

American Auditory Society Scientific and Technology Meeting March 2 – 4, 2023

PODIUM ABSTRACTS

PODIUM SESSION I: AMPLIFICATION I – OVER-THE-COUNTER (OTC) DEVICES

Evaluation of Over-the-Counter Earbuds to Improve Hearing and Communication

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Objectives: Barriers to hearing aid use include the cost of devices and inconvenience and cost of visiting a hearing professional. Recently, more affordable earbud-style devices with features designed to help people hear better (e.g. Apple AirPods Pro, Nuheara IQbuds PRO) have become available and may be easily purchased by consumers. The objective of this research was to evaluate the effectiveness of an over-the-counter earbud with smart hearing features using a multi-faceted approach, and determine how it can help improve hearing and communication for people with hearing loss or hearing difficulties.

Design: Objective, behavioural and subjective testing methods were applied. Objective measurements were conducted in an acoustic test room with a horizontal circular array of 16 loudspeakers to simulate a target talker and noisy environment. Performance measures of the device characterised the gain and compression provided for a particular hearing profile, and the amount of signal-to-noise ratio advantage achieved by activating directionality and noise reduction features. Speech-in-noise sentence testing was performed within the same laboratory arrangement. 17 adults (21-59 years) with self-reported speech-in-noise hearing difficulties and a Revised Hearing Handicap Inventory and Screening questionnaire score greater than 7 were recruited. Participants completed the test both unaided and with the earbuds customised using their pure-tone audiogram. To complement laboratory measures, real-world experiences were captured using a smartphone-based ecological momentary assessment (EMA) app over a four-week period. The EMA app recorded participants' listening experiences in their daily life with and without the earbuds while also measuring acoustic features of the environment.

Results: Acoustic measures showed that the gain provided by the earbuds generally overamplified loud sounds and underamplified soft sounds compared to NAL-NL2 hearing aid prescription. The directionality feature provided an improvement in speech intelligibility index (SII)-weighted SNR of around 5 dB. Speech-in-noise testing showed that intelligibility increased from 54.6% to 66.4% on average when participants wore the earbuds, and participants rated that their listening effort and mental demand reduced. EMA data revealed that participants found their overall hearing experience and speech understanding slightly better in their daily life, however, the benefit was mostly limited to certain situations. Some participants reported comfort issues and stigma associated with earbuds not being perceived as assistive listening devices.

Conclusions: The data demonstrate that while differences to traditional hearing aids exist, over-the-counter earbud-style hearing devices can enable people with hearing loss or hearing difficulties to hear quiet sounds more easily, improve speech understanding and increase listening comfort during conversations in noisy situations. The real-world data provides rich insight to complement the laboratory measures and highlights a range of user considerations that influence whether these devices are suitable and desirable for an individual.

Outcomes of Self-Fitting Over-the-Counter (OTC) Hearing Aids When Compared to Hearing Aids Fit by Hearing Care Professionals

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Objectives: Over-the-counter (OTC) hearing aids present more accessible and affordable solutions compared to traditional prescription hearing aids. Most existing research on OTC hearing aids was performed on early-generation direct-to-consumer devices such as personal sound amplification systems. The aim of this study was to compare the outcomes of self-fitting OTC hearing aids when compared to audiologist-fit hearing aids. Our hypotheses was that the self-fitting hearing aids will be non-inferior to audiologist-fit hearing aids in terms of self-reported as well as behavioral outcomes.

Design: The first of two studies included a prospective cross-sectional survey design (n=656) and compared hearing aid benefit and satisfaction measured using the International Outcome Inventory for Hearing Aids (IOI-HA) between individuals who obtained prescription hearing aids from hearing care professionals (HCPs) or self-fitting OTC HAs. The second study included a randomized parallel-group clinical effectiveness trial (n=68) comparing the outcomes of self-fitting OTC hearing aids to the hearing aids fit by HCPs. Outcome measures included the Abbreviated Profile of Hearing Aid Benefit (APHAB), IOI-HA, QuickSIN and digits-in-noise (DIN) tests.

Results: The first cross-sectional suggested that there was no significant difference in overall hearing aid outcomes between prescription hearing aid users fit by HCPs and users of self-fitting OTC hearing aids using regression analyses controlling for age, gender, duration of hearing loss, duration before hearing aid purchase, self-reported hearing difficulty, and unilateral versus bilateral fitting. In the second trial, the groups did not differ significantly in age or four-frequency pure tone average. After the two-week field trial, the self-fitting group had an initial advantage when compared to HCPs group on the self-reported benefit and satisfaction measures, including the APHAB (Cohen's d for independent samples t-test, -0.4; 95% CI -0.9 to 0.1) and IOI-HA (effect size r for Mann-Whitney test, 0.3; 95% CI 0.0 to 0.5), but not in speech recognition in noise. However, at the end of the six-week trial, no meaningful differences were evident between the groups on any of the outcome measures.

Conclusions: The results of the two studies presented suggest that self-fitting OTC hearing aids with remote support provide comparable outcomes to hearing aids fit by HCPs using best practice. These studies provide early evidence to inform clinical practice and policy in relation to OTC hearing aids.

Priming Effects: Labeling Hearing Aids as "Prescriptive" or "Over-the-Counter"

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Objectives: Previous research has shown that priming effects are measurable within hearing aid research and these effects not only have an impact on device preference, but also hearing performance. The recent release of FDA guidelines for OTC hearing aids has created an urgency to understand the impact of OTC devices on the hearing aid market. Device labeling has been proven to influence consumer preference in hearing aid research, but the specific effect of labeling devices as "over-the counter" (OTC) or "professional" has not been previously

investigated; therefore, this study was designed to investigate the impact of OTC labeling on consumer behavior, perception and hearing performance.

Design: Ten experienced hearing aid users and ten naïve listeners (defined as never having tried hearing aids) with mild-to-moderate hearing loss were recruited for this study. They were told they were participating in a research study comparing a "professional" hearing aid to an "OTC" hearing aid. In reality, the participants were wearing the same set of devices for both conditions. The participants completed a set of standardized questionnaires, the Revised Hearing Handicap Inventory Screener (RHHI-S), the Expected Consequences of Hearing Aid Ownership (ECHO) questionnaire for the naïve listeners, the Satisfaction with Amplification in Daily Life (SADL) questionnaire for the experienced hearing aid users, and the Big Five Personality Inventory (BFI). They were then fit with a set of RIC hearing aids programmed to a standard audiogram for moderate hearing loss (N3). The researcher primed the participant by providing a scripted definition of the device that provided one negative and one positive aspect for each label. The order of the labeling condition was randomized. The participants then listened to a live spoken passage in quiet and completed the QuickSIN, followed by a composite questionnaire to assess their subjective experience, which included questions such as perceived device performance, projections of device value for oneself and others, and expected cost for the device. They then repeated these measures for the other condition. After the completion of the repeated measures, the participants were asked for their device preference, a forced choice if they were to purchase a device today, and a projection if they would regret the purchase they chose in 3 months.

Results: A repeated measures ANOVA of the QuickSIN results shows no significant effect of the device label on speech-in-noise performance. Statistical analyses of the subjective measures also shows no significant effect of the device label.

Conclusions: In this study, a priming effect as a result of labeling a hearing aid as "OTC" or "professional" was not found; however, other trends emerged in the data. These trends are not statistically significant, but point to potential avenues of further investigation. These trends are found amongst the outcome measure of purchasing regret and the QuickSIN, which shows a possible detriment to speech-in-noise performance when an experienced hearing aid user switches from personalized hearing aid programming to depersonalized programming (i.e. one's own finely-tuned devices to a standard audiometric fit). In summary, while the priming effect of device labeling was not measurable in this study, the results generated additional research questions for the impact of OTC devices on consumer behavior and hearing performance.

Revisiting Consumer Attitudes towards Direct-to-Consumer Models of Hearing Healthcare

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Objectives: Converting health care solutions available through prescription and licensed providers into Over-the-Counter (OTC) products or services is a common strategy to reduce cost and improve access. Hearing healthcare has recently undergone this transition with the introduction of OTC hearing aids, paving the way for direct-to-consumer (DTC) hearing healthcare models. Although research has explored the feasibility of these DTC pathways, little is known about consumer attitudes and opinions of these non-traditional hearing healthcare models. In fact, understanding consumer attitudes towards DTC hearing healthcare can aid in the optimization of these models by identifying perceived limitations of these pathways by the intended user. Using a consumer market research survey, the purpose of the present study was to:(1) identify how changes in the hearing healthcare market may be associated with consumer choice and attitudes towards these DTC hearing

healthcare models, and (2) determine if there are specific target group(s) that are more inclined to consider DTC hearing healthcare.

Design: A 27-item questionnaire was launched online via Qualtrics Survey Panels from March 22nd to 25th, 2022 to US residents only. The questionnaire was developed using findings from semi-structured interviews, and a previous soft-launch of the questionnaire among 300 individuals. All respondents in the present study were 50 years old or older, and not hearing aid owners. Using consecutive sampling, a minimum quota of 1000 completed responses was set, with a maximum of 70% of respondents identifying as white. Respondents who completed the survey at one-half the median response time (or less) was automatically excluded for quality control. Responses were obtained from 1,377 individuals. Three hundred and forty responses were excluded due to study ineligibility, partial completion of survey, and/or poor-quality responses.

Results: The majority of respondents reported discomfort with pursuing hearing aids via DTC pathways, with 84% (874/1,037) indicating they would pursue hearing healthcare via an in-person model. Individuals who were older (OR: 0.95, 95% CI: 0.92 - 0.98), reported an income greater than \$150,000 (OR: 0.29, 95% CI: 0.08 - 0.91), and were not interested in hearing aids (OR: 0.42, 95% CI: 0.23 - 0.79) were less likely to pursue hearing healthcare online. Those who had previous experience with DTC eyeglasses (OR: 1.97, 95% CI: 1.27 - 3.02), and did not have (OR: 2.61, 95% CI = 1.59 - 4.31) or were uncertain (OR: 2.05, 95% CI: 1.13 - 3.70) about their insurance coverage for hearing aids were more likely to pursue hearing healthcare online.

Conclusions: Consumer hesitancy towards DTC hearing healthcare models suggest that these new pathways may not find immediate acceptance. However, DTC market changes in other healthcare fields may aid in the development of consumer trust towards DTC hearing healthcare. In addition, focused public health messaging is necessary to improve consumer confidence in DTC hearing healthcare.

Using an OTC Hearing Device With and Without Audiology Service

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Objectives: Hearing loss is a prevalent condition among older adults. One of the most effective remediation approaches for hearing loss is wearing hearing aids. It is noteworthy, however, that less than one-fourth of people who have hearing loss utilize hearing aids. The lack of accessibility and affordability may cause a low rate of hearing aid use. Therefore, the low cost of over-the-counter (OTC) hearing devices may help address this issue. However, a major problem is that older people may not know how to utilize OTC hearing devices appropriately if audiological services are not available. Furthermore, manufacturer manuals with poor readability and suitability may not be adequate for users to learn how to correctly operate the device. The purpose of this study was to 1) evaluate the acquired knowledge and operational skills, and 2) investigate the hearing-related outcomes among older adults with mild-to-moderate hearing loss who received different levels of instruction for an OTC hearing device. We hypothesized that those who received audiology service would have more knowledge and operational skills when using an OTC hearing device, as well as better hearing-related outcomes, compared to those who followed manufacturer user instructions.

Design: The study used a single-blind, prospective, randomized design. We recruited 85 older adults, and 34 with mild-to-moderate hearing loss were eligible. A total of 30 participants completed the study. Three levels of instruction [original manufacturer's user manual (n = 9), revised optimized written instruction (n = 12), and audiology service (n = 9)] were randomly administered after the assessment of candidacy.

Results: There were no significant differences in knowledge and skills, as well as hearing-related outcome measures, across different levels of instruction. The scores for both knowledge and skills for using the OTC hearing device were comparable across instructional levels. We did not find any main effects for the instructional level when using either acquired knowledge [$F(2,24) = 1.06, p = .36$] or skills [$F(2,24) = 1.36, p = .28$] as the dependent variable in a series of mixed models. Although no significant differences in outcome measures for using the hearing device were identified between different levels of instruction, all the participants received benefits from using the hearing device. A series of paired t-tests revealed that participants had a significant reduction in hearing handicap ($t(29) = 3.36, p = .0022$), a significant improvement in spatial hearing ability ($t(29) = -2.86, p = .0077$), a significant improvement in self-listening efficacy in various daily situations ($t(29) = -2.99, p = .0057$), and a significant improvement in speech recognition in noise both objectively ($t(26) = 2.65, p = .014$) and subjectively ($t(26) = 4.18, p = .0003$). Satisfaction was significantly associated with the knowledge of using the hearing device ($r = .41, p = .03$) but not with the skills ($p = .53$). Different levels of instruction did not result in different levels of satisfaction [$F(2,27) = 0.01, p = .99$].

Conclusions: Older adults with mild-to-moderate hearing loss can benefit from using direct-to-consumer or OTC hearing devices, with and without professional service.

Barriers/Facilitators to Over-the-Counter Hearing Aid Use in People With Dementia

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Objectives: Over-the-counter (OTC) hearing aids are intended to promote affordability and accessibility of amplification with the ultimate goal of increasing hearing aid use in adults with age-related hearing loss. Proponents of OTC hearing aids underscore potential social, emotional, and even cognitive benefits of amplification; however, attainment of hearing aid benefit hinges on effective device use. Evidence suggests that older adults with intact cognition can successfully self-select, program, and manage OTC hearing aids. Undoubtedly well-meaning family members will purchase OTC hearing aids for community-dwelling older adults with cognitive impairment and hearing loss. However, to date, it is unknown whether individuals with cognitive impairment can understand and effectively use OTC hearing aids. The present study is the first phase of a sequential exploratory mixed methods investigation to examine, quantify, and describe the usefulness of OTC hearing aids for older people with cognitive impairment.

