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PODIUM ABSTRACTS

PODIUM SESSION I: COCHLEAR AFFAIRS

Functional Regeneration Without Hair Cell Regeneration in the Mammalian Cochlea

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Objectives: One of the most important objectives in hearing science today, is the regeneration of sensory hair cells and their synaptic elements. This objective is predicated on the notion that regeneration of structure (hair cells and their synaptic elements) will directly lead to the regeneration of function. However, this relatively straight forward notion fails to consider first-order principles of cell biology and molecular signaling. The objective of the current work is to determine whether or not functional recovery from injury is dependent on the presence of hair cells within defined regions of the cochlea.

Design: Both control and noise injured animals were used. Distortion product otoacoustic emission and compound action potential recordings were employed as functional outcomes measures while cytocochleograms were deployed for morphological studies across the length of the cochlea.

Results: In a set of animal experiments we show that functional recovery can be achieved even though cytocochleograms confirm the presence of dead hair cells.

Conclusions: This phenomena of functional regeneration without hair cell regeneration can be observed across phyla and suggest that a more clinically relevant yet underappreciated objective should be functional regeneration with or without hair cell regeneration.

A Joint-OAE Diagnostic Profile Applied to Mildly Hearing-Impaired Ears

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Objectives: Otoacoustic emissions arise from one (or a combination) of two basic mechanisms within the cochlea: nonlinear distortion and coherent reflection. Distortion- and reflection-source OAEs are impacted independently by various factors, suggesting that they provide distinct information about cochlear function and dysfunction. While our understanding of OAE generation has progressed and research applications advanced, their usage in the audiology clinic remains rudimentary and fails to exploit their potential for the differential diagnosis of sensory hearing loss. In this study our objective was to test an expanded Joint-OAE Profile that utilizes information offered by both emission classes in the diagnosis of mild sensory hearing loss, which is often missed by current diagnostic techniques. Both seminal and recent studies have confirmed the deleterious impact of slight-to-mild hearing losses on childhood communication and education.

Design: To generate the Joint-OAE Diagnostic Profile, we presented rapid swept-tone stimuli to evoke distortion-product (DP) OAEs and stimulus-frequency (SF) OAEs in an interleaved manner over a 5-

octave frequency range (0.5-16 kHz) at 10-12 stimulus levels to 20 normal-hearing subjects and 15 subjects with mild hearing-impairment (20-40 dB HL). The SFOAE, evoked by a single, low-level swept tone, was measured as a gauge of coherent reflection; and the separated distortion-component of the 2f1-f2 DPOAE was measured as a gauge of cochlear nonlinearity. We conducted relational and combined analyses of both OAE results together using metrics that characterize the peak strength of each emission, as well as its compressive properties. Novel and improved fitting and analysis methods were implemented.

Results: Using a simple clinical diagnostic framework, we found that the Joint-OAE profile recorded with sweeping tones can detect mild hearing loss relatively well. Additionally, impaired ears mostly fall outside of the normative distributions of our OAE metrics: peak strength, compression knee, compression slope, amplitude, and SNR. We found that the joint-OAE profile for each impaired ear is not affected in the same way, i.e., one hearing loss might impact the DPOAE more than the SFOAE while another shows the opposite pattern, even if the audiograms from these two ears are similar. Also, our results confirm that distortion and reflection emissions can be differently affected by hearing loss and do not always shift in unison.

Conclusions: Findings suggest that a Joint SFOAE-DPOAE profile captures variance among mild sensory hearing losses that look similar by audiogram but may have different etiologies, underlying pathologies, and/or perceptual difficulties. We speculate that the Joint-OAE profile achieves its diagnostic accuracy by capitalizing on the distinct generation mechanisms of both classes of OAEs.

Reliability of Contralateral Suppression of Otoacoustic Emissions in Children

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Objectives: It was reported that various pathologies may influence medial olivocochlear (MOC) reflex in children. The MOC reflex is usually investigated by measuring amount of contralateral suppression of otoacoustic emissions (OAEs). However there is lack data on reliability of such measurement in children. Therefore the purpose of the present study was to investigate short-term reliability of contralateral suppression of transiently evoked OAEs (TEOAEs) in this age group.

Design: TEOAEs were recorded in a group of 51 normally hearing children of age 3-6 years. TEOAEs were recorded using the linear protocol (all stimuli at the same level and polarity); stimulus levels were kept at 60 dB peSPL; and a 60 dB SPL broadband noise was delivered to the contralateral ear as suppressor. Two measurements were conducted for each subject. Broadband (whole signal) and half-octave values of TEOAE response levels, signal to noise ratios, and suppression were investigated.

Results: The difference between two suppression measurements was in average around 0.2 dB for broadband values. The reliability of suppression was highest for global values and lowest for 1 and 1.4 kHz half-octave bands. In order to get high suppression reliability, signal to noise ratios of above 20 dB are required.

Conclusions: These results call into question the credibility of many previous studies showing the impact of various pathologies (e.g. auditory processing disorders) on the suppression effect because in these works either the obtained signal to noise ratios were not given or were too low.

Medial Olivocochlear Efferents and Development of Auditory Perception in Noise

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Objectives: The function of medial olivocochlear efferents in human hearing is long debated. Although the antimasking hypothesis, based on animal models, suggests that efferents are involved in the discrimination of transient signals in noise, the corresponding evidence in humans is generally weak and controversial. Instead of directly testing the antimasking hypothesis in humans, we examined the hypothesis that efferents are involved in the development of antimasking function in humans. This hypothesis was guided by the observation of deleterious long-term effects of efferent sectioning on frequency selectivity, and spontaneous discharge rate of auditory nerve fibers in neonatal cats. Accordingly, the objective of the present study was to examine the relationship between medial efferent inhibition and frequency discrimination in noise as a function of age in children.

