis, we converted sound pressure level (dB values) into physical sound pressure units (pascals) and conducted a two-way ANOVA on the converted data. The results of the multivariate test using Wilks' lambda revealed statistically significant effects. Across all tested volume levels, the device effect was significant, yielding [$F(3) = 70.820$, $p < 0.0001$], with a partial R^2 of 43.5%. Likewise, a significant interaction effect between the device and the earbud was found, yielding [$F(3) = 13.182$, $p < 0.0001$], with a partial R^2 of 12.5% for the right ear. All devices were found to be statistically significantly different from one another when compared using the Bonferroni correction. Across all tested volume levels, the device effect was significant, yielding [$F(3) = 54.976$, $p < 0.0001$], with a partial R^2 of 37.4%. Likewise, a significant interaction effect between the device and the earbud was found, yielding [$F(3) = 26.602$, $p < 0.0001$], with a partial R^2 of 19.7% for the left ear. However, device comparisons using the Bonferroni correction revealed statistically significant differences between all devices, except between the Blackberry Android and the iPhone.

The findings further revealed noticeable variations in audio output between the left and right ears when using the same earbud across all tested devices. While some of these differences exceeded the thresholds established by the NIOSH noise exposure exchange rate guidelines, statistical analysis indicated that these differences were not significant at a 0.5 confidence level. However, from a practical standpoint, the observed discrepancies are considered meaningful, as they may have implications for user safety and listening experience, particularly during prolonged exposure. Additionally, our findings showed that the iPhone produced effects and outputs more similar to those of the BlackBerry Android than to any other type of phone tested in this study.

Discussion

Hearing loss among the younger generation is escalating and the reasons have not been well documented. Findings from this study focused on one aspect that might be one of the escalations. As reported by Fausti et al. [5], the Hearing Alliance of America reports that the levels of hearing loss among college graduates are now 15% greater than those of their parents, and a possible cause is listening to loud music. In fact, one study revealed that over 75% of its participants reported a variety of auditory symptoms after listening to music, including ear ringing, hearing loss, pain in the ears, limited concentration, and decreased tolerance to certain environmental sounds [19].

Not only listening to loud music but also the means of listening to music are important, with many young adults now using corded or Bluetooth earbuds daily. However, many believe that the earbuds help to cancel surrounding noise, neglecting the hazard associated with listening to music on the device. Findings from this research show that at a particular volume level, one earbud produced different outputs in dBA on different devices, and not only with different devices but also different outputs on right and left ears. The electric circuitry of an earbud could affect the voltage inputs when different earbuds are used on the same device, but not when one earbud type is used on different devices. Thus, the findings of this study reveal that earbud outputs are not standardized by manufacturers. We found that the outputs across different devices were found to be statistically significant.

The prevalence of hearing loss in the United States is increasing. In 2017, 25% of American adults, aged between 20 and 69, were documented to have noise induced hearing loss (NIHL) as reported by the Center for Disease Control and Prevention. The number of Americans with hearing loss increased from 13.2 million (6.3% of the US population) in 1971, to 20.3 million (8%) in 1991, and to 48 million (15.3%) in 2011 [22]. It is possible that nonoccupational noise exposure contributed to the increase in hearing loss, because the Occupational Health and Safety Administration OSHA regulations have reduced occupational hearing loss significantly. According to the findings of Gopal et al. [23], listening to music on an iPod Touch through earbuds at 100% volume for as little as 30 minutes can cause a temporary threshold shift and weaker otoacoustic emissions, posing a risk of auditory damage. Findings from this study revealed that both types of earbuds produced sound levels averaging above 98 dB across all devices at volume 100%.

The sudden jump in hearing loss among the younger generation in the world therefore needs critical assessment as well as serious investigation and intervention. The exponential increase in earbud usage began in the early 21st century, close to when there was an exponential increase in hearing degradation change the younger generation [14]. According to the National Institute on Deafness and Other Communication Disorders (NIDCD) [24] (p. 1), "Long or repeated exposure to sound at or above 85 decibels can cause hearing loss" (report of March 2014, updated March 2022). If this is the case at 80% volume, the output in dBA recorded from both earbuds tested in this study will not be appropriate for any users. Research has confirmed that earbud users increase the volume level of their devices to approximately 100% volume whenever there is background noise [25]. Our findings suggest that earbuds should be labeled with noise ratings, and that manuals should include volume levels along with corresponding dBA outputs for safe use.

According to CDC [26], the U.S. EPA recommended a 70 dBA exposure limit level for environmental noise to prevent hearing loss. The 85 dBA action level recommended by the OSHA has been recognized acceptable level for hearing loss prevention as well. However, 85 dBA is the standard level for occupational hearing loss and is not recommended for nonoccupational hearing loss. Hearing impairment due to voluntary use of earbuds is considered nonoccupational hearing loss. In 2007, Daniel [27] concluded that hearing impairment among children and teenagers has risen due mostly to voluntary exposure to loud noise, such as the use of earbuds on a daily basis. This could be one of the sources for nonoccupational hearing loss among the younger generations. Findings from this study have revealed that use of the two types of earbuds tested could expose users to sound levels above 85 dBA, the limit recommended by OSHA.

The 70 dBA level for hearing loss prevention recommended by the U.S. EPA is also documented. According to the EPA's 1974 report [28], the limit is for an equivalent continuous average exposure level (Leq) over 24 h. Likewise, the 70 dBA limit considers daytime and nighttime exposures to be equally hazardous to hearing. The EPA further expanded on the number of hours per day and the equivalent decibel level that might be high enough to cause hearing damage. The conclusion was that the 24 h limit is equivalent to a 75 dBA, 8 h workday exposure, with no noise exposure (i.e., noise < 70 dBA) during the remaining 16 h [29]. If this standard remains the case, both the tested earbuds will, based on the results from this study, not be appropriate for anyone to use at 60% volume level. On average, many young adults have confirmed using their earbuds at 60% and above volume level daily [14]. Our study showed that the average volume level, accepted to be comfortable for listening among earbud users as revealed in [14], will produce hazardous output with the tested earbuds.