Design: Qualitative interviews are conducted to gather stakeholder-perceived barriers to and facilitators of OTC hearing aid use in older adults with cognitive impairment. Stakeholder groups include: 1) community-dwelling older adults with cognitive impairment and hearing loss; 2) care partners of community-dwelling older adults with cognitive impairment and hearing loss; and 3) direct care professionals who work with older persons with cognitive impairment. Interviews are held and recorded via secure Zoom videoconferencing, then transcribed and analyzed in nVivo software following established steps for thematic analysis. From the resulting themes, we identify barriers to and facilitators of effective OTC hearing aid use in older persons with cognitive impairment both within and between stakeholder groups.

Results: Data collection is ongoing (target enrollment is $n = 20$ per group). Reported results reflect thematic analysis of interviews with 10 care professionals, seven care partners, and five individuals with cognitive

impairment. Identified barriers to OTC hearing aid use in older persons with cognitive impairment include hearing aid stigma; care partner stress and burden; reliance on additional technologies such as Bluetooth and smartphone applications; low confidence in the effectiveness of self-programmed hearing aid settings; reduced ability for persons with cognitive impairment to problem-solve and/or troubleshoot technology issues; and difficulty obtaining reliable self-report of sensory symptoms from persons with cognitive impairment. Participants identified affordability and the convenience of reducing or eliminating office visits as the primary benefits of OTC hearing aids for older people with cognitive impairment. Stakeholder-perceived facilitators of effective OTC hearing aid use in persons with cognitive impairment include readily available technical support; concise written instructions with pictures; high-quality instructional videos; care partner self-efficacy for technology use; and high levels of mutual trust between the person with cognitive impairment and their care partner.

Conclusions: Older adults with cognitive impairment face a complex set of challenges when using OTC hearing aids. In order to benefit from OTC devices, these individuals may need specialized instructional modes as well as delivery models and fitting paradigms specifically designed to facilitate effective care partner involvement. A subset of future OTC hearing aids should be tailored and delivered to meet the unique needs of individuals with cognitive impairment and their care partners.

PODIUM SESSION II: HEARING CARE SERVICE DELIVERY AND TINNITUS

Patient Demographics and Hearing Screening in Primary Care Clinics

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Objectives: Despite decades of research documenting sex and racial differences in healthcare utilization in the U.S., few studies have examined how these characteristics influence hearing healthcare. This is an important gap, as hearing loss is one of the most common chronic health conditions in U.S. older adults and untreated hearing loss is associated with numerous negative health outcomes. Drawing on data from a previously conducted multi-site, pragmatic clinical trial, we aimed to examine how the hearing healthcare pathway and the role of primary care provider (PCP) encouragement for improving adherence differ by patient sex and race.

Design: The primary goal of the parent pragmatic clinical trial was to understand what level of PCP involvement is required to encourage older adults (aged 65-75 years) to follow through with routine hearing screening by comparing three settings: a) at-home screening with instructions but no PCP encouragement, b) at-home screening with instructions and PCP encouragement, and c) in-office screening with instructions and PCP encouragement. A total of 660 patients completed the trial, with 220 patients enrolled in each protocol. We used logistic regression models to examine sex and race differences in whether patients a) completed a hearing screening within 60 days of a routine PCP visit, b) scheduled, and c) completed a diagnostic evaluation and, if completed, d) received a hearing loss intervention plan from a hearing healthcare provider. We restricted our analysis to patients who self-identified as Black/African American (n=233) or White (n=394); female (n=402) or male (n=225) (total n=627). Each protocol included roughly one-third of patients (at-home screening with no PCP encouragement n=209, at-home screening with PCP encouragement n=208, in-office screening with PCP encouragement n=210).

Results: There were no significant differences by sex or race in screening failure. There were no significant differences by sex for any other aspect of the hearing healthcare pathway. In terms of race, there were no

differences within the groups that received PCP encouragement (either at-home or in-office), but in the at-home group with no PCP encouragement, Black patients scheduled and completed diagnostic assessment at a third the rate of White patients (20% versus 66.67%, respectively). Logistic regression models show that Black patients had a significantly lower odds of scheduling (OR=0.49, 95% CI=0.28-0.86) or completing (OR=0.50, 95% CI=0.28-0.88) assessments compared to White patients across all groups.

Conclusions: Results from this secondary analysis show that PCP encouragement plays a differential role in improving adherence to the hearing healthcare pathway by race. Specifically, a lack of PCP encouragement in the home-based setting resulted in a significantly lower level of adherence to hearing health follow-through after failed screening among Black patients. In contrast, we found no differences across the three protocols based on sex. Hearing healthcare is increasingly recognized as a public health issue, with national reports issuing calls to increase the affordability and accessibility of hearing healthcare, especially for racial minority groups. Results from the current study suggest that such approaches should take into consideration PCP encouragement as a means for increasing uptake of the hearing healthcare pathway among Black individuals.

Generational Differences in Prevalence of Hearing Loss and Hearing-Aid Use

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Objectives: Evaluate generational differences in the prevalence of audiometric hearing loss, self-reported hearing difficulties, and hearing-aid use in a sample from the general population.

Design: Individuals in this study were participants in the Medical University of South Carolina (MUSC) Longitudinal Cohort Study of Age-Related Hearing Loss (ARHL), an ongoing community-based cohort study of ARHL. The current cross-sectional study used data from baseline examinations. A pure-tone average (PTA) was calculated from thresholds at 0.5, 1.0, 2.0 and 4.0 kHz. The dichotomous outcome measures were audiometric hearing loss (PTA >25 dB HL, better ear), self-reported hearing difficulties (Revised Hearing Handicap Inventory ([RHHI] score >6), and self-reported hearing-aid use. For analyses that evaluated outcomes of audiometric hearing loss and self-reported hearing difficulties, the sample included individuals with complete baseline data for both outcomes (n=1558). A subsample of participants with hearing loss (PTA >25 dB HL, either ear) were included in analyses that evaluated hearing-aid use as an outcome (n=793). The main determinant of interest was generation, defined as Greatest Generation (born 1901-1924), Silent Generation (born 1925-1945), Baby Boom Generation (born 1946-1964), Generation X (born 1965-1984), or Millennial (born 1985-1996). Logistic regression models were used to evaluate associations of generation (referent group: Greatest Generation) with the aforementioned outcomes. All models were adjusted for age and sex, and models evaluating self-reported hearing difficulties and hearing-aid use as outcomes were additionally adjusted for PTA (better ear). Results from preliminary models are presented as odds ratios (OR) with corresponding 95% confidence intervals (95% CI).

Results: Of the 1558 individuals in this sample, 56.9% were female and the mean age was 63.7 (range 18-89+ years). The number (percentage) of participants with audiometric hearing loss defined by PTA and self-reported hearing difficulties defined by RHHI were 793 (49.0%) and 760 (48.8%), respectively. The number (percentage) of hearing-aid users was 319 (40.2%). In age-sex adjusted models, more recent generations had lower likelihood of audiometric hearing loss (Silent: 0.57 [0.40, 0.81]; Baby Boom: 0.52 [0.33, 0.81]; Generation X: 0.26 [0.10, 0.69]; Millennial: 0.54 [0.12, 2.36]). After adjusting for age, sex, and PTA, generation was not consistently associated with self-reported hearing difficulties (Silent: 0.91 [0.64, 1.29]; Baby Boom: 0.88 [0.55, 1.40]; Generation X: 0.75 [0.34, 1.66]; Millennial: 0.22 [0.01, 0.66]). In individuals with

hearing loss, more recent generations had lower likelihood of hearing-aid use in models adjusted for age, sex, and PTA (Silent: 0.64 [0.45, 0.92]; Baby Boom: 0.25 [0.13, 0.45]).

Conclusions: In this community-based sample from the general population, more recent generations were less likely to have audiometric hearing loss, which may be attributed to systematic, population-wide modifications to risk factors of ARHL. Accordingly, estimates of the burden of hearing loss based on PTA should account for these generational changes. There was not strong evidence of generational differences in self-reported hearing difficulties after accounting for audiometric hearing loss. Among individuals with hearing loss, more recent generations were less likely to use hearing aids, which warrants additional research to understand reasons for these declines.

A Large-Scale Study of Progression of Hearing Loss in Australian Children

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Objectives: It is estimated that hearing loss severity progresses in 6 to 56% of children, however, the ability to predict the probability and degree of progression for every child in a clinic is very limited. Knowledge of the nature and degree of progression, and the ability to predict progression for every child will aid counselling parents, assist in determining the frequency of follow-ups for hearing loss monitoring, and facilitate choice of hearing devices. To date, the nature of hearing loss progression and the factors influencing it have been assessed in smaller scale studies within fewer than 500 children. In this study, we make use of the clinical database of Hearing Australia, the Australian government's hearing provider, which services almost all children with permanent hearing loss in Australia. This provides a unique opportunity to study this question in the Australian context and use a big data approach to predict progression of hearing loss in children. Although the high incidence of progressive hearing loss is well-documented, the factors contributing to it are not well known. For example, the evidence regarding the importance of aetiology in predicting hearing loss progression is unclear. The aetiology information available in Hearing Australia's clinical records could help determine whether this is an important factor to consider in hearing loss progression in children.

Design: Clinical data was obtained for 29,705 children (14,315 female, 15,337 male and 37 other/unknown) with hearing loss (>25 dB HL at any frequency) who visited Hearing Australia clinics and who had audiograms recorded on at least 4 occasions. Only audiometric data obtained from ear-specific behavioural testing was included. In addition to audiometric data, demographic details, aetiology (where available), newborn hearing screening outcomes, age at first assessment and device fitting information were extracted. Progression was assessed according to three definitions that have been employed in the literature: ≥ 10 dB change at two adjacent octaves between 500-4000 Hz, ≥ 20 dB change in the three-frequency average hearing loss, or ≥ 10 dB in the four-frequency average. The significance of each variable in predicting progression was assessed using logistic regression models.

Results: The proportion of children progressing varied markedly with the definition employed from 8% to 52%. Although aetiology was unknown in 51% cases, where it was known, it was a significant predictor of progression. Anoxia and CMV were associated with a higher risk of progression and Connexin 26 mutations with lower risk. Progression was significantly more likely for higher initial degrees of hearing loss and for greater age at first presentation. There was no significant effect of asymmetry of hearing loss on progression. Female children were significantly more likely to progress than males, although the effect size was small. Where hearing loss did progress, the average rate of progression in the four-frequency average was approximately 2 dB/year.

Conclusions: Big data reveal smaller effects difficult to detect in smaller scale studies and allows for more accurate prediction of progression on an individual basis.

Advancing Hearing Health Equity for Older Adults: The HEARS RCT

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Objectives: Age-related hearing loss that impairs daily communication is independently associated with adverse health outcomes, but the use of hearing aids by older adults is low and disparities exist. The incorporation of community health worker (CHW)-partnered models, including peer mentors, is an approach that reduces barriers and addresses disparities. Within hearing care, particularly for older adults, CHW-partnered models have received limited study, despite national and international recommendations. The HEARS (Hearing health Equity through Accessible Research & Solutions) intervention was designed as a structured hearing care program delivered by CHWs in a community setting that incorporates provision of a low-cost amplification device with education and counseling on age-related hearing loss. An initial pilot study demonstrated feasibility and acceptability. To assess the efficacy of CHW-delivered hearing care when provided to older adults, a randomized clinical trial was conducted to test the hypothesis that the intervention improves self-perceived communication function 3-months post-intervention compared to waitlist control.

Design: An open label randomized clinical trial was conducted between April 2018 and October 2019 with 3-month data collection completed in June 2020. The trial took place in 13 community sites, including affordable independent housing complexes (n=10), senior centers (n=2), and an older adult social club (n=1) in Baltimore, Maryland. 348 older adults were screened and 151 participants with hearing loss were randomized. Participants were randomized to receive a CHW-delivered hearing care intervention (n=78) versus waitlist control (n=73). The 2-hour intervention consisted of fitting a low-cost amplification device and instruction. The primary outcome was change in self-perceived communication function (Hearing Handicap Inventory for the Elderly-Screening [HHIE-S]) from baseline to 3-months post-randomization. The average treatment effect was estimated using the doubly-robust weighted least squares estimator, which uses an outcome regression model weighted by the inverse probability of attrition to account for baseline covariate imbalance and missing data.

Results: Among 151 participants randomized (mean [SD] age, 76.7 [8.0] years; 101 (67.8%) females; 65 (43%) self-identified as African American; 96 (63.6%) with low income [$<$ \$25,000 annual household income]), 136 (90.1%) completed 3-month follow-up for the primary outcome. In the intervention group, 90.5% completed the intervention session and reported at least 1 hour of daily amplification use at 3-month post-randomization. Self-perceived communication function significantly improved in the intervention group compared with the control group, with an estimated average treatment effect of the intervention of a -12.98 point HHIE-S change (95% CI: -15.51, -10.42). No intervention-related adverse events were reported.

Conclusions: Among older adults with hearing loss, a CHW-delivered personal sound amplification device intervention, compared with a waitlist control, significantly improved self-perceived communication function at 3 months. The improvements were comparable in magnitude to improvements documented for older adults who received conventional clinic-based hearing care with provision of hearing aids by audiologists. To the authors' knowledge, this randomized clinical trial was the first of a CHW-delivered hearing care intervention designed for older adults that included provision of amplification. Furthermore, this trial was the largest trial to date of a hearing care intervention in the U.S. of African American older adults and low-income older adults with hearing loss.

A Genome-Wide Association Study Identifies Shared Genetic Links Between Tinnitus and Health-Related Comorbidities

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Objectives: Tinnitus, the phantom perception of sound, is a prevalent hearing health condition. Epidemiological studies have identified environmental and health-related risk factors for tinnitus. Tinnitus is associated with several comorbid conditions, such as neuropsychiatric, metabolic, and cardiovascular diseases. However, the molecular mechanisms underlying the associations between tinnitus and health-related comorbid factors remain elusive. We hypothesized that shared genetic variability underlying tinnitus and health-related comorbidities could explain their association. The objective of the present study was to identify shared genetic links between tinnitus and health-related comorbidities.