Design: Efferent inhibition using otoacoustic emissions, and frequency discrimination (FD) thresholds (in quiet and noise) were measured in young adults (n=37) and children (age=5 to 12 years; n=127) in a cross-sectional design.

Results: Results revealed an intriguing relationship between efferent inhibition, frequency discrimination in noise and age. In a regression model, efferent inhibition predicted a small but statistically significant variance in FD thresholds in noise. Adding age to the regression model substantially improved the prediction. The prediction was further improved significantly by an interaction term between efferent inhibition and age. Simple regression equations (lines) could be fitted between efferent inhibition and FD thresholds in noise for 5, 6, 7, 8 and 9 year-olds, but not for the older children (10 and 11-12 years) and adults. Not surprisingly, no relationship was found between efferent inhibition and FD thresholds in quiet for any group.

Conclusions: These findings suggest that age moderates the relationship between efferent inhibition and auditory perception in noise. Present findings also caution for an oversimplified relationship between efferent inhibition and measures of auditory perception.

Development of a Test Battery for Cochlear Synaptopathy

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Objectives: Some people report auditory dysfunction, such as difficulty understanding speech in noise, despite normal audiometric findings (i.e.,<20 dB HL from .25 to 8 kHz). This phenomenon has been called "hidden hearing loss" (HHL) or cochlear synaptopathy (CS) and can be caused by noise exposure and aging. CS has been confirmed histopathologically in animal models of hearing, but confirmation in live humans is lacking. Our purpose was to assess a test battery on young adults at low risk for CS and two

high-risk groups for this condition, young musicians in a marching band (Noise-Exposed) and middle-aged (Older) adults with normal hearing. We hypothesized that audiologic measures resulting in significant differences among low- and high-risk groups may be sensitive measures for CS.

Design: In this cross-sectional study, 26 young adults at low-risk for CS (M Age = 22.9 y, SD = 3.0 y), and two high-risk groups, 24 young musicians (Noise-Exposed) (M Age = 21.6 y, SD = 2.9 y) and 22 middle-aged adults (Older) (M = 45.5 y, SD = 9.0 y) were administered the following tests: pure-tone air and bone-conduction audiometry, high-frequency audiometry > or = 10 kHz, otoacoustic emissions, electrocochleography, auditory brainstem response, Acceptable Noise Levels (ANLs), Edgerton-Danhauer Nonsense Syllable test in noise and reverberation (T = 1.0 s), QuickSIN, ratins of listening effort, masking level difference, Gaps in Noise, Tinnitus Handicap Inventory, and Liberman's Listening Questionnaires. All variables were assessed for normality by Shapiro Wilk tests. Four-frequency pure-tone average (FFPTA) and SP/AP ratio passed normality assumptions. For these two variables, ANOVA was used to determine group differences. For the other variables, differences among the groups was assessed using non-parametric Kruskal-Wallis tests.

Results: The Low-Risk Adults had significantly lower mean FFPTAs (M = 4.4 dB; SD = 4.0) than either the High-Risk Noise Exposed (M = 7.3 dB, SD = 4.0 dB) or the Older High-Risk groups (M = 8.3 dB, SD = 3.4 dB) ($p = 0.0017$). The High-Risk Older group had significantly higher mean audiometric thresholds > or = 10 kHz than the Low-Risk and High-Risk Noise Exposed groups ($p< 0.001$). The Low-Risk Adults (M = 0.44 mV, SD = 0.2 mV) had significantly higher mean ABR amplitudes of wave I than the High-Risk Older Adults (M = 0.29 mV, SD = 0.2 mV) ($p< 0.04$). The High-Risk Older group (M = 9.2 dB, SD = 6.5 dB) had significantly higher mean ANL scores than the younger Low-Risk (6.0 dB, SD = 4.6 dB) and High-Risk Noise Exposure (M = 4.7 dB, SD = 3.9 dB) groups. The Low-Risk group rated their listening abilities in noise ($p = 0.0134$), in reverberation ($p = 0.0097$), and in multi-talker babble ($p = 0.0246$) significantly better than did the high-risk groups.

Conclusions: We conclude that high frequency audiometry > or = 10 kHz, amplitude of ABR wave I, the ANL test, and subjective ratings of listening abilities in conversations involving noise and reverberation show promise as tests for CS.

Noise-Induced Cochlear Synaptopathy Is Shaped By Hair Cell Injury

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Objectives: Prior work has provided extensive documentation of threshold sensitivity and sensory hair cell losses after noise exposure. It is now clear, however, that cochlear synaptic loss precedes such losses, at least at moderate noise doses, silencing affected neurons. To date, cochlear synaptopathy has been studied most extensively using a noise exposure model in which injury was produced by a relatively short duration, moderately intense noise producing large, but temporary, threshold elevations. However, noise exposure to humans may take many forms, and underlying mechanisms may differ for reversible vs. irreversible changes and for short vs. long exposures producing similar threshold shifts. Here, we begin to address such questions, characterizing noise-induced injury to hair cells, synapses and their functions as noise dose is varied over a range from apparently non-pathological to a point where hair cells are permanently destroyed.