According to Heinrich et al., long-term exposures to noise levels greater than 75 dBA, as recommended by the U.S. EPA in 1974, have the potential to cause metabolic changes in sensory hair cells, death of the cell, and decreased ability to perceive sound. Certainly, exposure to high-intensity noise for long durations can increase the risk of ear damage and cause permanent hearing damage (NIHL) [30]. The two earbuds tested in our study at 60% volume had their output greater or equivalent to 75 dBA when connected to any one of the four devices (Samsung, Google Android Pixel, Blackberry, and iPhone 6x). This is concerning, as these days many users use their earbuds for more than 8 hours daily and at a volume level equal to or above 60%.

We further found some variation between the right ear and left ear outputs of the same earbuds, which is also concerning. The differences were not statistically significant but practically meaningful, as they have implications for user safety and listening experience during prolonged exposure.

The NIDCD lists some activities that could put one at risk for NIHL: activities such as driving snowmobiles, target shooting and hunting, listening to music or watching movies at high volume through earbuds, and attending loud concerts either in an enclosed or open environment. Findings from our study revealed different outputs in dBA of the same type of earbud connected with the different devices at the same volume level. The majority of the differences in the outputs were found to be statistically significant. The results further indicate that one type of earbud does not fit all devices, as different outputs were recorded from various devices using the same earbud. Therefore, the variability in outputs produced by one type of earbud across different devices could result in users gradually developing NIHL without noticing.

Conclusions

The goal of this study was to investigate the average sound level (LAeq) output of two different earbud brands connected to four different phones (Samsung Android Galaxy, Google Android Pixel, Blackberry Android, and iPhone 6x). The same earbud designs were used for the study to ensure that different design types (in-ear, on-ear, or over-ear) did not contribute to output differences. Results showed that one size does not fit all, meaning that one type of earbud is not always safe to use on different devices at the same volume level. Standardization of a product should mean that it functions the same way at the same volume level on different devices. Thus, our study suggests that, for general usage, standardization should be done on earbuds and devices. The two earbuds tested produced different outputs in dBA in the right and left ear on the same device, which shows that the sensitivity of the tested earbuds was not consistent across the two ears.

Manufacturers continue to make more enticing devices, neglecting any associated risks. In most earbud brands, the associated risk of injury, aside from eliminating distraction and blocking out other sounds in the surroundings, is totally neglected. Music on the go is now one of the main factors that expands the usage of earbuds among young adults, children, and teenagers. Some of the potential risks associated with the use of earbuds include hearing threshold shifts, NIHL, and accidental injury. The findings from our study underline these risks. According to the 2021 report of the Acoustical Society of America (ASA), "auditory health risk is highest for people using personal audio systems for more than an hour a day at more than 50% volume over a five-year period" [31]. Findings from our study suggest that government intervention is necessary to regulate the manufacturing of earbuds, since many children and teenagers now use earbuds daily. The outputs in dBA for the two different earbud brands tested in our study, and connected with four different cell phone brands from different manufacturers, revealed that one earbud does not fit all. This suggests that users should check for device compatibility before buying an earbud.

To prevent an epidemic of NIHL among young adults, standards, public awareness, and education is necessary. The earbud brands tested in this study showed a significant difference between the outputs of the right and left ears under the same input volume level. More investigation is necessary to establish the extent of the problem among different earbud brands. Findings from this study could help promote awareness among frequent earbud users. They could also serve as a wake-up call for policymakers to enforce standards on earbud manufacturers. Finally, audiologists might use our findings to advise patients with hearing threshold shifts.

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AUDITORY DEVELOPMENT IN POLISH INFANTS AND TODDLERS AS ASSESSED WITH THE LITTLEARS® AUDITORY QUESTIONNAIRE

Contributions:
A Study design/planning
B Data collection/entry
C Data analysis/statistics
D Data interpretation
E Preparation of manuscript
F Literature analysis/search
G Funds collection

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Abstract

Introduction: The aim of the study was to assess the development of auditory behavior in Polish infants and young children with normal hearing who were attending childcare facilities. They were considered by their parents or guardians as being typically developing.

Material and methods: The study participants included parents and other caregivers of 293 children attending various nurseries in Lublin, Poland. The children's chronological age ranged from 2 to 35 months. The LittlEARS® Auditory Questionnaire was used as the assessment tool. Although the tool is designed to assess children up to 24 months of age, it was also used to evaluate somewhat older children to determine whether they had achieved an auditory development level equivalent to at least that of a 2-year-old.

Results: The study showed that all 25 children up to 12 months of age exhibited faster auditory development than the standard curve. Of the other 268 children 13 to 35 months old, delays were observed in 27% of them and faster development in 34%. Analysis of the responses to individual LittlEARS® Auditory Questionnaire items revealed that questions where children commonly encountered difficulties (i.e., "no" was the most frequent answer parents gave) involved questions 8, 14, 31, and 35.

Conclusions: The LittlEARS® Auditory Questionnaire is both user-friendly and reliable for screening assessments, suggesting that standard 12- and 24-month developmental screenings for children may be helpful in identifying auditory problems at an early stage. There is also a need to adapt tools suitable for children over 24 months of age, such as the PEACH questionnaire, into Polish.

Keywords: early childhood • risk of hearing impairment • auditory development • CAPD • speech therapy

OCENA ROZWOJU SŁUCHOWEGO POLSKICH NIEMOWLĄT I MAŁYCH DZIECI ZA POMOCĄ KWESTIONARIUSZA SŁUCHOWEGO LITTLEARS®

Streszczenie

Wstęp: Celem badania była ocena rozwoju zachowań słuchowych u polskich niemowląt i małych dzieci z prawidłowym słuchem, uznawanych za rozwijające się typowo.