Design: We conducted a genome-wide association study (GWAS) of tinnitus-related distress. We used the UK Biobank database. The sample included in the present study comprised 132,438 individuals reporting European ethnicity with a complete set of phenotype, covariates, and genotype data. The sample included 38525 participants with tinnitus and 26889 participants reporting tinnitus-related distress. The GWAS was conducted on tinnitus and tinnitus-related distress measures using the mixed model, with age, sex, age and sex interaction, noise exposure, music exposure, the first ten principal components of the genome, genotype batch effect, and test site as covariates. To test the study hypothesis, we conducted the enrichment analysis on the GWAS results using FUMA to identify shared genetic links between tinnitus and other health conditions.

Results: A locus (lead SNP: rs71595470) in the vicinity of GPM6A showed a significant association ($p < 5E-8$) with tinnitus, with 19 other independent loci showing suggestive association ($p < E-6$). Tinnitus-related distress was associated with 15 independent loci achieving suggestive significance. The enrichment analysis revealed a shared genetic component between tinnitus and psychiatric traits, such as bipolar disorder, feeling worried, cognitive ability, fast beta electroencephalogram, and sensation seeking. Metabolic, cardiovascular, hematological, and pharmacological gene sets revealed a significant association with tinnitus. Anxiety and stress-related gene sets revealed a significant association with tinnitus-related distress. The GWAS signals for tinnitus were enriched in the hippocampus and cortex, and for tinnitus-related distress were enriched in the brain and spinal cord.

Conclusions: The study provides insight into the genetic processes underlying tinnitus and comorbid conditions. The genetic epidemiology underlying tinnitus could guide the development of prophylactics and therapeutics. Further collaborative efforts are required to investigate the genetic landscape of tinnitus.

A Preliminary Study of Tinnitus Activities Treatment-Online

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Objectives: It is well known that tinnitus has negative consequences on an individual's life. Many patients who are bothered by their tinnitus report problems with sleep and social-functional impairments, emotional wellbeing (e.g., depression, irritability), general health (e.g., dependence on drugs, headaches, and imbalance), and hearing and communication (e.g., an inability to hear television, radio, or environmental sounds). Reactions to tinnitus can be severe, which requires our attention. To address these reactions, we developed counseling programs such as Tinnitus Activities Treatment (TAT) and trained audiologists to implement TAT through in-person intervention at audiology clinics. TAT focuses on the areas most impacted by tinnitus: concentration, thoughts and emotions, hearing and communication, and sleep. TAT uses a collaborative approach with the patient in management of tinnitus and includes picture-based counseling on tinnitus. Coping strategies and sound therapy are also integrated in TAT. However, despite our efforts to provide free tinnitus counseling materials to audiologists and clinicians, patients' access to treatment is limited. Several reasons include the lack of tinnitus counseling services available, the need for multiple clinic visits, and high associated costs of therapy. Therefore, we developed materials for remote delivery of TAT that could be easily accessible by the general public through a website or smartphone App. The purpose of this study was to investigate the preliminary effectiveness of our remote counseling program, TAT-Online, in reducing tinnitus severity and related problems in adults with tinnitus.

Design: We recruited 22 adults with chronic tinnitus to complete this study on TAT-Online using a quasi-experimental, single-subject design. We enrolled 11 males and 10 females who had an average age of 61 years. Participants viewed multiple, video-recorded counseling sessions that included a discussion of the causes, prevalence, and mechanisms of tinnitus, as well as reactions to tinnitus. Participants also completed homework to practice the strategies in the videos. The program was self-paced with quizzes at the end of each weekly module and intended to take 6 weeks of total time. Lastly, participants completed questionnaires on tinnitus, tinnitus severity, and quality of life at three intervals: before, during, and after the counseling program.

Results: Participation in TAT-Online study was very good with only one dropout in the study. Based on the outcomes of several tinnitus questionnaires, our study population had less bothersome tinnitus than a typical clinical population of tinnitus patients. Additionally, results from the Tinnitus Primary Functions Questionnaire revealed that concentration was affected more than thoughts and emotions. For participants with bothersome tinnitus, ratings on the Tinnitus Primary Functions Questionnaire indicated a reduction in tinnitus severity for several subscales.

Conclusions: Our preliminary results indicate that remote counseling for tinnitus using videos and self-paced materials is received well by people with tinnitus who would like to learn more about tinnitus and how to manage it. For participants who have bothersome tinnitus, we observed a reduction in tinnitus severity for certain areas affected by tinnitus. Feedback from individual participants was that the information in the sessions was interesting and beneficial with practice.

PODIUM SESSION III: SPEECH TESTING, PROCESSING AND PSYCHOACOUSTICS

Audiometric Variables that Influence Speech Recognition in Quiet and Noise

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Objectives: Difficulties understanding speech in noise are perhaps the most common complaint of individuals with hearing loss. While speech in noise abilities generally decrease as the degree of hearing loss increases, previous research has demonstrated that the audiogram alone is relatively poor at predicting how well an individual patient can understand speech in noise, or how well they perceive their ability to communicate in daily life. Such investigations generally use some measure of pure-tone average as their metric for determining the degree of hearing loss. While this provides a general measure of hearing acuity, PTA-based measures fail to consider the configuration of the audiogram, nor do they consider hearing at low and high frequencies that fall outside of the PTA calculation but may still facilitate speech recognition. Here we address this issue by examining the ability of two metrics, Speech Intelligibility Index (SII) and audiometric configuration, to predict speech recognition performance in quiet and noise while controlling for type of hearing loss.

Design: Data were obtained retrospectively from 10982 patients who underwent audiometric assessment at Stanford University. Each of these patients completed pure-tone audiometry, NU-6 word recognition in quiet (WRQ) and the QuickSIN in each ear. All tests of speech recognition were presented at a minimum of 70 dB HL, or at higher levels designed to maximize audibility for their hearing loss. We then classified each audiogram according to the type of hearing loss (conductive, mixed, sensorineural, or normal hearing), and the configuration of pure-tone thresholds commonly described by clinicians and scientists (sloping, flat, rising, and so on). Finally, we obtained the SII for each patient using their audiometric thresholds and the presentation level used for their tests of speech recognition.

Results: While preliminary, our results suggest that many patients possess audiometric configurations that do not match those commonly defined in audiologic textbooks. More importantly, our results suggest that once the type of hearing loss has been accounted for, audibility, as defined by the SII, accounts for more of the performance variation in both quiet and noise than the audiometric configuration. SII is particularly effective at accounting for variation in word recognition scores in quiet. However, there remains significant unexplained variation in the QuickSIN SNR loss across patients.

Conclusions: Taken together, these results suggest that audibility, as determined by the SII, provides additional information which is not accounted for by audiometric configuration or commonly used PTA-based measures. In most patients, word recognition scores in quiet could be largely predicted by the SII, suggesting that audibility is the primary driver of performance in these patients. In contrast, there was a greater amount of variation in QuickSIN SNR losses that could not be explained by audibility alone as predicted by the SII. This emphasizes the need for tests of speech recognition that are more sensitive to other variables that may contribute to recognition of speech in noise, such as poor peripheral encoding of a signal, or central factors related to executive function.

Identifying Latent Factors Linked to Individual Differences in Speech Recognition

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Objectives: Many research studies seek to link individual differences in speech recognition accuracy to various underlying factors, such as cognitive ability. A common approach to data analysis in these studies is to report correlations of summary measures of performance across tasks, but the interpretation of such correlations

critically depends on assumptions about how these measures map onto underlying factors of interest. As an alternative, this work evaluates the use of latent factor models fit to trial-level data from multiple experimental tasks as a method of testing competing hypotheses about the underlying structure that accounts for apparent relationships between different tasks. This method was evaluated on its ability to test hypothesized latent factor models against one another and estimate individual differences in those factors across participants.

Design: Latent factor models were fit to trial-level data from two experiments. In the first experiment, young adults with normal hearing (N = 48) listened to and repeated sentences that were presented in adverse listening conditions, including time compression, vocoding, in the presence of two competing talkers, and spoken by talkers with non-native accents. In the second experiment, young adults with normal hearing (N = 52) completed three working memory tasks (reading span, digit span, and free recall) and speech recognition for sentences that were mixed with competing speech and vocoded. In both experiments, trial-level data were fit using Bayesian parameter estimation with models that predicted the probability of correct responses in each task as the sum of individual differences in each latent factor scaled by the amount that factor contributes to performance of each task. This approach allowed us to dissociate latent factors from their contribution to task performance, which enabled tests of the likelihood that any hypothesized factor had a significant impact on performance in each task.

Results: In experiment 1, a model which included a latent speech recognition factor that varied across participants and affected recognition in every adverse condition was a better explanation for the data than a model which did not include such latent factors. This finding demonstrates that young adults with normal hearing show meaningful variation in speech recognition accuracy. In experiment 2, a model which split working memory task performance into two factors, one of which was general across memory tasks and one of which was specific to long lists in the digit span task, was a better explanation for the data than a model which included only a single global factor. This finding indicates that the structure of individual differences in cognitive task performance is not always evident from task design. In both studies, individual differences in latent factors across participants were well-differentiated and reliable.

Conclusions: Bayesian model fitting provides the flexibility to test hypotheses about the latent factors that explain trial-level task performance against one another. This approach to data analysis enables articulating the link between speech recognition accuracy and other latent factors as a set of mathematical equations that predict trial-level performance, which would advance the field by providing precise and falsifiable representations of theoretical models.

Experience with the Adaptive Everyday Word Test

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Objectives: Fixed length word recognition (WR) tests, whether in quiet or noise, become increasingly less reliable as scores approach 50% or when short word lists are used. Low WR scores may adversely influence clinical decision-making. Test reliability can be improved by using longer word lists at a cost of increased test time. However, wordlist length is typically capped at 50 words. To solve this dilemma, we developed the Adaptive Everyday Word Test (aEW). The aEW consists of 20 digitally recorded lists, each containing 15 words. The words are presented three words at a time, shortening test time. The lists can be added together while testing, making lists of more than 50 words feasible. WR testing stops when the binomial standard deviation estimate reaches an a priori reliability criterion. Thus, aEW scores have uniform reliability regardless of the final score. We compared the performance of the aEW test to standard fixed wordlist length NU-6 or W-22 tests in a representative clinical sample. We specifically wanted to determine if the aEW saved test time,

and how well aEW, NU-6, and W-22 scores compared to Speech Intelligibility Index (SII) based predicted WR performance. We reasoned that if aWR scores compared less favorably to SII predictions, the test should not be used.

Design: A total of 900 audiometric records from individuals with age- or noise-related hearing loss seen at the Mayo Clinic Jacksonville between 2015 and 2017 were selected. The aEW test was used in 524 cases (mean age: 62.02 yrs., standard deviation: 15.02 yrs., 49.8% female), and the remaining 376 cases used either 25-word half lists for the NU-6 or W-22 tests (mean age: 67.05 yrs., standard deviation: 15.32 yrs., 43% female). WR test times were calculated for aEW cases and compared against W22 benchmark test times. Simple linear regression was used to compare observed aEW, NU-6 and W-22 scores from each ear to speech intelligibility index-based predicted WR scores for the measured audiogram.

Results: Test time: The average test duration for one 25-item W-22 was 84 seconds. The average aEW test time was 91 seconds, 7 seconds longer than the 25-item W-22. However, W-22 scores that fell between 88% and 12% would be less reliable than aEW scores. The aEW would save over 1 minute/word list relative to the 50-item W-22. W-22 scores would be less accurate when they fell between 70% and 30%. **SII prediction:** The R2 for the regression between aEW and SII score was 0.54 and 0.59 for the right and left ears, respectively. For 25-wordlist-based scores, the R2 was 0.27 and 0.28 for the right and left ears, respectively. **Observation:** Two individuals could not reliably recall three-word tokens during the aEW test. They were subsequently found to have early dementia.

Conclusions: The aEW test appears to improve WR accuracy and decrease test time. Arcsine transformations are not required to compare two aEW scores. Ultimately, the aEW test empowers clinicians to deliberately control WR test accuracy, which should improve subsequent clinical decision-making.

Audiovisual Speech Cues Facilitate Children's Recognition of Degraded Speech

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Objectives: Listeners use phonotactic knowledge to anticipate word identity as they process speech input in real time. Acoustically degrading speech disrupts this processes, resulting in slower and oftentimes inaccurate speech recognition. In adverse listening situations, adult listeners leverage their ability to integrate audiovisual speech to improve word recognition accuracy. The purpose of this study is to quantify the extent to which school-age children with normal hearing and children who have hearing loss can leverage the same audiovisual cues. Because visual speech cues can disambiguate acoustically degraded speech, even at the phonemic level, we hypothesize that access to audiovisual speech cues promote word recognition in children. To test this hypothesis, we are implementing a word-gating task, whereby children are asked to recognize target words when provided with partial phonetic content. We predict that children will require fewer gates of phonetic content to recognize acoustically degraded words when they have access to coincident visual speech cues.

Design: Sixteen school-age children aged 6-10 years were recruited to complete an audiovisual and auditory-only gating task. The target speech stimuli were low-predictability sentences ending in a disyllabic target word. A native-English speaking female with a midwestern dialect produced all stimuli while she was audio- and video-recorded. The final words of each sentence were temporally divided into 5 gates that contained subsequently more phonetic content: phonological onset, +100 ms, +200 ms, +300 ms, and the whole word. Children with normal hearing were assigned to either a control condition, whereby speech was presented with full spectral resolution, or a degraded speech condition, whereby speech was noise-band vocoded into eight

spectral channels. Children with hearing loss were assigned to the control condition. Within a condition, participants were presented with an equal number of auditory-only and audiovisual trials. Target words were counterbalanced across the auditory-only and audiovisual modalities so that each participant heard each target word in only one modality. Trials were blocked by gate, with earlier gates preceding later gates. Data are summarized by recognition accuracy of the target words at each temporal gate.

Results: Children with normal hearing recognized words with less phonetic information (i.e., fewer gates) in the control versus the degraded speech conditions, consistent with the idea that spectral degradation slows incremental processing of words. In the degraded speech condition, children were more successful at recognizing words when they had access to audiovisual speech cues, suggesting that coincident audiovisual speech facilitated word recognition. There was no benefit of audiovisual speech cues in the control condition. Children with hearing loss had similar performance to children with normal hearing who were assigned to the degraded condition.