Design: We assessed cochlear physiologic and histologic consequences of a range of noise exposures varied in duration from 15 minutes to 8 hours and in level from 85 to 112 dB SPL. Exposures were delivered to CBA/CaJ mice (16 wk, MF, n=236) and outcomes were compared with those from strain- and age-matched controls held identically except for the experimental exposure. Hair cell- and neural-based response thresholds and suprathreshold levels were assessed for a broad range of frequencies (~5-45 kHz) at 24 hours or 2 weeks post noise. For the same ears, analysis of immunostained cochlear whole mounts provided counts of outer and inner hair cells (OHC, IHC) and IHC synapses with auditory nerve fibers.

Results: Noise exposures produced threshold elevations ranging from trivial (~5 dB) to large (~50 dB) at 24 hr, followed by varying degrees of recovery. There was little to no IHC loss, but OHC loss could be substantial at highest frequencies for highest noise doses. Synapse loss was an early manifestation of noise injury and did not scale directly with either temporary or permanent threshold shifts. With increasing noise dose, synapse loss grew to ~50%, then declined for exposures yielding permanent hair cell injury. All synaptopathic, but no non-synaptopathic exposures produced persistent neural response amplitude declines; those additionally yielding permanent OHC injury also produced persistent reductions in OHC-based responses and exaggerated neural amplitude declines.

Conclusions: Findings show that widespread cochlear synaptopathy can be present with and without permanent noise-induced sensory cell injury or loss and that differing patterns of cellular injury influence synaptopathic outcomes. Improved understanding of the extent to which synaptic mechanisms are damaged in common forms of acquired sensorineural hearing loss like that produced by noise exposure will have broad implications for efforts to identify drugs or other treatments with the potential to target these mechanisms for prevention or rescue. Practically, this knowledge will inform clinical diagnostics aimed at identification of individuals with synaptic loss/cochlear deafferentation, the monitoring of new treatments for safety and efficacy and monitoring of individuals at risk of hearing compromise from drug and noise exposure. Work supported by grants from the U.S. Department of Defense and the NIH/NIDCD.

PODIUM SESSION II: BRAIN AND HEARING

Using Functional Near-Infrared Spectroscopy to Measure Listening Effort

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Objectives: Two experiments considered the feasibility of using functional near-infrared spectroscopy (fNIRS) to measure listening effort in listeners with and without hearing aids. Our working hypothesis was that prefrontal cortex (PFC) oxygenation would be higher under conditions involving a greater listening load. Listening load was broadly construed to include sensory as well as cognitive factors. The prefrontal cortex includes the dorsolateral prefrontal cortex and the inferior frontal gyrus, brain areas that have been implicated in functional magnetic resonance imaging (fMRI) studies of listening effort. Although fMRI is a spatially superior imaging modality, it presents technical challenges, particularly when testing listeners using hearing instruments.

Design: In Experiment 1, 16 hearing-impaired older adults (62-83 years of age) were asked to complete an n-back task in various conditions presented as blocks in a within-subjects design that crossed memory load (0B, 1B, 2B, 3B), n-back modality (auditory, visual), and hearing aid use (aided, unaided). Sound presentation in aided and unaided auditory conditions was set to 35 dB SL above each individual

participant's unaided pure-tone average. N-back response time was assessed for each trial. Prefrontal activation was measured for each block of trials. Self-reported listening effort was a retrospective evaluation obtained after each block of trials.In Experiment 2, 28 young adults completed a speech-in-noise (SPIN) task at two levels of target word predictability (high context and low context) and two levels of signal-to-noise ratio (SNR, +4 and -2).

Results: In Experiment 1, we found that PFC oxygenation increased with n-back level in both auditory and visual conditions. There was no main effect or interactions involving hearing aid use. However, the extent to which hearing aids reduced PFC oxygenation in the left lateral PFC (an area encompassing the inferior frontal gyrus) was positively correlated with age and pure-tone average thresholds. In addition, overall PFC oxygenation was weakly and non-significantly correlated with self-reported listening effort and reaction time, respectively, suggesting that PFC oxygenation assesses a dimension of listening effort that differs from these other measures.In Experiment 2, we found a main effect of SNR, with higher levels of PFC oxygenation for lower-levels of SNR. There was no effect of target word predictability and no interaction.

Conclusions: Both sets of results demonstrate that prefrontal activation tends to increase with listening load - i.e., oxygenation increases were observed as a function of increases in working memory demands, and decreases were observed as a function of SNR. Although the results of Experiment 1 found no overall effect of hearing aids, they revealed that oxygenation in the left lateral PFC may be particularly important in assessing the potential benefit of hearing aids. These findings are generally consistent with prior work conducted with fMRI and support the use of fNIRS in future studies involving listening effort.

Brain-behavior Measures in Reverberant Speech Perception

New Investigator Presentation

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Objectives: People experience difficulties understanding speech in noisy and reverberant environments. Individuals with similar hearing abilities often vary greatly in their ability to successfully understand degraded speech. Our poor understanding of the underlying causes of this variability hinders the development of effective treatment options tailored to help individual listeners. Reverberation results in temporal smearing, diminishing cues like onsets which are required to successfully understand speech. Cortical auditory evoked potentials (CAEPs) can be elicited in response to these acoustic landmarks in continuous sounds/speech. This study analyzed the effects of reverberation on the neural encoding of speech through CAEPs and related them to perceptual difficulties in reverberant speech perception. We hypothesized that greater reverberation would 1) reduce amplitudes and increase latencies associated with the neural encoding of multiple acoustic changes within a stimulus and 2) increase perceptual difficulties.