Materiał i metody: Uczestnikami badania byli rodzice i opiekunowie 293 dzieci uczęszczających do różnych żłobków w Lublinie. Wiek chronologiczny dzieci mieścił się w przedziale od 2 do 35 miesięcy. Jako narzędzie oceny wykorzystano kwestionariusz słuchowy LittlEARS®. Choć został on opracowany w celu oceny dzieci do 24. miesiąca życia, zastosowano go również u dzieci starszych, aby sprawdzić, czy osiągnęły poziom rozwoju słuchowego co najmniej na poziomie dwulatka.

Wyniki: Badanie wykazało, że wszystkie 25 dzieci w wieku do 12 miesiąca życia charakteryzowały się szybszym rozwojem słuchu w porównaniu ze standardową krzywą rozwojową. W grupie 268 dzieci w wieku od 13 do 35 miesięcy opóźnienia w rozwoju słuchu stwierdzono u 27% badanych, natomiast przyspieszony rozwój u 34%. Analiza odpowiedzi na poszczególne pytania kwestionariusza LittlEARS® wykazała, że największe trudności (najczęściej udzielaną przez rodziców odpowiedzią było „nie") dotyczyły pytań 8, 14, 31 i 35.

Wnioski: Zaproponowano wprowadzenie obowiązkowych badań przesiewowych rozwoju słuchowego dzieci w 12. i 24. miesiącu życia. Ponadto wykazano, że kwestionariusz słuchowy LittlEARS® jest zarówno łatwy w użyciu, jak i wiarygodny w ocenie przesiewowej. Istnieje jednak potrzeba adaptacji do języka polskiego analogicznego narzędzia odpowiedniego dla dzieci powyżej 24. miesiąca życia, takiego jak na przykład kwestionariusz PEACH

Słowa kluczowe: wczesne dzieciństwo • ryzyko niedosłuchu • rozwój słuchowy • CAPD • terapia logopedyczna

Key to abbreviations	
CAPD	central auditory pro¬cessing disorder
CHAPS	Children's Auditory Performance Scale
ELF	Early Listening Function
FAPI	Functional Auditory Performance Indicators
FISHER	Fisher's Auditory Processing Problems Checklist
IT-MAIS	Infant-Toddler Meaningful Auditory Integration Scale
PEACH	Parent's Evaluation of Aural/Oral Performance of Children
SAB	Scale of Auditory Behaviors

Introduction

Normal hearing is essential for speech development. However, it is important to broaden the perspective and emphasize that sound reception is a condition for the development of auditory perception, which in turn forms the basis for the proper progression of language and speaking skills [1]. There is a group of children who, despite having normal sound reception in the peripheral structures, are unable to fully process the auditory information reaching them [2].

There are psychoacoustic tests that allow one to assess speech understanding in distorted conditions, interaural integration and separation, temporal aspects of auditory information processing, and short-term auditory memory [3]. However, all these tests are designed for children over 7–8 years of age, as they require active cooperation between the examiner and the subject. Age-appropriate test batteries have been established, tailored to the developmental capabilities of the child. In exceptional cases, for younger children (aged 4–6 years) who are able to speak and cooperate with the examiner, these tests may be conducted to assess the potential risk of central auditory processing disorder (CAPD). In children even younger, objective methods, such as P300 wave registration, are typically applied if concerns are raised by the parents or guardians about the child's auditory processing ability [4,5].

There are certain questionnaires that attempt to systematize observations of the child's behavior and assess the risk of CAPD or even hearing impairment. Examples of popular screening tools adapted to the Polish language include the Children's Auditory Performance Scale (CHAPS), Fisher's Auditory Processing Problems Checklist (FISHER), and the Scale of Auditory Behaviors (SAB) [6]. All these screening tools are designed for children of school age, by which time speech development should be largely complete [7]. Therefore, any issues detected at this stage require therapeutic intervention, and this could possibly have been prevented if there were tools available for earlier stages of development.

Questionnaires designed for newborns and young children include the Infant–Toddler Meaningful Auditory Integration Scale (IT-MAIS), Early Listening Function (ELF), Functional Auditory Performance Indicators (FAPI), Parent's Evaluation of Aural/Oral Performance of Children (PEACH), and the LittlEARS® Auditory Questionnaire; however, only the latter has been validated in Polish [8,9]. An additional tool – the LittlEARS® Evaluation of Early Speech Production Questionnaire – has been developed to complement the LittlEARS® Auditory Questionnaire, and further supports the monitoring of speech development in children from birth to 18 months, as well as in children with hearing loss during the initial months of hearing aid or cochlear implant use. The questionnaire comprises 27 yes/no questions completed by parents or guardians, and follows a structure analogous to that of the auditory development assessment tool [10–12]. The additional tool was originally published in German and has since been translated into multiple languages; however, it remains unavailable in Polish.

There are four fundamental types of auditory abilities, each reflecting different levels of response to speech. These include detection (recognizing the presence or absence of sound), discrimination (noticing similarities and differences between sounds), recognition (also known as identification, which involves assigning meaning to sounds), and comprehension (the ability to understand speech, drawing on linguistic experience) [13]. The 6th, 12th, and 24th months of a child's life represent key milestones in speech development. Around 6 months of age, a child begins to produce reduplicated babbling, involving the repetition of consonant–vowel combinations, which may mark the transition from detection to sound discrimination. By the end of the first year, the child progresses from the preverbal (prosodic) stage to the vocabulary stage, indicating the development of auditory skills to the level of sound identification. After the second year, the child enters the early multi-word (sentence) stage, achieving the ability to comprehend speech sounds. These stages thus constitute a critical window for closer observation of the child's behavior and auditory and language stimulation [7]. The LittlEARS® Auditory Questionnaire was initially designed to determine the auditory age of children with hearing impairments who use hearing aids or cochlear implants during the first two years following device fitting. However, it is also suitable for children from birth to 24 months of age, regardless of their hearing level, to monitor the rate and degree of their auditory development based on established norms [9,14], and this is what the present study involves.