Conclusions: When the acoustics of speech are disrupted by spectral degradation or hearing loss, audiovisual cues may facilitate word identification in school-age children.

Effects of Interaural Asymmetry and Spread of Excitation on Fusion

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Objectives: The combination of information at the two ears resulting in the perception of a singular auditory percept is referred to as binaural fusion. The stimulation received by bilateral cochlear implant (CI) users sometimes fails to foster binaural fusion, particularly when there is a large interaural asymmetry in the place of stimulation. It is not clear what underlies inter-individual differences regarding the effects of interaural asymmetry on binaural fusion. It is hypothesized that broader spread of current in the cochlea will minimize the effects of interaural asymmetry on binaural fusion. The goal of this study was to assess, for CI users, the extent to which the degree of interaural asymmetry affects binaural fusion and whether that can be predicted by spread of current in the cochlea.

Design: Seven bilateral CI users participated in the two experiments:(1)Binaural fusion: Bilateral CI users were presented with 1000Hz pulse trains. The interaural correlation of the envelopes of the pulse trains were altered to manipulate the interaural correlation of the signal. In order to manipulate interaural asymmetry, stimulation was delivered by pairing, separately, one electrode from one ear with several different individual electrodes from the contralateral ear. Listeners indicated the spatial diffuseness of the sound they perceived and whether they perceived a unitary auditory "image" or two auditory images by rotating a dial to manipulate a visual representation of their perception superimposed on a picture of a head. The effects of interaural asymmetry were assessed by determining the optimal interaural electrode pairing (i.e. the pairing yielding the most fused sound) and then analyzing the change in fusion with increasing distance from that optimal interaural electrode pairing.(2)Spread of excitation: Current spread was estimated using the forward-masking subtraction method to generate spread-of-excitation (SOE) functions by measuring electrically evoked compound action potentials (eCAPs) in response to stimulating different probe and masker electrodes.

Results: Preliminary results show that a subset of participants exhibited a clear effect of interaural asymmetry on binaural fusion, where binaural fusion decreased with increasing interaural asymmetry. The area under the

normalized SOE function was compared with the change in fusion across interaural electrode pairings. SOE was not predictive of the perceptual consequences of interaural asymmetry.

Conclusions: In summary, the results did not indicate that there is a strong relationship between SOE and the effects of interaural asymmetry on binaural fusion. This may indicate that the signal is being transformed along the auditory pathway, minimizing the effects of SOE. This also may reflect the relatively small sensitivity to interaural asymmetry for binaural fusion compared to other binaural tasks such as interaural time difference sensitivity.

Cochlear Synaptopathy in Service Members with Self-Reported Temporary Hearing Loss

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Objectives: The goal of this study was to analyze the relationship between hearing thresholds, subjective hearing complaints, objective measures of hearing performance and self-reports of noise exposure history in a large cohort of US Service Members (SMs).

Design: A cohort of approximately 12,000 SMs was recruited to complete a series of questionnaires and listening tasks in conjunction with their annual hearing test requirement. Data collected from each participant included pure-tone audiometric thresholds, performance on a 500 Hz binaural tone-in-noise detection task (NoS π), a 4-question survey of self-reported hearing handicap (derived from the Tinnitus and Hearing Survey [THS]), and a 2-question survey asking how frequently participants had noticed a change in their hearing after exposure to a loud noise (Temporary Threshold Shift [TTS]). Lastly, speech intelligibility was measured on a subset of participants using the Modified Rhyme Test (MRT).

Results: The large cohort size made it possible to plot the dependent variables as a function of exact value of the better-ear threshold at 4 kHz. Results showed that THS scores and NoS π detection systematically decreased over the entire range of Normal Hearing (NH), from -10 dB HL to +20 dB HL. In addition, by plotting THS and NoS π results as a function of TTS it is apparent that individuals who never report experiencing a hearing change after noise exposure (~35% of the sample) have substantially better hearing performance than individuals who report having TTS a few times in their lifetime (~55% of the sample), and individuals who report TTS more than once per year (~10% of the sample) have much worse hearing performance than other NH listeners. Results from the MRT suggest that speech intelligibility (percent correct) does not change with hearing threshold in the NH range, but response time systematically increases with threshold for NH individuals who have a history of TTS.

Conclusions: The data from this study suggest that all individuals with NH thresholds should not be treated as a homogenous group because significant deficits in hearing performance may occur before hearing thresholds exceed 20 dB HL. The data also indicate that TTS is a significant risk factor for developing hearing difficulties even in cases where hearing thresholds remain in the NH range. This result has major implications for hearing conservation programs that focus exclusively on permanent threshold shifts. Importantly, this study included explicit questions about an individual's lifetime history of noticeable TTS, compared to most previous work that has focused on questionnaires designed to capture lifetime noise exposure history. The results of this study may indicate that there are differences in individual susceptibility that cause different listeners with the same lifetime noise exposure history to have different hearing outcomes. **DISCLAIMER:** The views expressed in this abstract are those of the author(s) and do not necessarily reflect the official policy of the Department of Defense or the U.S. Government.

PODIUM SESSION IV: ELECTROPHYSIOLOGY AND DIAGNOSTICS

Effect of Extended High-Frequency Hearing on Cochlear and Brainstem Function

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Objectives: Many individuals have hearing loss in the extended high frequencies (EHFs) despite having clinically normal audiograms. Recent work suggests that EHF hearing loss is associated with subtle cochlear dysfunction in the standard frequencies, as measured by distortion product otoacoustic emission (DPOAEs). DPOAEs, according to the dual-source model, are the vector sum of distortion and reflection components. In contrast, stimulus-frequency OAEs (SFOAEs), recorded at a low-probe level, are frequency-specific and represent reflection-source OAEs. The extent to which EHF hearing can affect SFOAEs in the standard frequencies is unclear. In addition, it is unknown whether cochlear deficits associated with EHF hearing loss have any consequences on subsequent brainstem functioning. The goals of this study were to (1) examine the relationship between EHF hearing and SFOAEs recorded at standard frequencies, (2) examine the relationship between EHF hearing and auditory brainstem responses (ABRs), and (3) test the extent to which SFOAEs contribute to ABR outcomes. The central hypothesis is that EHF hearing is a marker of subclinical deficits in the standard frequencies.

Design: Otologically-healthy individuals with clinically normal audiograms were enrolled in this study (17-39 years; n=45). In addition to standard audiometric frequencies, thresholds were measured at 10, 12.5, and 16 kHz. SFOAEs and ABRs were measured from both ears of all participants. SFOAEs were recorded using a suppressor paradigm with a probe (40 dB SPL) and suppressor tone (60 dB SPL). The suppressor frequency was 47 Hz lower than the probe frequency. SFOAE level and noise floor were estimated at 1, 2, and 4 kHz. ABRs were recorded for 2048 sweeps with 80 dB clicks at 11.1/s and 90.1/s rates. Absolute and interpeak latencies and absolute amplitude and amplitude ratios for waves I, III, and V were obtained for analyses.

Results: Out of 45, 17 individuals had EHF hearing loss (>20 dB HL at any EHF; bilateral loss= 13). Partial correlation, controlling for age, showed a significant relationship between pure-tone averages for standard frequencies and EHF. The pure-tone average for EHF was related to the SFOAE level and SNR even when age and pure-tone average for standard frequencies were adjusted. Initial analyses showed no relationship between the pure-tone average for EHF and ABR measures except for the wave I/III ratio at the 11.1/s rate. The effect of individual EHF thresholds on SFOAEs, ABR, and their interactions are currently being analyzed.

Conclusions: Poorer EHF hearing is associated with higher thresholds in the standard frequencies. In addition, hearing in the EHF is related to the outer hair cell integrity at the standard frequencies. Contributions of SFOAEs to the observed ABR outcomes will be discussed. Overall, initial results suggest that poorer hearing in the EHF is associated with subtle deficits in cochlear and brainstem processing. These findings have implications for understanding the mechanisms for perceptual deficits experienced by listeners with EHF hearing in the presence of normal audiograms.

Substance Misuse: Effects on Auditory and Vestibular Function

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Objectives: There are very few cohort-based studies assessing the effects of substance misuse on the auditory or vestibular systems. None have comprehensively assessed both peripheral and central audiological and vestibular function within the same subject group. The goal of this project is to comprehensively evaluate hearing and vestibular function in adults who misuse illicit drugs, prescription opioids, and/or alcohol. It was hypothesized that individuals who chronically misuse substances (with or without experiencing overdose) would exhibit hearing loss in the extended high-frequency (EHF) range, consistent with typical manifestations of ototoxicity. Furthermore, it was hypothesized that permanent central and/or peripheral vestibular damage would exist, with the severity likely influenced by substance type or duration of use.

Design: Participant inclusion criteria were adults 19-59 years of age with a history of chronic use (six months or more) of illicit drugs, prescription opioids, and/or alcohol. To date, we have collected data for 48 participants (goal = 60). Participants completed a detailed health- and use-history questionnaire, the Montreal Cognitive Screening (MoCA), tympanometry, standard and EHF pure-tone audiometry, EHF distortion-product otoacoustic emissions (DPOAEs), high-level click auditory brainstem response (ABR) testing, sentence recognition in noise using the BKB-SIN test, vestibular bedside, oculomotor testing, video head impulse testing (vHIT), cervical and ocular vestibular evoked myogenic potentials (cVEMP and oVEMP), clinical dynamic visual acuity, and a standing balance test.

Results: Results thus far indicate mean MoCA scores were below passing, with primary deficits on memory-related items. Audiometric thresholds in the standard and EHF ranges were on average 10 dB and 20 dB poorer, respectively, than a healthy comparison group. DPOAEs and group differences were consistent with the audiometric thresholds. ABR wave III and V amplitudes and latencies were consistent with published age-matched data. Mean speech understanding in noise was ~2 dB poorer than published age-matched data. Oculomotor abnormalities, particularly abnormal smooth pursuit, suggest central vestibular dysfunction in approximately 40-44% of participants. A higher absent VEMP response rate was observed (11% for cVEMP and 29% for oVEMP) as compared to published age-matched data; however, when present, mean VEMP peak-to-peak amplitude results were comparable to adult normative data as well as mean vHIT gain, reflecting normal high-frequency otolith and semicircular canal function, respectively. Functionally, 64% of participants failed a tandem stance, suggesting a high risk of fall in a substance misuse population. Impacts of substance type and duration of use will be evaluated.

Conclusions: Results to date suggest negative impacts to hearing, vestibular, and balance function. Given the reduced cognitive test results and the link between hearing loss and cognitive decline, the present results potentially warrant the inclusion of questions about substance misuse in the otologic and audiology case histories, frequent diagnostic monitoring, and increased urgency for management of hearing loss. Similarly, central vestibular dysfunction increases the risk of falls, head trauma, and potentially reduced physical independence in adults who misuse substances. These results suggest consideration for implementing vestibular/balance screenings and accessible interventions in this vulnerable population. Future analyses will address potential differential effects on hearing and vestibular/balance by substance type, duration, and other health factors.

Optimal ASSR Stimulus Repetition Rates in Normal and Hearing-Impaired Infants

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Objectives: Since the introduction of newborn hearing screening, it is performed routinely in newborns to detect hearing loss. Objective measures, such as auditory steady state responses (ASSR), are often used in the screening and to determine the hearing loss after a failed screening. In the Eclipse® (Interacoustics A/S, Denmark) device, standard repetition rates around 90/s are used together with frequency-specific chirp stimuli centered at 500, 1000, 2000, and 4000 Hz, respectively (the narrow-band (NB) CE-Chirps). Detection of a response is done by means of an automatic detection algorithm, which evaluates harmonics of the stimulus-specific repetition rate. This study investigates if the current ASSR measurement method can be improved by choosing repetition rates individually for the four NB CE-Chirps among the 20, 40, 65, and 90/s ranges. This is investigated by measuring NB ASSRs in infants using insert phones with two different combinations of the four stated repetition-rate ranges. It is expected that group mean ASSR detection times, detection rates, and signal-to-noise ratios (SNR) will be dependent on the repetition rate and NB stimulus' center frequency. We hypothesize that lower centre-frequency stimuli will have the same or lower detection times / higher detection rates / higher SNR for lower stimulation rates. For higher centre-frequency stimuli similar trends are expected for higher stimulation rates. Reduction in ASSR detection time and increase in detection rates can be explained in terms of increases to SNR that might occur in either the fundamental or any of the higher harmonics of the stimulus repetition rate.

Design: ASSR measurements were performed in 20 normally hearing and 15 hearing-impaired infants aging from three to 12 months. Both ears were tested simultaneously using NB CE-Chirps. The stimulus level for the normally hearing infants was 40 dB nHL while for the hearing-impaired infants individualized levels of 10 dB SL (sensation level) were used. In the low frequencies (500 and 1000 Hz) the repetition rates of 20/s, 40/s, 65/s, and 90/s were tested while in the high frequencies (2000 and 4000 Hz) only the repetition rates of 65/s, and 90/s were tested.

Results: Results were analyzed separately for each stimulus frequency in terms of the number of successful detections for each repetition rate tested. For the normally hearing infants, significant differences were found for the 1000-Hz frequency band, where using 65/s lead to more detections than the 20/s and 40/s rates; and in the 4000-Hz frequency band, where using 90/s lead to more detections than any of the lower repetition rates. For the hearing-impaired infants, significant differences were found for the 500-Hz frequency band where 40/s lead to more detections than 90/s; for the 1000-Hz frequency band where 40/s lead to more detections than 20/s; and finally at 2000 Hz where one of the two 65/s was better than the other and the two repetition rates near 90/s.

Conclusions: We recommend using lower repetition rates like 40/s when stimulating in the low center frequencies (500 and 1000 Hz) and 65/s or the standard of 90/s for the higher center frequencies (2000 and 4000 Hz).

Extended High Frequency Thresholds, Otoacoustic Emissions, and Medial Olivocochlear Reflex

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Objectives: The purpose of this study was to investigate hearing thresholds at extended high frequency range (EHF) and their possible relationships with transiently evoked otoacoustic emissions (TEOAEs), spontaneous otoacoustic emissions (SOAEs), and medial olivocochlear reflex (MOCR) as evaluated by the inhibition of TEOAEs by contralateral noise.