Design: Electrophysiological recordings and behavioral responses were obtained from 20 young normally hearing adults (9 female; mean age: 28.3; 23 - 37 yrs.). Naturally-produced /da/, /ba/, and /pa/ tokens were concatenated to create two-syllable /daba/ and /dapa/ stimuli. In addition, 11 versions of

the natural /ba/ with increasing the voice onset times (VOT; 0-60 ms) that spanned the perceptual range from /ba/ to /pa/ were also concatenated with the natural /da/. The two-syllable tokens were then processed to produce two reverberant versions of each stimulus (reverberation times - RT60: 400 and 1200 ms). Passive CAEPs (the P1-N1-P2 complex) were elicited to the anechoic and reverberant versions of the natural /daba/ and /dapa/ tokens as well as /daba/ with the added 60 ms VOT (perceived as /dapa/). Listeners also completed a behavioral task, where they labeled the second syllable of the anechoic and reverberant versions of the /daba/ - /dapa/ continua presented monaurally to the test ear and provided a confidence rating for the label they assigned.

Results: A comparison of CAEPs obtained in response to clean and reverberant stimuli revealed the effect of reverberation on the neural coding of speech: while the responses to the first syllable were minimally affected by the reverberation, the responses to the second syllable were increasingly degraded with increasing reverberation. Preliminary analyses of the behavioral responses showed that increased reverberation shifted the /ba/-/pa/ classification boundary, resulting in a greater number of tokens being labeled /ba/, as well as increased variability in category labeling. Listeners were also less sure of the identity of the more reverberant stimuli.

Conclusions: CAEPs reflect reverberation-related acoustical changes to speech tokens and appear to reflect the perceptual difficulties experienced while listening to reverberant speech. These data will help clarify the effects of reverberation on neural speech encoding in normal-hearing adults, which may then serve as baseline data in the further study of reverberation-related changes in speech processing in populations with impairments. In the long term, these results will aid the design of diagnostic tests for use in hard-to-test populations and lead to individualized rehabilitation strategies to improve speech perception in difficult listening situations.

Contributions of Envelope and Temporal Fine Structure Cues to Sentence Recognition in Noise for English and Mandarin Chinese

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Objectives: Envelope (E) cues have been shown to play a critical role for speech perception in quiet. The contribution of the temporal fine structure (TFS) cues for speech perception in noise is still under debate. We have shown previously that TFS plays a dominant role in tone recognition in quiet and that both E and TFS contributed to tone recognition in noise. The present study was designed to investigate the relative contributions of the E and TFS on English and Mandarin Chinese sentence recognition in noise. We hypothesized that the Mandarin-speaking listeners would rely more heavily on TFS cues due to the tonal nature of the language than the English-speaking listeners would.

Design: Two experiments were carried out. In Exp. I, 17 native English-speaking, normal-hearing listeners and 9 native Mandarin-speaking, normal-hearing listeners between the ages of 18 and 38 years were recruited. A total of 500 English and 500 Mandarin AzBio sentences were mixed with speech-spectrum-shaped noise at 5 different signal-to-noise-ratios (SNRs) (-18 to +6 dB with 6-dB steps). The TFS and E were then extracted from each of the 30 frequency bands using Hilbert transform. Twenty-five combinations of TFS and E (each at one of the 5 SNRs) from the sound mixtures of the AzBio sentences at various SNRs were created. Sentence recognition tasks were performed using the processed sentences. In

Exp. II, 13 native English-speaking, normal-hearing listeners and 20 native Mandarin-speaking, normal-hearing listeners between the ages of 18 and 45 years were recruited. The masking noise was the two-talker babbles (TTB) of respective languages. All other aspects of the experiment were identical to Exp. I.

Results: The sentence recognition in noise showed a strong reliance on the SNR in E. The TFS showed a small effect on sentence recognition in noise. These observations were true for both types of maskers, i.e., speech-spectrum-shaped noise and two-talker babbles and were consistent in both languages, i.e., English and Mandarin Chinese.

Conclusions: The results suggest that the E plays a dominant role in sentence perception in background noise. The TFS plays a minor role despite its important contributions to lexical tone perception in quiet and in noise. The relative contributions of E and TFS cues to sentence recognition in noise show no differences in the two types of languages, i.e., English and Mandarin Chinese.

Listening Effort: A Marker for Hidden Hearing Loss

New Investigator Presentation

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Objectives: Diagnosis of hearing loss relies heavily on characterizing hearing sensitivity, however, as many as 8% of audiology patients complain of hearing difficulties even when diagnosed with normal hearing sensitivity. While audiometry is sensitive to outer hair cell function, disorders of the auditory nerve may go undetected. Tasks of speech recognition in the presence of background noise are intended to provide a more ecological test of hearing difficulties; however, cognitive processes may compensate for peripheral disorders in such tasks. Therefore, performance on clinical and laboratory tasks of speech recognition may not accurately reflect reported difficulties. Effortful cognitive compensation comes at a cost to cognitive spare capacity. In the present study, we hypothesized that measures of listening effort and cognitive spare capacity would be more sensitive to reported hearing difficulties than performance on two clinical speech recognition tasks.

Design: Adult participants with thresholds ÔÇ£ 25 dB HL between .25-8 kHz were asked to complete the Speech, Spatial, and Qualities of Hearing Scale (SSQ) to quantify difficulty hearing in adverse conditions. Performance on AzBio sentence recognition in the presence of four-talker babble at several signal-to-noise ratios (SNR) was assessed. After each list of the AzBio, participants completed the NASA Task Load Index - visual analog scale, rating mental demand, physical demand, temporal demand, perceived performance, effort, and frustration. Second, cognitive spare capacity was measured using the Word Auditory Recognition and Recall Measure (WARRM) - dual word recognition and working memory task.