Material and methods

The study included parents and caregivers of 303 children aged 2 to 35 months from 39 childcare facilities ("żłobek" in Polish) in Lublin, Poland. Parents or primary caregivers were asked to provide observations of their child's auditory behaviors by completing the LittlEARS® Auditory Questionnaire. It was designed to focus on children considered to be typically developing, aged from birth to nearly 3 years. "Typically developing" means that none of the children had ever been referred for additional diagnostic assessment, nor had they received any formal diagnosis or opinion from a specialist clinic. This was largely due to their young age, since many developmental disorders are not typically identified until after the age of 3 or 4, when standardized diagnostic tools become applicable. The selection of children was therefore based on the absence of

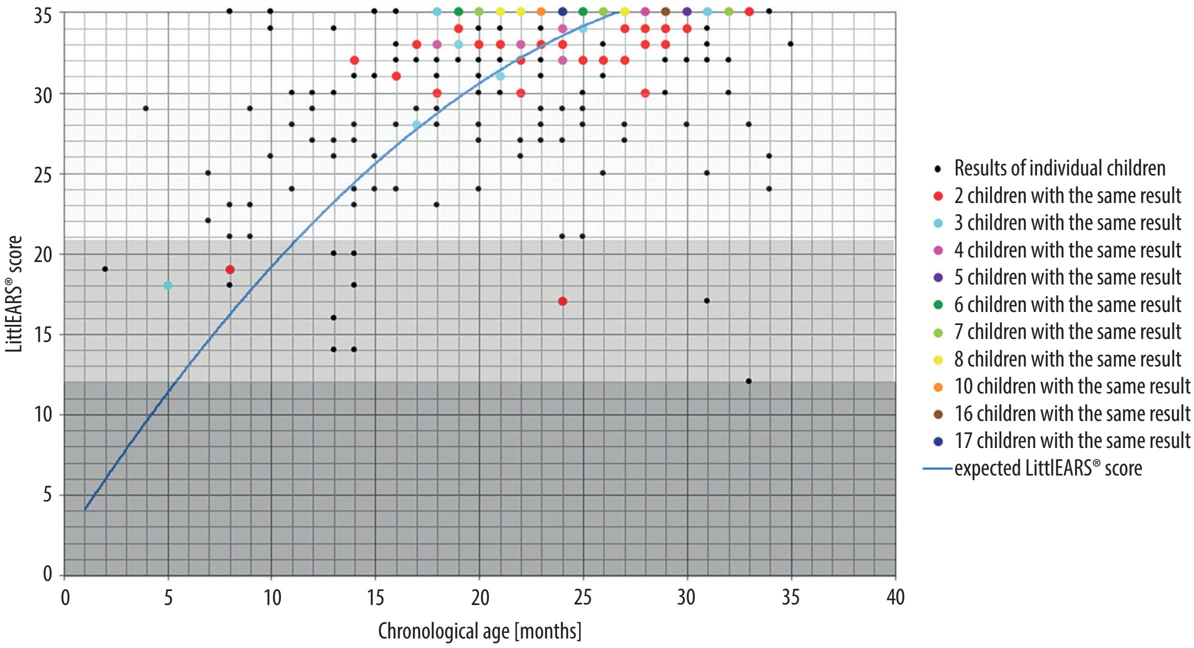

Figure 1. LittlEARS® Auditory Questionnaire scores plotted against chronological age of the children. The three shaded horizontal bands indicate the boundaries of developmental phases (0–12 Sound detection; 12–21 Sound discrimination; 21–30 Sound identification; 30–35 Comprehension). The solid blue line is the standard provided with the LittlEARS questionnaire [14]. The shaded areas illustrate the types of behaviors exhibited by children at each level of auditory development: children whose scores fall within a band are considered to be developing normally; those above it have accelerated development, and those below it have delayed development

any reported concerns from parents or carers, with no behavioral or developmental red flags being raised prior to participation. Although the questionnaire is intended for assessing hearing development in children up to 24 months of age, the decision was made to experimentally apply the questionnaire to a group of older children as well. Thus, the test results were interpreted in terms of whether the child had at least reached a level of development typical for a 2-year-old.

Note that in Poland attendance at nurseries and even kindergartens is not mandatory. Until the age of 5, attending an appropriate care or educational institution is voluntary and remains the parents' choice. Children typically spend a few hours each day in a nursery, with a legal maximum of 10 hours. (At age 6, children are expected to complete a one-year school preparation program, and from ages 7 to 18 schooling is compulsory.)

First, approval was obtained from the directors of the respective institutions to distribute the questionnaires. Parents or carers of the children attending the nurseries were provided with both oral and written information about the purpose of the study, as well as contact details should they wish to inquire about their child's auditory development. No nursery staff members took part in the study. Parental figures were also informed that the study was anonymous and that by submitting the completed questionnaire they were consenting to its use for scientific purposes.

The LittlEARS® Auditory Questionnaire forms were distributed to the parents or carers of the children, along with instructions to complete all 35 'yes or no' questions and to provide the child's gender, date of birth, and any information about diagnosed disorders. The respondents filled out the Polish version of the questionnaire, adapted by Obrycka et al. [9,15] from the English version, following the back-translation procedure recommended by the International Test Commission, which helps minimize translation-related errors. Some 10 responses were excluded from the analysis: in one case, the child's date of birth was not provided; 6 children exceeded the maximum age limit of 35 months; and 3 had diagnosed conditions such as hearing impairment or issues related to muscle tone or sensory integration.

Ultimately, the results for 293 children were analyzed (148 boys, 137 girls, and 8 children of unspecified gender). The children's chronological ages ranged from 2 to 35 months. The age group of 2–12 months included 25 children; the 13–24 months group consisted of 161 children; and the 25–35 months group comprised 107 children. The chronological age of children was calculated in the standard way, based on the child's date of birth and the date of the assessment. The auditory age, on the other hand, was determined based on the number of points obtained in the LittlEars® Auditory Questionnaire. The number of points scored by the children is plotted against their ages in **Figure 1**.