Design: Study group consisted of 40 adults with normal hearing. TEOAEs were recorded with a linear protocol (identical stimuli), a constant stimulus level of 65 dB peSPL, and contralateral broadband noise (60 dB SPL) as a suppressor. TEOAE response levels, signal-to-noise ratios (SNRs), raw dB TEOAE MOCR, normalized TEOAE MOCR, and latency were investigated. Each subject was tested for the presence of SOAEs using the synchronized SOAE (SSOAE) technique. EHF was evaluated at: 9, 10, 11.2, 12.5, 14, and 16 kHz.

Results: The response levels of TEOAEs correlated significantly with the hearing thresholds from the standard frequency range and did not correlated with EHF thresholds. MOCR on the other hand did not correlated with thresholds from the standard frequency range but correlated significantly with EHF thresholds. The better the EHF thresholds - the higher MOCR. Additionally, the number of SSOAEs correlated significantly with EHF thresholds and MOCR. The higher the number of SSOAEs the lower EHF thresholds and MOCR. Finally the MOCR was higher when the latency of MOCR changes in TEOAE was higher.

Conclusions: The MOCR as evaluated by TEOAEs seems to be related to the hearing in EHF. Studies available in the literature indicate that EHF and MOCR are related to similar aspects of auditory processing (e.g., localization or understanding speech in noise). Therefore, the association of these two measures appears not to be coincidental. However, whether indeed the MOCR and EHF portion of the auditory pathway modulate certain auditory processing abilities requires further more detailed research.

Efferent Functioning Following Resolved Otitis Media

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Objectives: Auditory experience plays a critical role in hearing development. Developmental auditory deprivation due to otitis media produces long-standing changes in the central auditory nervous system, even after the middle ear pathology is resolved. The effects of sound deprivation due to otitis media have been mostly studied in the ascending neural system but remain to be examined in the descending auditory pathway that runs from the cortex to the cochlea via the brainstem. However, alterations in the efferent neural system could be important because the descending olivocochlear pathway influences the neural representation of acoustic transients in noise in the afferent auditory system and is thought to be involved in auditory relearning following injury. The main objective of the present study was to examine the involvement of the medial olivocochlear efferents in reduced perceptual masking associated with auditory deprivation due to otitis media.

Design: Typically-developing children aged between 5 and 13 years participated in this study. Hearing thresholds, wideband absorbance, and stimulus frequency otoacoustic emissions (SFOAEs) were tested to enroll the participants. Contralateral inhibition of SFOAEs and speech-in-noise recognition in children with a medical history of otitis media (N= 76) and age-matched controls (N= 99) following a case-control design. Analysis of covariance with the group as a fixed factor and age as a covariate was used to compare groups. Linear regression was used to model speech-in-noise-recognition.

Results: The efferent inhibition of OAEs was significantly lower in children with a documented history of otitis media relative to controls (effect size= small). In addition, children with otitis media history required a more advantageous (2 dB) signal-to-noise ratio than controls to achieve the same criterion performance level. Importantly, the speech recognition threshold was related to efferent inhibition in children with otitis media history. These effects could not be attributed to the middle ear or cochlear mechanics, and these effects were observed even when there was no middle ear pathology at the time of experimentation.

Conclusions: The current study demonstrates dysfunction in the efferent neural feedback circuitry as a long-term consequence of otitis media complementary to an otherwise extensive literature that predicts perceptual effects of auditory deprivation due to central auditory degeneration.

Ears Rumble, But Which Muscle Takes the Volitional Tumble?

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Objectives: About 50% of us have the remarkable ability to voluntarily contract our middle ear muscle(s) creating a 'rumbling' in the ear. This act, called "ear rumbling", is thought to be driven by the tensor tympani muscle contraction. In the sound-evoked middle ear muscle reflex (MEMR), however, the stapedius muscle is the dominant driver. It may thus be possible that real-world listening, especially while talking/chewing, may be influenced by both middle ear muscles. Audiological tests only examine the sound-evoked MEMR; the acoustic influence of the tensor-tympani on middle ear sound transmission, and its interactions with the stapedius muscle, are virtually unknown. Our objective is to parse the acoustic consequences of the stapedius from the tensor-tympani muscle at the eardrum.

Design: Twenty-five normal-hearing adult volunteers, who were able to voluntarily contract their middle ear muscle(s), participated in the study. The voluntary contraction was verified by visual examination. We employed a double-dissociation paradigm with two manipulations: (1) voluntary MEM activation, i.e., rumble, in a go/no-go task, and (2) reflexive activation with varying stimulus levels [55/85 dB peak-to-peak (pp) SPL]. Bandlimited (0.8-4.2 kHz) clicks, as two-second-long trains at 80 Hz, presented bilaterally, both monitored and elicited the reflex acoustically. Click levels were chosen such that MEMR was not elicited acoustically at the lower level but most certainly elicited at the higher level. Clicks were generated in the frequency domain and flattened at the eardrum based on individual forward pressure level calibration. The click train was bookended either by "go/stop" voice prompts, during the go task, or their phase scrambled versions, during the no-go task. For the go task, participants were asked to "rumble" as soon as they heard the voice prompt "go" and stop rumbling as soon as they heard the prompt "stop". Participants were asked to refrain from rumbling in the no-go condition. Clicks were separated into seven 1/3rd octave frequency bands and the change in ear canal pressure (CEP) was tracked over the two-second period. A two-term exponential model was fit to the CEP over time to characterize frequency-specific response kinetics.

Results: Preliminary results show that the no-go/55 dB condition did not elicit any CEP as expected and will serve as the baseline. In the no-go/85 dB condition, 24/25 participants demonstrated robust CEP kinetics, i.e., change over time. Here, only the stapedius muscle is thought to have played a role. In the go/55 dB condition, 18/25 participants demonstrated robust CEP kinetics like no-go 85 dB. Finally, the go/85 dB condition shows variable and individual specific change (from no-go 85 dB) suggesting complex effects of both muscles being contracted concurrently.

Conclusions: Our results suggest that tensor-tympani influence signal transmission through the middle ear. When both middle ear muscles are activated, complex and individualized activity patterns are observed. Our results, possibly for the first time, show non-invasive dissociation of the two middle ear muscle activities. These findings are important for clinical, research, and modeling purposes that typically do not consider a tensor-tympani role in human hearing.

Therapeutic Benefit of Acute Mild Hypothermia Applied Following Non-Neuropathic Noise

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Objectives: WHO estimates suggest that ~6% of the world's population have disabling hearing loss; a statistic expected to increase with the rise in hazardous recreational or occupational noise exposures. Even low-to-moderate noise exposures can cause early cochlear synaptopathy without permanent shifts in hearing (also termed hidden hearing loss). This synaptopathy has been shown to hasten auditory nerve fiber degeneration and has been linked to age-related neurocognitive impairment. Unfortunately, there are no FDA-approved interventions for NIHL and prevention strategies primarily rely on suboptimal hearing protection devices. We have developed a non-invasive, non-pharmacological intervention strategy utilizing acute, localized mild therapeutic hypothermia (MTH) delivered to the inner ear. Here, we present comprehensive results from a preclinical model highlighting the benefits of MTH for protection of residual hearing and synaptopathy even when hypothermia is applied post-noise exposure.

Design: Male and female Brown Norway rats aged 15-20 weeks were screened for normal hearing thresholds and randomly separated into four groups: (1) Normothermic NIHL, (2) MTH-treated NIHL, (3) MTH Control (safety) and (4) Normothermic Control. The NIHL groups were exposed to a two-hour continuous 4-8 kHz noise-exposure at 105 dB inducing temporary changes in hearing. Localized cochlear induction of MTH (31-33°C) was achieved using a custom-developed cooling system in MTH groups for a two-hour period starting 15 minutes post-noise. Changes in auditory brainstem response (ABR) thresholds from baseline (pre-trauma) were compared across groups at multiple time-points up to 12 months post-noise. Cochleae from long-term experiments were harvested for immunohistological assessment of the hair cells and auditory nerve. In a separate set of male animals, cochleae were harvested at 24 hours post-noise for both NIHL groups and unexposed Normothermic Control animals (1,2,4) for RNA-sequencing. Differential gene expression analysis between the three groups was performed to gain insights into the mechanisms of MTH neuroprotection.

Results: MTH was safe, and did not impact hearing thresholds, animal behavior or mortality. Both NIHL groups showed significant temporary changes in hearing ($p < 0.001$) with reduced shifts (~15 dB) and earlier recovery to baseline levels (~14 days) observed for MTH-treated NIHL animals. Irrespective of biological sex, normothermic controls demonstrated significantly higher threshold shifts compared to MTH-treated animals. Immunohistochemistry of paired synapses and spiral ganglion count suggest beneficial effects of MTH. Differential gene expression results indicate noise-induced upregulation of inflammatory and apoptosis-related genes at 24 hours post-noise. KEGG pathway analysis of the three groups suggests that MTH-treatment significantly downregulates cytokine-signaling pathways compared to Normothermic NIHL animals.

Conclusions: Non-pharmaceutical localized induction of mild therapeutic hypothermia in the inner ear is a feasible, safe, and efficacious neuroprotective intervention following non-neuropathic noise exposure. MTH likely provides significant protection to cochlear structures via downregulation of inflammatory and apoptotic pathways.

The Diagnostic Utility of Cervical Vestibular Evoked Myogenic Potential as an Indicator of Vestibular Noise Injury

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Objectives: Chronic or repeated exposure to noise results in long-term and irreversible damage to the auditory and vestibular system which has been associated with a number of chronic health conditions in ageing adults such as imbalance and cognitive decline. Adults with noise-induced hearing loss have higher rates of imbalance and are more likely to experience falls. Animal models provide increasing evidence of noise-induced damage to the vestibular system, with the saccule being a primary point of injury. Yet, noise-induced vestibular loss (NIVL) remains an understudied despite the clear anatomical links and vestibular impairments that have been demonstrated in noise exposed adults. There exists a need for sensitive clinical tools to detect cochlear noise injury in at-risk populations. Cervical vestibular evoked myogenic potential (cVEMP) testing is a technique to measure the response arising from the saccule and the inferior branch of the vestibular nerve evoked by an auditory stimulus and measured from the sternocleidomastoid muscle. As an objective measure vestibulocollic pathway and saccular function, the cVEMP has received increasing attention in noise injury. The aims of this study were to explore the diagnostic utility of cVEMPS as an indicator of vestibular noise injury in an at-risk population

Design: Saccular function was assessed in 90 noise-exposed firefighters using cVEMP using the IHS SmartEP system and a two-channel electrode montage, with sound delivered through an insert headphone. The non-inverting electrode was placed on the low forehead (Fpz), the inverting electrode on the ipsilateral sternocleidomastoid muscle, and the common ground electrode will on the high forehead (Cz). cVEMPs were recorded using both a 500 Hz and 1,000 Hz tone burst using rarefaction polarity. Stimuli were presented at a stimulus repetition rate of 5.1/sec. At least 2 averaged responses of 80 sweeps were performed to ensure replicability. Two independent judges identified peak to trough amplitude of the P1-N1 and threshold level. Results were compared to age- and sex-matched controls. Absolute cVEMP amplitudes, latencies and thresholds were computed and compared between groups.

Results: Results demonstrate decreased P13 to N23 amplitudes in firefighters compared to age and sex-matched controls for 500 Hz stimuli [$W = 2210, p < .01$], as well as 1000 Hz stimuli [$p < .05$]. cVEMP amplitudes decreased with increasing noise exposure in firefighter participants [$p < .05$]. cVEMP latencies were observed to increase with increasing noise exposure, although this did not reach significance. Reliable cVEMP responses were obtained in all control ears, yet absent in 10% of firefighter ears.

Conclusions: As shown by others, our cVEMP findings in humans are consistent with animal studies suggesting the saccule is particularly susceptible to noise-induced damage. These results demonstrate measurable changes in saccular function as measured by cVEMP in noise-exposed firefighters compared to controls, and support that amplitude and morphological changes in cVEMP may be a reliable clinical marker of NIVL.

PODIUM SESSION V: HEARING LOSS AND ASSOCIATED RISKS

Alterations in Motor-Related Oscillatory Activity in Children with Mild-to-Severe Hearing Loss

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Objectives: Large-scale studies suggest that children with hearing loss, including both those with mild-to-severe hearing loss and those with profound loss, exhibit significant fine motor deficits when compared to children who are normal hearing. Previous work from our lab has shown that children with mild-to-severe hearing loss may exhibit hyperactivity in the motor cortices relative to their normal hearing peers, even during non-motor tasks. However, the underlying mechanisms that give rise to these alterations in neurophysiology and behavior are unclear. Thus, the goal of this study was to systematically investigate the impact of mild-to-severe hearing loss on the oscillatory dynamics serving movement in children. We hypothesized that children with mild-to-severe hearing loss would show frequency-specific increases in motor-related activity relative to children with normal hearing, and that these oscillatory patterns would be related to amount of auditory access (i.e., amount of hearing aid use), in line with previous work in non-motor tasks.

Design: A total of 43 healthy youth aged 7-15 years, including 23 children with normal hearing and 19 with bilateral mild-to-severe hearing loss who were fit with hearing aids, participated in this study. Participants performed an arrow-based Eriksen flanker task during magnetoencephalography (MEG). This task has been shown to reliably produce robust motor-related oscillatory activity around response onset. Data was epoched around response onset and transformed into the time-frequency domain using complex demodulation. Significant time-frequency bins of interest were imaged using beamforming, and the impact of hearing loss and hearing aid use (controlling for degree of hearing loss) were assessed.