Results: Preliminary data show that reported listening effort as measured by the NASA index, and not performance, on the AzBio sentences in babble predicts SSQ. Reported effort accounted for 21-33% of the variance in SSQ rating (depending on SNR), compared to only 0-9% accounted for by percent of words correct. Preliminary data also show a significant relationship between WARRM maximum word recall span and SSQ, when word recognition is at ceiling.

Conclusions: Measures of listening effort, such as the NASA Task Load Index in conjunction with the AzBio, or the WARRM, may be worthwhile supplements to traditional speech recognition tasks. These

measures could provide evidence for hearing difficulty that would otherwise go undetected by current clinical measures of hearing.

Benefit of Musical Training for Speech Perception Later in Life

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Objectives: Speech perception impairments are common in elderly adults and a public health concern in aging populations, particularly because effective treatments are lacking. Lifestyle factors have been of interest as potentially modifiable risk factors in aging research and musical training might be protective against age-related decline in auditory perception and cognition. Cross-sectional research on adult musicians showed better auditory processing and speech-in-noise perception and neuroimaging revealed underlying physiological advantages in auditory and higher-order processing brain regions. However, longitudinal cohort studies on long-term benefits of musical training for speech perception are lacking. The aim of this study was to determine the long-term effect of musical training on speech perception in adverse listening environments in a longitudinal cohort study of middle-aged to older adults.

Design: This study included 969 participants from the Epidemiology of Hearing Loss Study who participated in the baseline examination and had speech perception measures at the 20-year follow-up. We asked participants at baseline for their years of education, self-rated general health and musical training and defined musicians as having played an instrument at least once per month for at least 5 years. We assessed speech perception using the word recognition in competing message (WRCM) Northwestern University Auditory Test Number 6 at examination waves 1-5 and dichotic digits free recall test (DDT) at wave 5. Multivariable linear regression models were used to determine associations between musicianship and speech perception using musicianship as determinant and WRCM and DDT at the 20-year follow-up as outcomes respectively. We adjusted for age and sex and repeated the models additionally adjusting for education and self-rated health. In preliminary analyses, we investigated the decline in repeatedly measured WRCM using a linear mixed-effects model (LMEM) with age (mean centered) as the timescale variable and repeated WRCM (at least two follow-up measures) as outcome variable. The main determinant of interest was the interaction of musicianship with age. We adjusted for age group, sex, musicianship, education and health at baseline.

Results: Data were available on 969 participants (average 57 years, range 48-82 at baseline; 58% women; 214 musicians) who had a speech perception test at the 20-year follow-up. Musicians performed better on WRCM (4.89% difference; confidence interval (CI) 1.92,7.85; p=.001) and on DDT (2.87%

difference; CI 0.96,4.79; p=.003) in age-sex adjusted models. When additionally adjusting for education and self-rated health, effect sizes decreased and remained significant for WRCM (3.90% difference; CI 0.82,6.97; p=0.013) and not for DDT (1.65%; CI -0.29,3.59; p=0.096). In the LMEM in 1861 participants, musicians showed a smaller WRCM decline over time than non-musicians (0.14% per year; CI 0.05,0.23; p=.002).

Conclusions: Musicians show an advantage in speech perception abilities in adverse conditions in later life and less decline over time. This benefit remained true for word recognition in competing message when adjusting for education and general health indicating that the benefit of musical training might be unrelated to differences in socio-economic or health status. Future studies should determine potential mechanisms underlying this advantage. If confirmed, these findings could have important implications for developing speech perception intervention and prevention strategies.

Hearing Aids and Cognitive Function in Older Adults: Initial Results

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Objectives: Hearing loss has been associated with accelerated cognitive decline in older adults in many studies, and has been identified as a modifiable risk factor for dementia. Although hearing aids are a successful treatment for hearing loss, there is no treatment for cognitive decline, and whether hearing aid use can delay the onset of cognitive decline is unknown. This prospective longitudinal study is investigating the effect of hearing aid use on cognitive decline, and addresses many of the methodological limitations of previous studies.

Design: Patients who have attended the University of Melbourne Academic Hearing Aids Audiology Clinic are being recruited over the first 3.5 years of the study and assessed pre- and every 18 months post-hearing aid fitting. When numbers are sufficient, results will be compared with those of a control group of approx. 400 participants of a cohort study of aging in older adults. Pre- and post-hearing aid fitting assessments include cognitive function (a visually presented computerized assessment battery), hearing, speech perception, quality of life, activity, diet, loneliness and isolation, anxiety, depression, medical health and genetic risk.

Results: Initial multiple linear regression analyses, controlling for age, gender, cardiovascular conditions, education, and working or retired, were conducted for 94 participants (60-84 years) with mean better ear PTA 31dB. At baseline, increased hearing loss and age predicted poorer executive function, while higher education predicted better executive function and visual learning. At 18-month follow up, results for a subset of participants showed significant improvements in group means for executive function and working memory, despite significantly greater hearing loss over this period. Those with worse executive function at baseline also improved more. Reliable change index scores indicated that the majority of participants had either improved or did not decline in cognitive performance across the battery of cognitive assessments.

Conclusions: Despite a small initial sample size, hearing loss, age and education were found to significantly predict baseline cognitive function. At 18-month follow up, the majority of participants had either remained stable or demonstrated a meaningful clinical improvement in cognitive function, with significant group mean improvements for executive function and working memory. In addition to the above, updated results for a larger sample size will be presented, to further document the effects of hearing aid use on cognitive function, and whether this can delay cognitive decline.