Results

Figure 1 shows the scores from the LittlEARS® Auditory Questionnaire for all the children. The blue curve represents the expected score for each age. The grey-shaded

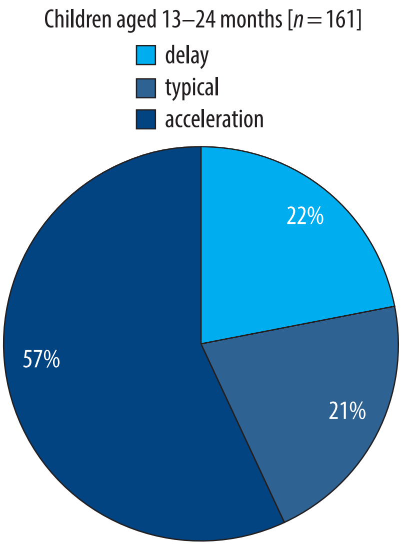

Figure 2. The auditory development of children aged 13–24 months ($n = 161$) based on their LittlEARS® Auditory Questionnaire scores and where the scores fell relative to the bands marked in **Figure 1**

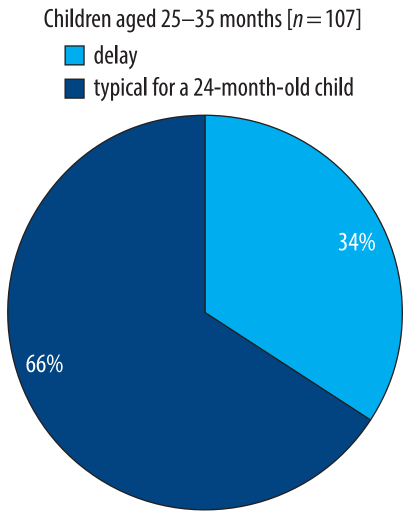

Figure 3. The auditory development of children aged 25–35 months ($n = 107$) based on their LittlEARS® Auditory Questionnaire scores and where the scores fell relative to the bands in **Figure 1**

regions indicate the range of questionnaire scores corresponding to various levels of auditory development (detection, discrimination, identification, and comprehension).

All children in the youngest group ($n = 25$) showed a higher level of development than expected. Their mean chronological age was 8.4 months ($SD = 2.6$), while the average number of points (responses marked "yes") was 24.8 ($SD = 5.6$), indicating that the auditory age of this subgroup was about 14.7 months ($SD = 5.0$) – that is, above the expected auditory age corresponding to the number of points scored. Children of this age are typically expected to function at the level of sound detection. However, according to their parents or carers, all the children surpassed this stage – some were still below the level of sound discrimination, but the majority had already reached the level of sound identification (see **Figure 1**).

The group of children aged 13 to 24 months ($n = 161$) was more diverse. The overall mean chronological age in this group was 20.0 months ($SD = 3.4$), and the average questionnaire score was 31.5 ($SD = 4.62$), indicating that the group functioned at the auditory level of children aged 21.1 months ($SD = 4.3$). This suggests that, overall, these children functioned at a slightly higher level of auditory processing development than expected based on the normative data. In more detail: 21% of them reached the developmental level expected for their age; 57% surpassed it, functioning at the level of sound identification and comprehension; and 22% scored below the expected level (**Figure 2**). Children with the lowest auditory development levels in this age group functioned at the sound detection and discrimination stage, which is typical for children aged 6 to 17 months.

Turning to the children aged 25 to 35 months ($n = 107$), it was expected that out of the 35 LittlEARS® questionnaire items, the respondent would give 34 or 35 "yes" answers, which would indicate that the children had completed all stages of auditory development typical for a 2-year-old. However, it was found that 71 of the children (66%) met this criterion (**Figure 3**). The average chronological age of the remaining 34% of the oldest children (those with suspected auditory development delay and recommended for monitoring) was 28.7 months ($SD = 3.0$), and their average questionnaire score was 29.2 points ($SD = 4.7$). This score corresponds to the expected score for a 19-month-old child ($SD = 4.5$) entering the level of sound identification in auditory development.

It is worth noting that the lowest LittlEARS® Auditory Questionnaire score among all participants (12 points, see **Figure 1**) was recorded in the oldest age group (25–35 months). This result was from a girl whose chronological age was 33 months, although her auditory age was approximately 5 months, corresponding to the transition from the sound detection phase to the sound identification phase (see blue line in **Figure 1**). Despite such a significant delay in auditory and speech development, no concerns had been raised about the child's behaviour and no early speech therapy or audiological intervention had been initiated.

Discussion

All the children in the study aged up to 12 months obtained scores higher than expected. Several hypotheses can be proposed to explain this outcome, including the positive influence of the environment (family lifestyle, parenting choices, childcare centre) or potential bias due to wishful interpretation by parents or carers. A better understanding would require an expanded study.

Deviations from the norm were predominantly observed in children aged 13 months and older, and these cases will be discussed in the following sections.