Results: As expected, this task induced motor-related alpha and beta event-related desynchronizations (ERD) prior to and during response onset, as well as a motor-related gamma event-related synchronization (ERS) at movement onset. There were no significant differences in gamma ERS activity between groups. However, children with mild-to-severe hearing loss exhibited widespread stronger (i.e., more negative) alpha and beta ERD activity during movement relative to children with normal hearing. Peak alpha differences included the right secondary somatosensory cortex, paracentral lobule, anterior cingulate, and left lateral occipital cortex ($p < .005$, corrected), while peak beta differences were found in the right pre- and post-central gyri, left parietal cortex, and medial parieto-occipital cortex ($p < .005$, corrected). Interestingly, hearing aid use had unique effects on alpha and beta dynamics in the children with mild-to-severe hearing loss. More daily hearing aid use was associated with a reduction (i.e., normalization) of alpha activity throughout the sensorimotor network, controlling for degree of hearing loss. On the contrary, more hearing aid use was correlated with greater recruitment of frontal regions in the beta band, controlling for degree of hearing loss.

Conclusions: In line with previous research, our study shows that children with mild-to-severe hearing loss exhibit hyperactivity throughout the motor network during movement relative to children with normal hearing. Importantly, hearing aid use seems to normalize this activity in a frequency-specific manner. Future work should directly probe whether speech-related motor patterns follow a similar pattern, and how these alterations are related to behavioral outcomes.

Social Isolation and Loneliness Among Older Adults with Hearing Loss in the ACHIEVE Study

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Objectives: In the United States, nearly one in four older adults are socially isolated and more than a third feel lonely. Social isolation and loneliness are significant public health concerns given their high prevalence (particularly since the COVID-19 pandemic) and strong associations with increased risk for dementia and other morbidities. Hearing loss is a potential risk factor for social isolation and loneliness, but evidence is limited and typically based on self-reported hearing. This study quantifies the cross-sectional associations of objective and subjective hearing function with social isolation and loneliness among older adults with hearing loss.

Design: This study uses baseline (2018-2019) data (N=936) from the Aging and Cognitive Health Evaluation in Elders (ACHIEVE) Study, a randomized controlled trial investigating the effect of hearing treatment on cognitive decline in a sample of community dwelling older adults with untreated, audiometric hearing loss (better-hearing ear pure tone average [PTA] ≥ 30 and < 70 dB hearing level) (ClinicalTrials.gov Identifier: NCT03243422). Hearing loss was quantified by the better ear, speech-frequency PTA (0.5-4 kHz) and sound-field speech-in-noise testing using the Quick Speech-in-Noise (QuickSIN) test. Hearing handicap was measured by the Hearing Handicap Inventory for the Elderly-Screening Version (HHIE-S). Social isolation was measured by the Cohen Social Network Index (social network size, social network diversity, embedded social networks). Loneliness was measured by the UCLA Loneliness Scale. Associations between each measure of hearing and social isolation and loneliness were assessed by Poisson regression with robust variance (social network size, social network diversity, embedded social networks) and linear regression (loneliness) adjusted for age, sex, race, education, chronic conditions (hypertension, cholesterol, diabetes, stroke), smoking, and study design characteristics (study site, recruitment type).

Results: Overall, participants were a mean age of 76.8 (4.0) years, 54.0% female, 87.4% White, and 53.0% had a Bachelor's degree or higher. Participants had mild (29.0%) or moderate or greater (71.0%) hearing loss. Better QuickSIN performance (top 3 quartiles vs. lowest [worse] quartile) was associated with larger social network size (IRR: 1.08, 95% CI: 1.00, 1.16), higher network diversity (IRR: 1.05, 95% CI: 1.01, 1.10), and higher embedded social network score (IRR: 1.13, 95% CI: 1.02, 1.25). Severe hearing handicap (vs. no hearing handicap) was associated with greater loneliness (β : 6.49, 95% CI: 4.92, 8.06) and more constricted social network size (IRR: 0.90, 95% CI: 0.81, 0.99), lower social network diversity (IRR: 0.94, 95% CI: 0.89, 0.99), and lower embedded social network score (IRR: 0.88, 95% CI: 0.77, 0.99). Differences in loneliness and social network characteristics between individuals with moderate or greater vs. mild hearing loss were not observed.

Conclusions: Speech-in-noise understanding and perceived hearing handicap are potentially useful clinical tools to identify older adults with hearing loss at greater risk for social isolation and loneliness. Once completed, the ACHIEVE Study will provide evidence on the effect of hearing treatment versus a successful aging education control intervention on social isolation and loneliness among older adults with hearing loss.

Association Between Hearing Loss & Loneliness: A Cross-sectional Population Study

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Objectives: Hearing loss (HL) is a potential risk factor for loneliness in older adults, but prior studies have not clearly demonstrated an association. This may be because HL measurements have varied across studies. In this study, aims were designed to: (A) investigate the cross-sectional association between HL (measured via pure tone audiometry) and loneliness (measured via the UCLA 3-item Loneliness Scale), and (B) examine hearing handicap, a measure of the adverse social-behavioral impacts of hearing loss, as a moderator. We hypothesized that audiometric HL is significantly associated with loneliness, and that the magnitude is stronger among those concurrently experiencing hearing handicap.

Design: We conducted a cross-sectional analysis using data from the Atherosclerosis Risks in Communities (ARIC) study with a prospective, biracial cohort recruited in 1987-1989 from four regional US sites (Minneapolis, MN; Washington County, MD; Forsyth County, NC; Jackson, MS). The analytic sample included participants with complete hearing data (collected in visit 6, 2015-2017, N=3,628) and loneliness data (assessed during semi-annual telephone interviews in 2020, N=2,736), and with a full set of covariates (final N=2,526). Four frequency pure tone averages (PTA: 0.5, 1, 2, 4 kHz) for the better-hearing ear were computed. Participants were categorized as having no HL (PTA:< 25 dB), mild HL (PTA: 26 - 40 dB), or moderate-to-severe HL (PTA: > 40 dB). Loneliness was assessed using the 3-item UCLA loneliness questionnaire (range 3-9), with participants categorized as not lonely (scores< 4) and lonely (scores > 4). Hearing handicap was evaluated using the 10-item Hearing Handicap for the Elderly (HHIE-S) questionnaire (range 0-40), with participants categorized as not impacted (even scores< 8) and impacted (even scores >10). We modeled the association between audiometric HL and loneliness via multivariable logistic regressions, adjusting for age, race/center, education, marital status, BMI (kg/m²), smoking status, diabetes, hypertension, stroke, and history of myocardial infarction. We explored the role of hearing handicap as a moderator for the association between HL and loneliness by including an interaction term between HL and hearing handicap.

Results: In a sample of 2,526 study participants (mean age: 79.3 \pm 4.3 years, 60.73% female, 17.7% Black), participants with moderate-to-severe HL (n=634) had 1.5 times the odds of reporting feeling lonely compared to participants with no HL (n=895) in fully adjusted models (95% CI: 1.06-2.12). While higher PTAs generally trended with higher loneliness scores overall, the observed association was not statistically significant for mild (n=997) vs. no HL. In additional analyses, the confidence interval for the interaction term included the null hypothesis, suggesting no significant differences in the odds of feeling lonely by hearing handicap status for participants with either mild or moderate-to-severe HL.

Conclusions: Participants with audiometric HL ranging across standardized moderate-to-severe levels showed 50% higher odds of loneliness in our sample. Mild audiometric HL was not significantly associated with loneliness. We did not find statistically significant differences in the association of HL of any severity with loneliness by hearing handicap status. Findings suggest that loneliness in older populations with HL may be influenced by factors beyond hearing health.

Hearing Loss and Prevalence of Depression in Older Adults in the U.S.

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Objectives: The prevalence of depressive symptoms in older adults is about 50% in the US. Depression can lead to the debilitation of mental and physical well-being. Hearing loss is a potentially modifiable risk factor for depression; however, there is a lack of nationally representative evidence of the association between hearing loss, hearing-aid usage, and depression. This study quantifies the association between objective hearing loss, hearing aid use, and prevalence of depression in a nationally representative sample of older adults in the United States.

Design: Data were from the 2021 round of the National Health and Aging Trends Study (NHATS), a nationally-representative prospective cohort study of Medicare beneficiaries aged 65 years and older in the contiguous United States. The analytic sample for this cross-sectional analysis included 2,352 participants with complete hearing, depression, and covariate data. Depression was measured by the Patient Health Questionnaire-2 (PHQ-2), which asks about the frequency of anhedonia and depressed mood over the past two weeks. A PHQ-2 score (range: 0-6) of ≥ 3 was used to indicate depression symptomology. Level of hearing loss was defined according to clinical cut points consistent with the American Speech-Language-Hearing Association: Normal hearing: ≤ 25 decibels hearing loss (dB HL); Mild hearing loss: 26-40 dB HL; Moderate or greater hearing loss: >40 dB HL. Prevalence ratios (PR) of depression symptomology associated with hearing loss were assessed using Poisson regression models with robust variance. Models adjusted for age, sex, education, race/ethnicity, smoking, and self-reported history of health conditions (high blood pressure, diabetes, heart attack, heart disease, stroke, lung disease, and cancer). Among participants with moderate/severe hearing loss, the association between hearing aid use and depression prevalence was assessed using the same approach.

Results: Overall, 28.4% of participants had normal hearing, 37.2% had mild hearing loss, and 34.2% had moderate or greater hearing loss. Participants were 4.5% over 90 years, 53.5% female, 82.8% White, and 64.4% had higher than a high school education. Mild hearing loss (vs. normal hearing) was associated with 2.28 (95% confidence interval (CI): 1.50, 3.45) times higher prevalence of depressive symptomology. Moderate or greater hearing loss (vs. normal hearing) was associated with 1.74 (95% CI: 1.03, 2.92) times higher prevalence of depressive symptomology. Among 809 participants with moderate or greater hearing loss, 401 participants reported hearing aid use. Hearing aid use (vs. no hearing aid use) was associated with 53% (PR: 0.47, 95% CI: 0.29, 0.74) lower prevalence of depressive symptomology among participants with moderate or greater hearing loss.

Conclusions: Participants with mild and moderate or greater hearing loss may be an important subgroup to monitor for depressive symptoms. The observed potential benefit of hearing aid use supports greater affordable access to hearing aids and treatment and the continued investigation of the effects of hearing treatment on depression in older adults.

Association Between Health Literacy, Cognition, and Hearing-Related Outcomes

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Objectives: The ability to obtain, process, and comprehend health-related information (a.k.a., health literacy) is associated with improved health outcomes due to the critical nature of interpreting self-care information about chronic illnesses. Regarding self-care, cognition is also an important factor to consider. Prior research has demonstrated that health literacy is strongly associated with cognitive ability in older adults. In the domain of hearing healthcare, little is known about how health literacy and cognition interact. This study sought to

evaluate the relationship between health literacy, cognition, and hearing-related outcomes among older adults with mild-to-moderate hearing loss who used direct-to-consumer hearing devices. We anticipated that older adults with limited health literacy and low cognitive capacity would have unfavorable outcomes with hearing device use.

Design: This was an observational cohort study. Thirty older adults with mild-to-moderate sensorineural hearing loss (aged 60-85 years; Mean = 70.2 years, SD = 6.7; 80% female; 87% black) participated in a nine-week trial of a direct-to-consumer hearing device. All participants did not have previous experience with amplification. The participants' health literacy was evaluated at the beginning of the trial using a six-item health literacy assessment instrument - the Newest Vital Sign (NVS). The Montreal Cognitive Assessment (MoCA), a clinical cognitive screening test, was used to measure cognition. The outcome measure for hearing device use benefit was the difference in global Abbreviated Profile of Hearing Aid Benefit (APHAB) scores between unaided and aided conditions.

Results: The mean health literacy score was 3.0 (SD = 1.64). The average cognitive score was 23.5 (SD = 2.73). Hearing literacy was significantly associated with cognition ($r = 0.57$, $p = .001$) and hearing device use benefit ($r = 0.64$, $p = .0001$). However, no significant correlation was observed between cognition and hearing device benefit ($r = 0.33$, $p = .07$). After adjusting for age, gender, education, and four-frequency better ear pure tone audiometry (PTA), a generalized linear model (GLM) revealed that health literacy was a significant predictor of hearing device use benefit [$F(1,29) = 14.25$, $p = .0009$]. Health literacy accounted for 30.2% of the variance in hearing device use benefits.

Conclusions: The results indicate that older adults with lower health literacy skills were associated with decreased cognitive abilities. Those with low health literacy levels benefited less from using hearing devices. Although cognition was not found to be significantly correlated with hearing device use benefits in this study, it could serve as an important mediator between health literacy and hearing device use.

Dementia Risk Attributable to Hearing Loss Among Older Americans

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Objectives: Hearing loss (HL) is a major modifiable risk factor for dementia, and the population attributable fraction (PAF) of dementia from HL in late-life in the US is ~2% when incorporating self-reported HL measures. However self-reported HL measures might underestimate clinically significant audiometric HL among older adults, and whether the PAF varies when solely considering objectively measured (audiometry) hearing among a nationally representative sample of older Americans is uncertain. We quantified PAFs of dementia from audiometric HL among a nationally representative sample of community-dwelling older adults in the US, hypothesizing these PAFs would be higher than previous reports.

Design: We used data from Round 11 (2021) of the National Health and Aging Trends Study (NHATS), a prospective cohort study representative of the US Medicare population aged 65+ years. We included community-dwelling beneficiaries with complete outcome data, and excluded those with incomplete or missing hearing and covariate data (n = 467). The final analytic sample consisted of 2,470 older adults. The primary outcome, prevalent dementia diagnosis, was classified using standardized criteria that included neurocognitive test data, self- or proxy-reported physician diagnoses of dementia, and informant questionnaires. Hearing was measured using pure-tone audiometry; we categorized HL by pure-tone average (PTA) (normal hearing, PTA < 25 dB; mild HL, PTA 26-40 dB; \geq moderate HL, PTA > 40 dB). We quantified survey-weighted PAFs of dementia by HL category, adjusted for age group, sex, race/ethnicity, education, smoking status, and number of chronic diseases (hypertension, diabetes, heart disease, heart attack, stroke, lung disease, cancer). We estimated nonparametric 95% confidence intervals (CI) for PAFs using 1000 bootstrapped samples. We also tested for effect modification of age and sex on HL-dementia associations by including interaction terms in the primary models and by performing stratified analyses.