PODIUM SESSION III: HEARING AIDS AND SPEECH UNDERSTANDING

The UCSD Hearing-Aid-Research Platform: Usability Assessment for Field Studies

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Objectives: A few open-source speech-processing platforms have been developed under the NIDCD initiative intended to promote hearing-aid research. Although there are many classes of users of these systems, the ultimate user is the research participant with hearing loss. The goal of this study was to evaluate one of these systems by exposing a sample of potential research participants in a short study involving self-adjustment in and out of the clinic. Research questions were: a) how do self-selected outputs and spectra compare with a threshold-based prescription in the clinic and in a natural environment with increased noise and reverberation; b) how do participants rate the system in terms of physical properties, acoustic performance, and smart-phone control; c) how willing would they be to use the system in an unsupervised field study.

Design: This study used the first wearable version of the UCSD open-source speech-processing platform. Using a smart-phone version of the Boothroyd/Mackersie Goldilocks procedure, twenty adult hearing-aid users with mild-to-moderate sensorineural hearing loss adjusted output and spectrum to preference while listening to speech at a conversational level of 65 dB SPL. They did so in the clinic and in a more natural environment. Results of the self-adjustment were compared with the NAL-NL2 threshold-based prescription in terms of real-ear output and phoneme recognition. Participants then completed a structured interview.

Results: As in previous studies, participants were able to complete the self-adjustment process and, as a group, found settings for low- and high-frequency output that were close to the NAL-NL2 prescription. The device was rated on a scale from 1 (very bad) to 5 (very good). Even though all participants commented on excessive size and weight, 60% of them rated the physical characteristics of the system as good or very good - when used in the context of a research study. Sound quality was rated as good or very good by 80%. The smart-phone control was rated as good or very good by 87% of participants. 60% indicated a willingness to wear the system in a research study for an average of 4 hours a day, 4 days a week, for 1 or 2 weeks.

Conclusions: The system was clearly usable for this study which, even though it involved a supervised field component, was basically lab-based. The questionnaire responses suggested that the system would also be usable, in unsupervised field studies, by a substantial proportion of potential participants. The

relationship between expressed willingness and actual adherence, however, will not be known until unsupervised field studies are actually undertaken.

Trends in EuroTrak Survey Results from 2009 to 2018

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Objectives: To investigate changes in EuroTrak survey responses over the period 2009-2018 related to prevalence of hearing loss and hearing aid usage.

Design: The first Eurotrak surveys were committed in 2009. Using a web based questionnaire format a 15.000 people sample were interviewed about hearing issues in each of Germany, France and United Kingdom. Since then, the surveys have been repeated in these countries in 2012, 2015 and 2018. Multiple other countries across the world have had similar surveys conducted albeit not at the same regular intervals. New questions have been added to the set, bringing new learnings on differences between countries and hearing aid provision systems.

Results: Analyzing the data across the 9-year period reveals interesting developments in hearing aid use patterns as well as factors important for use or non-use. Prevalence seems quite stable whereas uptake has developed positively. By pooling data across countries and time, analysis that is more refined can be performed showing statistically significant benefits of hearing aid usage in several domains compared to non-users. Adoption rates as well as use patterns vary across degree of hearing loss. Data seems to indicate that people with minor hearing loss not surprisingly show lower adoption rates than people with more severe losses and they use their hearing aids less. People with bi-lateral fittings are more satisfied and have higher use time per day. whereas the reasons for non-use have changed considerably.

Conclusions: Prevalence of self reported hearing loss is stable, uptake has increased in particular for bilateral fittings, satisfaction with hearing aids is increasing and the main reasons for none-use have changed considerably.

Customizing Individual Frequency Importance Weighting Measures

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Objectives: The weighted contribution of different frequency regions to speech recognition varies with configuration of hearing loss. Frequency weights have commonly been estimated across groups of listeners with similar configurations of hearing loss because estimating weights for each individual is prohibitively time consuming with most experimental approaches. To address individual differences in weighting, we designed a novel strategy for estimating frequency importance weights for an individual in a single experimental session. This strategy has been used to characterize individual differences in frequency importance weightings for adults with normal hearing, hearing aids, and cochlear implants. However, substantial work was needed to customize our strategy for each study, which limits its

usefulness to other researchers. Therefore, the goal of this work was to develop a set of guidelines for balancing experiment duration, resolution, and precision in measures of individual frequency weights.

Design: Four studies, two published and two ongoing, were customized to study adults with normal hearing, adults with moderate to severe hearing loss, adults with cochlear implants, and children with normal hearing. Data from these studies was analyzed for test-retest and split-half reliability, to empirically assess the reliability of different experiment customizations. In both analyses, the mean and maximum absolute difference in band weighting was compared across paired datasets within each individual to estimate the reliability of weighting estimates. Absolute differences were normalized with respect to the overall range of weightings, which provided a summary percentage that expressed the relative reliability of each experiment customization. Empirical reliability estimates were used as a basis for simulating reliability across experiment design parameters, such as the number of frequency bands and the number of trials. From these simulations, we derived guidelines for selecting design parameters which can produce efficient and precise measures of individual frequency weights.

Results: All four studies showed good reliability across all participant groups, which supports the general use of this approach to measure individual frequency weights. In adults, precise estimates can be obtained within a single experimental session. Similar precision can be obtained in children, although some children struggle to complete the desired number of trials. Guidelines suggest a minimum number of trials necessary to obtain good precision across different numbers of frequency bands and show a tradeoff between measurement precision and number of bands.