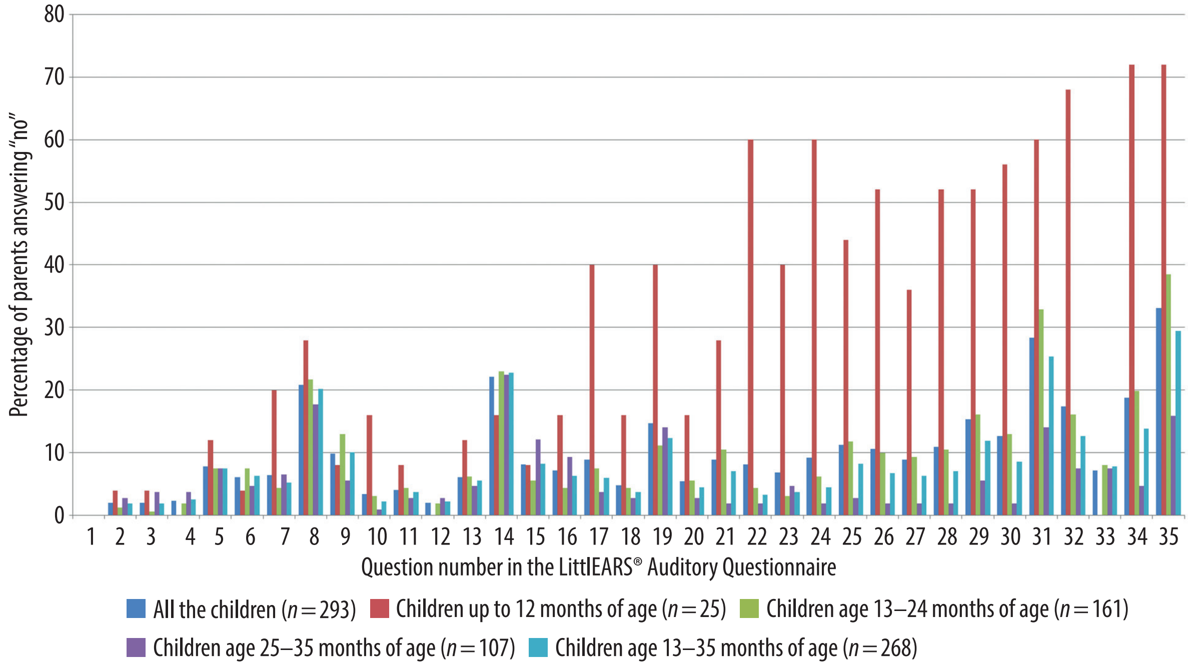

Figure 4. The percentage of parents who answered "no" to each question within the set of 35 LittlEARS questions

The findings can be categorized according to whether the three groups of children had accelerated auditory development, auditory development appropriate for their chronological age, or delayed auditory development. The pie charts show the percentages of children in each category: **Figure 2** is for 13–24 months ($n = 161$) and **Figure 3** is for 25–35 months ($n = 107$).

As shown in **Figure 2**, among children aged 13–24 months ($n = 161$), 78% did not require further monitoring, while 22% showed signs of delayed auditory development. It is surprising that in the first year of life, all children demonstrated faster-than-expected development, yet in the second year, around one-fifth required preventive action. Several factors may explain this. First, undetected perilingual hearing loss may be present: children with mild hearing impairment often develop similarly to their peers early on, with characteristic symptoms appearing only later. Second, parents typically have less experience observing their child during the first year of life; in the second year, their assessments may become more accurate, allowing delays to be identified. Third, these apparent delays may be early symptoms of a risk for auditory processing disorders or signs of immature auditory system development, potentially linked to environmental influences, the quality of the acoustic environment, and the child's auditory learning experience.

Figure 3 shows that among the 107 children aged 25–35 months, 66% achieved a score corresponding to the expected level for a 2-year-old. Since the test used in the study is standardized only for children up to 24 months and there are no higher bands for them to fall into, it is impossible to determine, based on this assessment alone, whether the children in the older age group were developing entirely typically. One can only conclude that they have mastered the fundamental stages of auditory development. Further evaluation would require the use of other diagnostic tools suitable for older ages. It is concerning, however, that 34% of the children had not mastered fundamental auditory skills, and based on the LittlEARS® Auditory Questionnaire results, they can be identified as having delayed auditory development. This percentage is higher than in the younger age group (compare with **Figure 2**). The reasons may again include undiagnosed hearing loss, as well as a lack of supportive environmental factors in the child's upbringing, such as insufficient auditory stimulation, exposure to noise, or limited verbal interaction. It is also possible that, just as wishful thinking may have led parents or guardians of the youngest children to overestimate their child's abilities and report higher scores than warranted, with this age group (25–35 months) parental anxiety may have led to underreporting. At the age of 3 years, children in Poland usually leave daycare and may begin preschool, representing a major change in their lives. Parents may feel uncertain about how their child will cope in a new environment, so when unsure whether they observed a behavior or not, they may err on the side of caution and report it less positively. This is a responsible approach and is strongly encouraged in assessments such as this one.

All children in the study achieved at least the basic level of sound detection. Among those identified by the LittlEARS® Auditory Questionnaire as requiring further monitoring, only a small number remained at the level of sound discrimination. The majority of children appear to be working hard in making progress from sound identification to sound comprehension.

Unfortunately, there also seem to be some children who have reached a stage of sound comprehension, but at a level lower than expected based on their chronological age.

These children may be at risk of not receiving adequate support for speech and auditory development; their difficulties may be subtle and go unnoticed or they may be underestimated on the assumption that, over time, they will catch up naturally.

To make a preliminary assessment of which factors tend to give rise to a delay in auditory development, we looked at those questions in the questionnaire to which parents or carers most frequently answered "no". The bar chart (**Figure 4**) shows the percentage of "no" responses to each question, divided by children's ages. Recall that some of the children over 13 months of age were identified in this study as having delayed auditory development, based on their LittlEARS® Auditory Questionnaire score.

The questions that presented the greatest apparent difficulties for children aged 13–35 months ($n = 268$) were numbers 8, 14, 31, and 35, to which more than 20% of respondents answered "no". Based on these questions, the following conclusions can be drawn: the parental figure's voice and music are not used for emotional regulation (questions 8 and 14); speaking in a gentle voice, singing, or playing music does not influence the child's behavior (question 31); and the child does not attempt to sing – whether along with a recording, with another person, or independently from memory (question 35).

Next, difficulties emerge in areas addressed by questions 9, 19, 29, 32, and 34, to which more than 10% of respondents caring for children aged 13–35 months ($n = 268$) answered "no". Based on these findings, it can be concluded that the children do not demonstrate an understanding of emotional prosody, as evidenced by their lack of an appropriate reaction to an angry voice. They also do not exhibit a tendency to repeat either individual words or sequences of syllables. Additionally, they are not yet able to reproduce sequences of syllables of varying lengths. Furthermore, they are unable to follow verbal commands – both simple ones, such as responding to the word "no", and more complex instructions, such as "Take off your shoes and come here".