Results: Among eligible participants (median age group, 75-79 years; 55% female; 82% non-Hispanic White), 37.5% had mild and 28.8% had \geq moderate audiometric HL. On average, a greater proportion of older adults with \geq moderate HL were aged 85+ years (30%), male (53%), identified as non-Hispanic White (85%), and had lower educational attainment (18%). The prevalence of dementia overall was 10.6%. Dementia risk attributable to HL was predominately driven by \geq moderate HL (PAF: 16.7%; 95% CI: 4.2, 28.7%). The PAF from mild HL was smaller and non-significant, which when combined with all HL categories yielded a large but non-significant PAF (18.7%, 95% CI: -5.4, 39.8%). There was evidence that HL-dementia associations differed by sex but not age; \geq moderate HL exhibited stronger associations among males (PAF: 39.7%; 95% CI: 19.7, 57.1%) than females (all PAFs non-significant).

Conclusions: In a nationally representative sample of community-dwelling older adults in the US, 17% of dementia cases were attributable to moderate or greater audiometric HL; estimates much larger than prior analyses that only considered self-reported HL. With strong assumptions, the preventative potential of HL reduction on dementia risk might be sizeable.

Hearing Loss and Fatigue in Middle-Aged and Older Adults

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Objectives: Fatigue is a prevalent symptom associated with physical and mental well-being. Prior evidence has documented associations between hearing loss and fatigue due to increased listening effort to compensate for degraded auditory signals. However, evidence in large population-based studies is limited and a life course perspective is needed to further examine how the association might differ by age. This study aims to investigate the cross-sectional association between hearing loss and fatigue by age in a nationally representative sample of middle-aged and older adults.

Design: We included 3,120 participants aged 40 years and older from the National Health and Nutrition Examination Survey 2015-16 and 2017-18. Fatigue was assessed based on self-reported frequencies of feeling tired or having little energy over the last 2 weeks (Not at all, Several days, More than half the days, Nearly every day). Audiometry was conducted in a sound-isolating booth using calibrated audiometric equipment. A better-ear pure-tone average (PTA) was calculated by averaging audiometric thresholds at 0.5, 1, 2 and 4 kilohertz and was analyzed categorically as having hearing loss (<25 decibels [dB]) vs. normal hearing (\leq 25 dB). We used multivariable-adjusted multinomial logistic regression to model the

relative risk ratios (RRR) of being in a higher vs. reference (not at all) frequency category of fatigue associated with hearing loss. We also included an interaction term between hearing loss and continuous age in years to examine how age modifies the association between hearing loss and fatigue. Primary models (Model 1) adjusted for age, sex, race, education, smoking, drinking, occupational and off-work noise exposure; secondary models (Model 2) considered additional adjustment of body mass index, hypertension and diabetes.

Results: Among 3,120 participants (mean age: 60 years; 51% female; 22% Black), 1,541 (49%) reported not having fatigue at all, 1,032 (33%) reported having fatigue for several days, 255 (8%) reported having fatigue for more than half the days, and 292 (9%) reported having fatigue nearly every day. Participants with hearing loss were more likely to report having fatigue for more than half the days during the past 2 weeks (Model 1: RRR=2.10, 95% confidence interval [CI]: 1.22, 3.61; Model 2: RRR=2.05, 95% CI: 1.20, 3.48) and for nearly every day (Model 1: RRR=2.20, 95% CI: 1.34, 3.61; Model 2: RRR=2.05, 95% CI: 1.21, 3.47) comparing to not having fatigue at all. There was a non-significant trend of a weaker hearing loss-fatigue association with older age (P-value for hearing loss \times age=0.09). In our primary models, at age 50, participants with hearing loss were 3.57 times (95% CI: 1.56, 8.14) more likely to report having fatigue nearly every day vs. not at all; the estimate decreased to 2.53 (95% CI: 1.51, 4.22) at age 60 and 1.79 (95% CI: 1.17, 2.72) at age 70.

Conclusions: Hearing loss is associated with fatigue in this nationally representative sample of middle-aged and older adults. Hearing loss might be targeted to manage fatigue and improve quality of life if further longitudinal studies support the association.

Sensory Gating and Noise Acceptance in Listeners (With)out Hearing Loss

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Objectives: Central inhibition in the auditory system, which declines with both aging and hearing loss, has been proposed to explain why listeners with similar audiological profiles can exhibit different reactions to noise while following speech. Indeed, auditory sensory gating-the inhibition of continuous, habitual, or redundant auditory information-has already been shown to predict Acceptable Noise Level (ANL) scores in normal hearing listeners. The Tracking of Noise Tolerance (TNT) test is a clinically oriented alternative to the ANL that uniquely measures how noise acceptance changes continuously over a two-minute trial. Here, we measured sensory gating for (non)speech stimuli in older adult listeners with normal hearing (NH) and with hearing loss (HL). We then compared these gating measures against two different performance outcomes derived from the TNT test.

Design: Twenty-three older NH adults (15 F, mean age = 64.7 years, range = 51-82) participated along with 16 age-matched adults with a moderate-to-severe degree of bilaterally-symmetric sensorineural HL (6 F, mean age = 77.3 years, range = 62-86). Sensory gating magnitudes of listeners' cortical auditory-evoked potentials (P1 and N1P2) were quantified as the relative change in amplitude when evoked by the first and second stimuli in pairs of 1 kHz tones and natural /ba/ syllables, separately. Performance on the TNT was measured for coherent English speech materials and for the International Speech Test Signal (ISTS) with co-located continuous speech-shaped noise. Listener TNT performance was quantified based on (1) average "acceptable/tolerable" noise level relative to speech/ISTS levels and (2) excursion of the noise level trace (i.e., average peaks - average valleys) across the two-minute trail.

Results: NH listeners exhibited stronger gating of P1 than HL listeners ($t(112) = 2.18, p = 0.05$), but the groups did not differ in N1P2 gating. Stimulus type (tone/syllable) did not affect gating magnitudes of either component. In contrast, signal type (speech/ISTS) interacted significantly with listener group to affect both average TNT scores ($t(37) = -2.75, p = 0.009$) and TNT excursion scores ($t(37) = -2.84, p = 0.007$). Whereas NH listeners tolerated more noise than the HL group when tested with speech, the groups did not differ when tested with the ISTS. Conversely, the HL group exhibited greater excursion than NH listeners when tested with the ISTS, but the two groups did not differ when tested with speech. Linear regression analyses revealed that average TNT scores were only predicted by listeners' audiometric thresholds ($\beta = -0.09, t(32) = -2.05, p = 0.049$). However, N1P2 sensory gating magnitudes for non-speech (1 kHz tones) negatively predicted TNT excursion scores for both speech ($\beta = -0.07, t(32) = -3.49, p = 0.001$) and ISTS ($\beta = -0.05, t(32) = -2.68, p = 0.012$) stimuli after controlling for listener thresholds.

Conclusions: Listeners' reactions to changing noise levels while following the TNT test's target signals were predicted by their central inhibition for non-speech stimuli at N1P2 generators. The TNT excursion score may be a useful profiling measure when considering the underlying central contributions to listeners' speech-in-noise difficulties.

PODIUM SESSION VI: AMPLIFICATION II – EVALUATION, OUTCOME AND REHABILITATION

Music Re-Engineering Impacts Music Enjoyment Among Single-Sided Deafness Cochlear Implantees

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Objectives: Previous work has demonstrated potential benefits of music re-engineering for improving music appreciation in cochlear implant (CI) users, which is known to be diminished compared to normal-hearing (NH) users. However, music appreciation in the single-sided deafness (SSD) population is not well-studied. Our objective was to investigate music appreciation in SSD cochlear implantees using music re-engineering software. We hypothesized that patient-directed music re-engineering may enhance music enjoyment in SSD CI users.

Design: A multidisciplinary team of neurotologists, audiologists, sound engineers, and web designers collaborated to create a novel music-re-engineering application. Adult SSD CI listeners were recruited from community and tertiary medical center settings. Participants rated excerpts from 5 major genres of music (country, pop, rock, rap, classical) on music enjoyment measures (pleasantness, musicality, naturalness) using a visual analog scale (scale of 1-10; 10=maximal enjoyment, 1=no enjoyment). Participants were asked to re-engineer excerpts by adjusting treble, bass, percussion, and reverberation, and again rated their enjoyment. Each participant completed the study under the following audio input conditions: 1) direct streaming into the CI, 2) external speaker with CI on (i.e., hearing through the CI and contralateral NH ear), 3) external speaker with CI off (i.e., hearing only through the NH ear). Hearing and demographic data were collected. Descriptive statistics were calculated and paired t-tests were performed to compare outcomes in all three conditions.

Results: Fourteen SSD CI users completed the study. Mean (SD) age was 42.07 (11.25) years. Average (SD) CI usage was 1.50 (1.03) years. Mean (SD) post-surgical CI pure tone average (PTA) was 35.56 (5.90) dB (with the CI on) and NH ear PTA was 10.42 (5.93) dB. Four individuals had residual hearing (mean PTA [SD] 68.3 [13.09] dB). 85% reported an interest in mixing music of their choosing. Mean (SD) music enjoyment rating (averaged across pleasantness, musicality, naturalness) in the 3 listening conditions were as follows: direct CI input pre-mixed 4.04 (1.75), post-mixed 5.66 (2.10); external speaker/CI pre-mixed 9.32 (0.97), post-mixed 9.46 (0.66); external speaker/CI off pre-mixed 9.64 (0.69), post-mixed 9.8 (0.40). The direct CI input condition demonstrated significantly lower pre- and post-mixed music enjoyment ratings compared to the other 2 conditions. Post-mixed excerpts were rated significantly higher than original pre-mixed excerpts across all measures of enjoyment in the direct-CI input condition, and higher in the ratings of pleasantness and naturalness in the external speaker/CI-on condition. In a subgroup analysis comparing individuals with and without post-implant residual hearing, there was no significant difference in pre-mixed music enjoyment in the external speaker/CI-on condition. Individuals with residual hearing showed a greater increase in post-mixed ratings of musicality compared to the non-residual hearing individuals (10 vs. 9.8, $p < 0.01$); however, there was no significant difference in post-mixed music enjoyment ratings of pleasantness and naturalness.

Conclusions: User-directed music re-engineering enhances music enjoyment for SSD CI listeners when the audio is streamed directly into the device and when played through external speakers. CI users with residual hearing in their implanted ear may show some benefit in music enjoyment compared to CI users without residual hearing.

Participant-Identified Listening Goals in the ACHIEVE Study

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Objectives: This study was an exploratory examination of participant-identified listening goals among older adults with mild to moderate hearing loss participating in the Aging and Cognitive Health Evaluation in Elders randomized clinical trial (ACHIEVE RCT; ClinicalTrials.gov Identifier: NCT03243422). Client Oriented Scale of Improvement (COSI) listening goals will be discussed across the study and relative to geographic location.

Design: Baseline data from the ACHIEVE RCT were used for this exploratory analysis. Participants were 490 adults with untreated mild-to-moderate hearing loss in their better ear, aged 70-84 years old. Recruitment occurred through either the Atherosclerosis Risk in Communities (ARIC; ClinicalTrials.gov Identifier: NCT00005131) longitudinal study or de novo from the community at four study sites located in Forsyth County, NC; Jackson, MS; Minneapolis Suburbs, MN; and Washington County, MD. A best-practices, audiologist-guided administration of the Client Oriented Scale of Improvement (COSI) was used to elicit, prioritize, and categorize listening goals. Specifically, COSI goals were identified by each participant at the onset of the intervention, defining up to three difficult listening situations they would like to improve through the hearing program, in order of importance to the participant. Each goal was coded by the site audiologist into one of nine pre-determined categories (TV/Radio at normal volume, conversation in noise, phone/doorbell ring, conversation in quiet, church/meeting, social/emotional, telephone conversation, hear traffic, and other). Coded goal category frequencies were calculated across and within study sites.

Results: A total of 1427 listening goals were identified among 490 participants included in this study. Across all 4 study sites, the most frequent goal category was Conversation in Noise (n= 413; 29%), followed by Conversations in Quiet (n= 296; 21%) and TV/Radio at Normal Volume (n= 280; 20%). The most frequent goal categories identified within the North Carolina, Minnesota, and Maryland sites were Conversation in Noise, Conversations in Quiet and TV/Radio at Normal Volume. At the Mississippi site, the most frequent goal categories elicited were TV/Radio at Normal Volume and Church/Meeting (n= 71; 21% each) followed by Conversations in noise (n= 70; 20%). The top-ranked goals were also examined across and within each site. Across all sites, Conversations in Noise was most frequently listed as the primary listening goal of patients (n= 158; 33%), followed closely by Conversations in Quiet (n= 156; 32%) and then Church/Meeting (n= 65; 13%). Within sites, only North Carolina participants identified Conversations in Noise most frequently as the primary goal (n= 56; 49%). Conversations in Quiet was the most frequent primary goal at the Mississippi, Minnesota, and Maryland sites (32%, 39%, and 30%, respectively).

Conclusions: Although listening in noise was the most prevalent goal identified, it was not the most important problem for every adult. Patients may have felt that difficulties with conversations in quiet, hearing at church and meetings, or listening to the TV were more significant to their daily activities. The frequency and prevalence of identified listening goals varied between the 4 study sites. Future work will investigate variables that influence listening goals, how listening goals are met after hearing intervention, and whether goals change over time.

Development of Empowerment Audiology Questionnaires (EmpAQ) to Measure Hearing-Related Empowerment

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Objectives: Over the last few years, the concept of empowerment has emerged from studies of mhealth technologies, such as smartphone-connected hearing aids and multimedia educational resources for hearing aid users. However, there is currently no hearing-related measure of empowerment. A previous qualitative study conceptualised empowerment along the hearing patient journey and identified five dimensions of empowerment: knowledge, skills and strategies, participation, self-efficacy, and control. The objective was to develop an outcome measure of empowerment for adults with hearing loss for both clinical and research use.