Conclusions: Estimating frequency weightings for speech recognition on an individual basis is feasible across many different types of listeners. This work enables research on cross-condition differences in frequency weighting on an individual level, such as changes in amplification strategy or speech material, as well as prediction of individual variability in frequency weighting from other auditory properties, such as audibility and spectral resolution.

Real-World Experience Implementing Compression Ratios from 3:1 up to 10:1

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Objectives: Conventional wisdom in clinical practice suggests that compression ratios greater than 3:1 are detrimental to sound quality and should be avoided. Many manufacturers limit maximum compression ratios to 3:1 due to fast attack and release times, reinforcing the idea that this limit should be universally applied, despite acknowledgment by developers of fitting algorithms that such limits should be dependent upon compressor speed. The CAM2 algorithm implemented in the Earlens contact hearing solution allows the manufacturer to choose limits for the maximum compression ratio, potentially benefiting the user by maximizing audibility of soft speech cues particularly in very high frequencies up through 10 kHz. The Earlens system utilizes a slow-acting wide dynamic range compressor that can effectively handle higher compression ratios up to 10:1. The objective of the current study is to determine if increased audibility provided via higher compression ratios leads to any decrements in subjective sound quality. We hypothesized that listeners would rate sound quality similarity between the high and low compression ratio limits - showing no decrement with the higher compression ratio limit.

Design: Participants meeting the indications for use of the Earlens contact hearing aid were enrolled in an IRB-approved within-subjects study. Two programs were created - a “high CR” program with a maximum compression ratio limit of 10:1 and a “low CR” program with a maximum compression ratio limit of 3:1. Participants were fit with the two programs in separate device memories with the order of programs counterbalanced across participants. Participants completed a sound quality questionnaire while listening to a music sample with a large dynamic range through the two programs and then wore devices with the two programs in the field for a week. At the one-week follow up appointment, the same sound quality questionnaire and a modified version of the Glasgow hearing aid benefit profile (GHABP) questionnaire were completed to evaluate and compare the experience of listening in the field with the two programs. Preference data was also collected to determine whether the patients preferred one program over the other.

Results: The results from the sound quality, preference, and GHABP questionnaires indicate that programs with the two compression settings were rated similarly by the listeners. This confirms the hypothesis that higher compression ratios can be effectively applied without the deleterious effects on sound quality that have been reported with high compression ratios with faster acting compressors in acoustic hearing aids. Analyses also confirm that although the digital compression ratio can approach 10:1, the effective compression ratio that the user perceives for speech sounds is actually far lower due to a slow-acting compressor, preserving both speech envelope information and long-term audibility.

Conclusions: The accumulated evidence of improved sound quality due to the broad-spectrum audibility achieved with a direct-drive hearing aid applies to the Inductive contact hearing solution. A compilation of the experience with an actual device implementing the CAM2 algorithm has led to some interesting findings regarding how high-frequency amplification may need to be implemented differently than what is considered conventional wisdom in acoustic devices.

Evaluation of Hearing Aid Spatial Features: Effects on Interaural Cues

New Investigator Presentation

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Objectives: As hearing aid technology continues to progress, digital signal processing capabilities allow for more advanced processing schemes. Here, we systematically evaluated a high-end product from one of the major hearing aid manufacturers, which includes features meant to enhance spatial hearing ability in noise. Different from regular "in-noise" hearing aid programs which utilize traditional directional microphone technology, this device allows for improved performance in noise while giving the listener access to sounds in a 360-degree space. This device is advertised to allow for varied level of attention to be given to sound sources to the side and behind the listener. Spatial features from this hearing aid were compared to more traditional microphone settings (omni-directional and full-directional) and interaural cues were evaluated across microphone configurations.

Design: Binaural acoustic recordings were collected in anechoic and simulated reverberation at the National Center for Rehabilitative Auditory Research (NCRAR). Spondees were presented from speakers located ±75° relative to midline. Hearing aids were assessed using open and occluding non-customized domes for receiver-in-the-ear (RIC) style hearing aids placed on a Bruel & Kjaer Head and Torso Simulator (HATS). Signal processing schemes were systematically evaluated by changing one component

at a time by manipulating microphone configuration and weighting of speech-in-noise spatial features. Interaural time and level differences were estimated using binaural models for each test condition.

Results: Results show reliable measurements of interaural time and level differences when evaluating across several test conditions. Some differences in interaural cues were observed when the "onset," or initial wave of the sound, was compared to interaural cues from the full duration of the recordings. The most notable finding was when comparing interaural level differences (ILDs). ILDs were enhanced when spatial features were set to "high" in comparison to omni-directional, full-directional, or low spatial feature settings. Additionally, a trend toward enhancement of interaural time differences was observed when spatial features were set to "high."

Conclusions: Spatial features in hearing aids are possible because of enhancements in digital signal processing and ear-to-ear communication in the devices. However, clinicians are not currently able to measure or verify spatial features in hearing aids with existing verification systems. The work proposed here shows that interaural cues can be measured reliably to evaluate spatial features in hearing aids. Best practice in audiology includes the ability to verify hearing aid features such as directional microphones, noise reduction, frequency lowering, etc. As manufacturers develop additional features utilizing ear-to-ear communication to enhance or alter interaural cues, the demand for verification of spatial features will likely increase. Future directions for this research include evaluation of interaural cues in noise and reverberation.

Longitudinal Study of Tinnitus and Change in Audiometric Hearing Thresholds

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Objectives: To examine the longitudinal association between persistent tinnitus, bothersome tinnitus and change in pure-tone audiometric hearing thresholds.