It was found that parents or guardians answered "no" to almost all questionnaire items relating to music, with one exception: whether children listen when the radio/CD/tape player is turned on (question no. 6). This is rather concerning: children were exposed to music but did not hum along, nor did they repeat memorized fragments after the song was turned off. This lack of engagement with music does not support prosodic development. The children had difficulty repeating sequences of long and short syllables, suggesting difficulties in temporal processing of sounds.

One possible explanation is that parents or carers may be playing recorded songs to children, but over time these recordings become background noise. Instead of supporting auditory and language development, they may actually be hindering it. The parents may believe their children are actively listening to these songs, but the responses to the other questionnaire items suggest otherwise.

Conclusions

The present study leads to the conclusion that it might be beneficial to consider introducing a "12- and 24-month developmental screening" or a "well-child check-up" into clinical practice, with the aim of assessing a child's auditory and speech development at an early age. A speech therapist would be the most appropriate professional to conduct such an evaluation. The LittlEARS® Auditory Questionnaire has been proven to be a useful screening tool for this type of preventive assessment.

It should, of course, be noted that the presented results are based on normative data established over a decade ago. The observed acceleration in auditory development in some children, and delay in others, may be related to global shifts in lifestyle and child-rearing practices, including being cared for in a nursery. Thus, it may be worth considering a revalidation of the questionnaire, along with a new study involving children who are confirmed to be typically developing – verified through additional assessments using a cross-check method.

Adapting the second part of the LittlEARS® Auditory Questionnaire – the LittlEARS® Evaluation of Early Speech Production Questionnaire – to Polish would also be beneficial. Additionally, there is a need to adapt a questionnaire suitable for children over the age of 2 years into Polish, such as the PEACH Questionnaire.

Another recommendation is to enhance educational efforts aimed at parents of newborns and infants. Key topics to address include a child's exposure to noise, the role of music in auditory development, and communication strategies that support auditory and speech development. The latter would be tailored to the child's actual developmental level, which does not always correspond to their chronological age. Encouraging parents and others to actively sing to children is particularly valuable, and workshops could be arranged to promote this practice. Live singing directed at a child has a greater impact on development than even the best recordings. It forms the foundation for dialogue, speech, communication, and, most importantly, emotional bonding. Additionally, adding well-designed music and speech-rhythm activity into childcare settings could provide significant benefits to children.

Finally, there is a need to expand research and examine early childhood environments more closely. First, it is important to verify whether the hypothesis that children are constantly exposed to recorded background music is true. Second, a broader investigation is needed into the role of modern technological devices such as tablets, computers, and smartphones in contemporary family life. Finally, it is an interesting question as to whether the time that children are spending in childcare has an effect on their auditory development. What effects do factors such as the duration of nursery attendance, the type of activities provided, group size, and other organizational aspects of childcare have? Indeed, how does nursery attendance in general affect children's auditory development compared to staying at home under the care of a family member or a nanny? Addressing this issue could provide valuable insights for future research in early speech and hearing prevention.

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REPORT ON THE 2ND INTERNATIONAL PEDIATRIC AUDIOLOGY CONGRESS (IPAC), 4–6 APRIL 2025, ISTANBUL, TURKEY

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The 2nd International Pediatric Audiology Congress took place in Istanbul on 4–6 April 2025. As it happened, the inaugural congress was also held also in Istanbul in April last year. This year's congress focused on bridging gaps in pediatric audiology and exploring the latest advances in the field. A consistent hallmark was collaboration of specialists from around the world to provide a unified state of the art.

During the opening session, participants listened to keynote lectures delivered by Onur İpek (secretary-general of Cochlear Implant Derneği – CID), Betül Mutluç (CI user and vice-president of CID), and Robert Mandara (president of European Association of Cochlear Implant Users – EURO CIU). Hüseyin Deniz presented a study on facial nerve stimulation of a child 10 years after cochlear implantation. He highlighted a unique situation where stimulation occurred both with the processor turned on and off. Dr Chryssoula Thodi showcased research on speech disorders accompanying auditory processing disorders. Her study focused on children with single-sided deafness (SSD). She identified significant differences in how children with SSD function in noisy environments, including weaker phoneme identification, less rhyme recognition, and lower behavioral performance indicators.

The second day began with an opening ceremony hosted by Prof. Şule Cekic and Prof. Patricia Mancini. Honorary presidents received awards recognising their scientific contributions. Prof. Christine Yoshinaga-Itano presented an intriguing study on early diagnostics, vaccines, and genetic treatments, with her research focusing on hearing loss caused by congenital cytomegalovirus (CMV). She emphasized the necessity of conducting newborn screening before discharge from neonatal units. She also highlighted ongoing research into a CMV vaccine, which could significantly reduce the number of newborns affected by the virus. Prof. Hesham Kozou raised the possibility of gene therapy for children with congenital genetic hearing loss. He shared preliminary results from his team's research and underscored the importance of genetic testing when a child with profound congenital hearing loss presents with no confirmed cause. Prof. Kozou emphasised the crucial role of differential diagnosis in identifying syndromic conditions such as Usher syndrome, Alport syndrome, and CHARGE syndrome.

Award to the authors of the presentation *Prevalence of tinnitus in a sample of 43,064 children in Warsaw, Poland* for winning second place in the "Oral Presentations" category at IPAC 2025

In a "Hearing Screening" session, Dr Theresa Byrne (Ireland) and Dr Chryssoula Thodi (Cyprus) presented studies on the development and effectiveness of current screening programs in their countries, beginning as early as the 1980s. However, these programs were only fully developed and implemented at the beginning of the 21st century.

In an "Oral Presentations" session, Aleksandra Kołodziejak, MSc, presented three studies from the Institute of Physiology and Pathology of Hearing, Poland.