Design: A semi-structured interview study was conducted in adult hearing aid users from Australia (n=10) and Sweden (n=8) who had worn hearing aids for between 6 to 36 months. A thematic template analysis was used, based on Zimmerman's Theory of Empowerment. The results generated content for the development of an outcome measure of empowerment, based on best practice COSMIN guidelines. The relevance and clarity of the measure was evaluated through (i) cognitive interviews with a total of 16 adults with hearing loss (n=8 for both Australia and Denmark), and (ii) an expert panel of international audiologists and researchers, who rated each item for relevance, clarity and dimension (from 1-4, where 1=does not fulfil criterion, 4=fulfils criterion). The items were then further refined and their psychometric properties identified by applying modern psychometric Rasch analysis, from adults with hearing loss (study 1; n=307). and traditional classical test theory analysis (study 2: n=187)

Results: A pool of 47 items were initially generated across the five themes of empowerment. Following refinement as a result of 16 sets of cognitive interviews, the final pool of items was 33. Initially, overall relevance, clarity and dimension was 3.53, 2.94 and 3.38 respectively, increasing to higher scores of 3.96 and 3.70, and 3.92 in round two, demonstrating the value of involving key stakeholders. Item reduction by Rasch analysis using RUMM2030 identified 18 items with high response dependency (overlap), poor fit to the model, and outliers, which were removed. This resulted in two unidimensional measures (i) EmpAQ-15 for research or in-depth clinical use (15 items), and (ii) EmpAQ-5 for clinical use (5 items), with a Person Separation Index of 0.877 and 0.633 respectively. Classical test theory analysis showed both measures had high internal consistency and construct validity.

Conclusions: The EmpAQ-15 and EmpAQ-5, developed using best practice principles, are the first self-report measures developed for the measurement of empowerment along the hearing journey. They can be freely downloaded from <http://osf.io/caj84/>. The next stage is to implement the EmpAQ measures into clinical practice.

Can In-Situ Self-Reports Prevent Narrative Effects? An EMA Study

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Objectives: Previous studies have found that the way a person perceives the hearing aid (HA) fitting process (the fitting narrative) can significantly influence the HA outcomes measured using retrospective self-reports, regardless of the electroacoustic characteristics of the HAs. The objective of the present study was to determine if this narrative effect would impact outcomes measured using in-situ self-reports such as the Momentary Ecological Assessment (EMA). It is hypothesized that the narrative effect would be observed in retrospective self-reports, which are often shaped by respondents' personality, attitudes, and beliefs, but not in in-situ self-reports, which are based on respondents' experiential knowledge.

Design: Thirty adults with hearing loss completed the study. A crossover design with deception was used. The participants were told that the purpose of the study was to compare the outcomes of two different HA fittings: Best Practice Fitting vs. Streamlined Fitting. In the Best Practice Fitting, assessments of listening need, speech-in-noise performance, background noise acceptability, and loudness discomfort levels were administered. The participants were told that these measures were used to adjust the HAs to better fit their personal needs. In contrast, the Streamlined Fitting did not involve any assessments and this fitting was described as a computer-generated fitting which was quicker and simpler, but less customizable. Although the fitting procedures were different, the HAs were identical acoustically across the two conditions. EMA and retrospective questionnaires were administered during and at the end of the 3-week field trial in each condition, respectively. The

International Outcome Inventory for Hearing Aids (IOI-HA) was used in both retrospective and in-situ self-reports. At the end of the study, a preference questionnaire was also completed.

Results: Twenty-two out of 30 participants reported preference for one fitting over the other (14 and 8 preferred Best Practice and Streamlined, respectively). The participants reported that their preferences resulted mostly from the way their favorite fitting sounded, even though the HA settings were identical for both fittings. Two analyses were conducted to examine the narrative effect. The first compared the IOI-HA scores of the Best Practice and Streamlined conditions (i.e., the traditional placebo effect). Results (n=30) indicated that, for both retrospective and in-situ IOI-HA scores, there was no significant difference between the two fitting conditions. The second analysis compared the IOI-HA scores of the preferred vs. nonpreferred fittings (n=22). Retrospective IOI-HA results indicated that preferred fittings were perceived to yield better outcomes than the nonpreferred fitting (p=.006), suggesting a narrative effect. Contradictory to our hypothesis, the in-situ IOI-HA scores show the same trend (p<.001).

Conclusions: The study results imply that the story, or narrative, around the fitting methods significantly affects the participant's perceptions of HA outcomes. This narrative effect is robust, regardless of whether outcomes are measured using retrospective or in-situ self-reports. Future study designs should be mindful of this effect and incorporate ways to circumvent narrative effects when comparing the merit of HAs. EMA cannot prevent narrative effects.

Optimal Response Format for Microinteraction-Based Ecological Momentary Assessment (Micro-EMA)

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Objectives: Microinteraction-based Ecological Momentary Assessment (micro-EMA) is a type of EMA that single-question surveys are delivered through a smartwatch. Respondents can answer survey questions through a simple microinteraction involving a glance and a tap on the watch screen. Micro-EMA is new to audiology research and its most reasonable survey response format is unknown. The purpose of the study was to examine the validity, sensitivity, intrusiveness, and reproducibility of three response formats (binary, 5-point, and 10-point scales) for micro-EMA.

Design: Twenty-nine adults with hearing loss completed the lab study. A dual-task paradigm was used to answer the research question. During testing, participants listened to sentences in noise, responded to the notifications and questions on the smartwatch as soon as possible, and then repeated as much of the sentences as they could. The question shown on the watch was "Hearing well?" The speech was presented at -3, 0, 3, 6, and 9 dB relative to the signal-to-noise ratio (SNR) at which the participant could understand 50% of speech. The dual-task was repeated with the three response formats (Binary: YES/NO; 5-point: from VERY POOR to VERY GOOD; 10-point: from 1 to 10). Additionally, participants completed a baseline condition where they performed the speech recognition task without interacting with the smartwatch. The participants were then interviewed about their preferences regarding the response formats. One week later, the participants returned and repeated the same measures.

Results: Compared micro-EMA ratings across SNRs, such that a larger effect size means a bigger relative change and higher sensitivity. The effect sizes indicated that the binary scale was less sensitive than the 5-point and 10-point scales. Intrusiveness was quantified using response time (from survey notification to survey

submission) and the degree to which micro-EMA impacted the speech recognition score. The results indicated that the binary scale had a shorter response time (1.9 sec) than the 5-point (3.0 sec) and 10-point (3.5 sec) scales. For all three formats, micro-EMA had a negligible effect on speech recognition score relative to the speech-only baseline condition. Finally, the test-retest correlation indicated that, for two lab visits one week apart, the 5-point scale and the binary scale had the highest and the poorest reproducibility, respectively. The participants overwhelmingly preferred the 5-point scale over the binary and 10-point scales.

Conclusions: All three response formats are valid. Although the binary scale was less intrusive (shorter response time), it was less sensitive in detecting rating differences across SNRs and was less reproducible. In contrast, the 5-point scale had high sensitivity and reproducibility and was most preferred by the participants. Based on the lab results, it is concluded that the 5-point scale is the most reasonable selection for micro-EMA.

Inferring Real-World Listening Effort from Data-Logging with Hearing Aids

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Objectives: Despite advances in noise reduction technology, hearing-aid users report fatigue when listening in noisy conditions. This is assumed to be associated with increased listening effort. The increased effort can be measured in the laboratory (e.g., using pupillometry) when manipulating the signal-to-noise ratio (SNR) of speech in background noise, but no objective measure for real-world application currently exists. We propose and test whether a triangulation of sound data-logging (from hearing aids) combined with subjective feedback (e.g., from apps) and heart rate recordings (from wrist-born wearables) can be used as a proxy measure of hearing and listening effort in the real world by estimating how environmental noise and listening conditions impact cardiovascular stress.

Design: In the first study, observational data from 62 in-market hearing aid users were assessed for associations between ambient sound pressure level (SPL) and SNR and 5-min mean heart rate across 3-months of daily life. In the second study (ongoing, data collection finish January 2023), 24 hearing aid users with mixed hearing aid experience and bilateral mild-to-severe hearing loss participate in a laboratory-based noise impact test followed by a 2-week field trial. In the laboratory test, cardiovascular responses to different noise levels (low and high SNR) and listening activities (resting, reading, or active listening) are measured. In the field trial, participants live as normal while daily-life noise exposure and continuous heart rates are recorded. In addition, participants are instructed to self-initiate subjective feedback via button presses on the wearable whenever they encounter "extra effortful" listening conditions.

Results: The observational study documented that hearing aid users' heart rates were significantly associated with the ambient SPL and SNR, and that approximately 5% of the variance in 5-min mean heart rate was explained by changes in ambient sound alone. Higher SPLs were related to higher heart rates, and higher SNRs were related to lower heart rates, especially for louder (>60 dB SPL) environments. Preliminary data from the second study confirms these relationships. In addition, we expect to find that the strength of these associations will correlate with the magnitude of the cardiovascular responses measured from laboratory tests for different listening activities, and that associations are stronger on days and time intervals where the participants have indicated situations of "extra effortful" listening.

Conclusions: The observational findings support the use of cardiovascular biomarkers for assessing the impact of changing daily life listening conditions. Preliminary findings from the ongoing experimental study indicate that this impact is related to listening effort; that it is participant-specific; and that it can be predicted from laboratory assessments. We expect that real-world monitoring of hearing effort can aid in understanding individual users' end-of-day experience of fatigue, and potentially act as a guiding signal for future adaptive hearing aid processing.

Use of Natural Language Processing to Examine Hearing Aid Outcomes from Open-Ended Text

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Objectives: Hearing aid outcomes such as benefit and satisfaction are generally measured using structured outcome measures. However, not all items of these measures are relevant to all users and some items relevant to some users may not be captured in standardized measures. For this reason, open-ended questions are complementary to elicit responses that are highly relevant to individual users. The current study examined the psychologically meaningful dimensions using automated Natural Language Processing (NLP) techniques and compared it to a standardized hearing aid outcome measure.

Design: The study used a prospective cross-sectional survey design. Study participants (n=626) completed an online survey with demographic (e.g., age, gender) and audiological (e.g., duration of hearing loss, self-reported hearing difficulty) questions, open-ended questions about meaningful life changes following hearing aid use, and the International Outcome Inventory for Hearing Aids (IOI-HA). The responses to open-ended questions were analysed using the automated NLP software, Linguistic Inquiry Word Count (LIWC), which identifies psychologically meaningful language dimensions from the open-text response. The language dimensions were correlated with demographic and audiological variables as well as with the IOI-HA responses.

Results: The most frequently occurring language dimensions in the open-ended texts about meaningful life changes due to hearing aid use cognitive processes, social processes, I-words, motives, auditory perceptual processes, and affect (e.g., positive tones). LIWC dimensions had significant correlations mostly with residual activity limitations (IOI-HA Q3), residual participation restriction (IOI-HA Q5), and the IOI-HA total score. Age was significantly associated with the use of I-words, social referents, and lifestyle factors. Self-reported hearing difficulty and hearing loss duration were significantly correlated with cognitive processes, affect, and lifestyle factors.

Conclusions: LIWC helps identify meaningful psychological dimensions that are relevant to hearing aid users. The correlation between the LIWC variables and the IOI-HA supports the idea that the use of open-ended questions may complement the information obtained via the standardized hearing aid outcome and help optimize the outcome measurement in the clinical context.

Use of Machine Learning to Predict Adult Cochlear Implant Outcomes

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Objectives: Postlingually deaf adults who receive cochlear implants (CIs) routinely display enormous unexplained variability in speech recognition outcomes. Traditional clinical demographic, audiologic, and surgical factors (e.g., age, duration of hearing loss, residual hearing, etiology of hearing loss, distance of electrodes from the auditory nerve) together explain less than 40% of the variability in these outcomes, and our ability to prognosticate CI outcomes from pre-operative measures is even poorer. Our limited ability to reliably prognosticate speech recognition outcomes for patients considering CIs creates a barrier to effectively counseling patients pre-operatively or identifying patients who are at risk for a poor outcome after CI surgery. The objective of this study was to use a machine-learning approach for pre-operative prediction of adult CI speech recognition post-operative outcomes at 6 months of CI use.

Design: A prospective, longitudinal study was performed in 32 adults undergoing CI surgery. A battery of predictor measures was collected prior to surgery, including traditional demographic and audiologic measures, but also assessments of spectrotemporal processing and environmental sound awareness, non-auditory neurocognitive functioning, linguistic skills, and pre-operative patient-reported quality of life (QOL). Six months after CI activation, speech recognition measures were obtained across a variety of word and sentence recognition materials of varying complexity (monosyllabic words, meaningful and nonsensical sentences spoken by a single talker, and high talker variability sentences). Minmax scaling was applied to all measures such that their values ranged from 0 to 1. Missing values were imputed via KNN imputation (k=3). K-means clustering was leveraged to separate patients into 2 groups according to their demographic and pre-operative measures. Both a Kruskal-Wallis test and pairwise t-tests were performed on the measures obtained six months after CI activation to ascertain whether the two groups were associated with distinct outcomes.

Results: Clustering based on demographic and pre-operative measures yielded distinct groups with significant differences in the outcomes of 69% of the evaluated post-operative measures. By taking the mean of these significant, minmax-scaled, post-operative measures, we observed that these groups are associated with high or low speech recognition outcomes (0.76 and 0.45, respectively). Notably, the demographic and pre-operative factors that most strongly distinguished the outcome groups consisted of a combination of audiologic/auditory (pre-operative sentence recognition and environmental sound awareness), neurocognitive (verbal learning and memory), and QOL (Nijmegen Cochlear Implant Questionnaire, NCIQ) assessments.

Conclusions: Findings suggest that a battery of pre-operative assessments can help prognosticate and distinguish CI recipients who will or will not experience favorable speech recognition outcomes at 6 months after implantation. Importantly, participant groups were determined by measures beyond traditional demographic and audiologic measures currently used clinically to try to counsel patients regarding their likely outcomes. Specifically, some assessments of neurocognitive functioning and QOL may provide additional useful information in prognosticating CI outcomes. Lastly, clustering analysis provides a potential tool for identifying individuals who are at high risk of experiencing a poor CI outcome, which may have ramifications for suggesting individuals for whom more intensive counseling or rehabilitation may be needed.