1. *Symptoms of auditory processing disorder (APD) in children with tinnitus*, by Piotr H. Skarzynski, Natalia Czajka, Aleksandra Kołodziejak, Elżbieta Gos, and Danuta Raj-Koziak.
2. *Prevalence of tinnitus in a sample of 43,064 children in Warsaw, Poland*, by Piotr H. Skarzynski, Danuta Raj-Koziak, Aleksandra Kołodziejak, Natalia Czajka, and Henryk Skarzynski.
3. *Children's Tinnitus Questionnaire: a novel tool for assessing the impact of tinnitus on a child's everyday life*,

by Danuta Raj-Koziak, Elżbieta Gos, Marek Porowski, Aleksandra Kołodziejak, Piotr H. Skarzynski, and Henryk Skarzynski.

These studies sparked interest due to their focus on tinnitus in children, therapeutic possibilities, and the need for developing methods for diagnosis and rehabilitation of children with the condition. Moreover, paper two won second place in the "Oral Presentations" category.

On the third day, Aleksandra Kołodziejak presented three posters based on studies by the IFPS team.

1. *Facial nerve palsy in children as a complication after otitis media*, by Aleksandra Kołodziejak, Natalia Czajka, Piotr H. Skarzynski, and Henryk Skarzynski.
2. *Evaluation of auditory outcomes after CI in children with CHARGE syndrome*, by Piotr H. Skarzynski, Aleksandra Kołodziejak, Emilia Czaplicka, Artur Lorens, Adam Walkowiak, and Henryk Skarzynski.
3. *Cochlear implantation in children with congenital herpes virus*, by Aleksandra Kołodziejak, Piotr H. Skarzynski, Natalia Czajka, and Henryk Skarzynski.

Dr Eualia Juan Pastor presented an interesting study on cochlear implantation in children with congenital single-sided deafness (SSD). She described the diagnostic process followed in her clinic and the outcomes of implanted patients. She emphasized the importance of presenting all possible therapeutic options to parents and raising awareness of how bilateral hearing can significantly impact a child's development and functioning. Prof. Merve Batuk presented a study on the challenges of cochlear implantation in children with additional disabilities. She discussed syndromes and disabilities associated with hearing loss (e.g., Down syndrome, cerebral palsy). She pointed out that hearing loss is not the only issue faced by such children, often leading to delays in diagnosing hearing loss. Prof. Batuk emphasised the need to adjust diagnostic and rehabilitative methods to suit children with disabilities.

The congress was an excellent opportunity to exchange knowledge with specialists from around the world. The issues addressed provided participants with insights into future research directions. The next congress will take place in April 2027, again in Istanbul.

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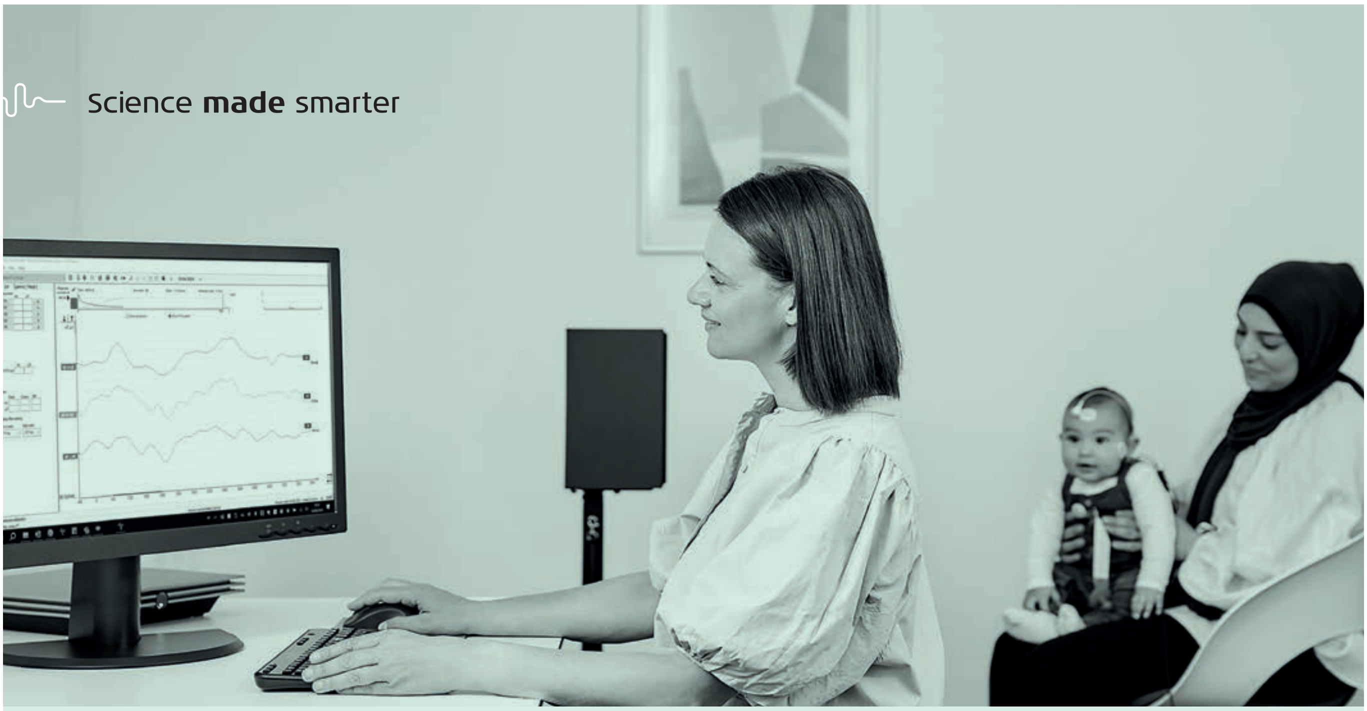

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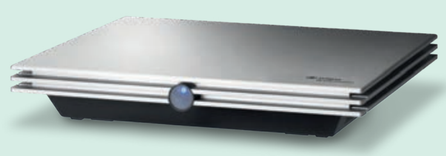

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