Design: We conducted a longitudinal study among 3,749 women (mean age 59y) in the Nurses' Health Study II, 2012-2018. Information on tinnitus was collected on biennial questionnaires. Hearing assessments were conducted by licensed audiologists at 19 geographically diverse audiology testing sites across the US. Pure-tone audiometry (0.5-8 kHz) was completed on 3749 participants at baseline and 3136 at 3-year follow-up (84%). After excluding participants with missing tinnitus information (n=30), the total analytic sample was n=3,106. Hearing loss was defined as ≥5 dB or ≥10 dB worsening of pure-tone average (PTA) hearing thresholds in the low- (PTA0.5,1,2 kHz), mid-(PTA3,4 kHz), and high-(PTA6,8 kHz) frequencies. We examined associations of persistent tinnitus (several days/week or more), bothersome tinnitus (persistent tinnitus that interferes with work, sleep or daily activities), and whether the associations varied by baseline PTA. Multivariable-adjusted logistic regression models examined independent associations between tinnitus and risk of 3-year worsening of audiometric hearing thresholds.

Results: At follow-up, a ≥5 dB HL worsening of hearing sensitivities in either ear occurred among 584 (19%) participants at PTA(0.5,1,2 kHz), 1182 (38%) at PTA(3,4 kHz), and 1516 (49%) at PTA(6,8 kHz). Persistent tinnitus was associated with higher risk of 3-year worsening of hearing thresholds across a broad range of frequencies. Compared with women without tinnitus, the multivariable-adjusted odds ratios [MVORs (95% CI) for low-, mid- and high-frequency PTA worsening ≥5 dB HL among women who reported persistent tinnitus were: 1.29 (0.99,1.67), 1.44 (1.16,1.78) and 1.38 (1.11,1.71), respectively. For ≥10 dB worsening, the respective MVORs were: 2.84 (1.55,5.23), 1.52 (1.10,2.09), and 1.41 (1.10, 1.82). Among women with bothersome tinnitus, the magnitudes of the associations were even greater. Compared with women without tinnitus, the MVORs for low-, mid- and high-frequency PTA worsening ≥5 dB among women who reported bothersome tinnitus several days per week or more were: 2.22 (1.12,4.43), 3.93 (1.95,7.92) and 2.57 (1.29,5.12). The risk of hearing threshold deterioration was elevated even among women with tinnitus and "clinically normal" hearing thresholds at baseline. Compared with women without tinnitus, the MVORs for low-, mid- and high-frequency PTA worsening ≥5 dB among women with baseline PTA ≤20 dB were: 1.36 (1.02, 1.81), 1.32 (0.98, 1.78), and 1.49 (0.91, 2.44).

Conclusions: Persistent tinnitus is associated with substantially higher risk of worsening hearing thresholds over 3 years, even among women with "clinically normal" hearing at baseline. The magnitude of the associations were even greater among those with bothersome tinnitus. In some individuals, tinnitus may be a harbinger of imminent hearing decline, thus continued monitoring of hearing sensitivities may be indicated, even for those who present without audiometric evidence of hearing loss. In the primary care setting, it could be valuable to elicit information on tinnitus to identify individuals at higher risk for hearing loss.

PODIUM SESSION IV: IMPLANTS AND PEDIATRICS

Binaural Cue Sensitivity for Cochlear Implant Recipients with Hearing Preservation

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Objectives: Bilateral acoustic hearing in cochlear implant (CI) recipients with hearing preservation can afford access to binaural cues in electric/acoustic stimulation (EAS). Sensitivity to acoustic binaural cues has been shown in some EAS listeners (Gifford et al., 2013, 2014), yet remains poorly understood and may be subject to limitations imposed by the electrical stimulation and/or amplification asymmetries. The primary purpose of this study was to investigate the effect of stimulus level, frequency-dependent gain, and the addition of unilateral electrical stimulation on sensitivity to low-frequency binaural cues. Based on previous research demonstrating binaural interference effects of a distant-frequency distractor on binaural target sensitivity for typical acoustic listening (e.g., Heller and Richards, 2010; Bibee and Stecker, 2016) or simulated EAS (van Ginkel et al., 2019), we hypothesized that a unilateral CI would significantly impair sensitivity to binaural cues in adult CI recipients with binaural low-frequency acoustic hearing.

Design: We recruited 16 adult CI EAS listeners (mean age = 50.2 years) for participation in this IRB-approved study. Detection thresholds were measured for interaural time and level differences (ITD and ILD) carried by a low-frequency, bandpass noise (100-800 Hz) in three listening conditions: acoustic hearing only at 90 dB SPL, acoustic hearing only at 60 dB SPL with NAL-NL1 (Keidser & Grant, 2001)

frequency-dependent gain, and acoustic hearing plus unilateral CI at 60 dB SPL with NAL-NL1 gain applied to the acoustic channels only. The 100-800 Hz target stimulus used was within the passband of acoustic hearing audibility and within the range of CI stimulation for all participants.

Results: Rank-based repeated measures analysis of variance (ANOVA) demonstrated that most EAS listeners had access to ecologically relevant ITD and/or ILD cues. Specifically, there were no significant effects of presentation level, frequency-specific amplification, or the addition of unilateral electrical stimulation on the resultant thresholds for ITDs (Œß2(2) = 2.0, p = 0.37) or ILDs (Œß2(2) = 2.6, p = 0.27) at the group level. Additional correlation analyses related ITD and ILD thresholds to the degree of EAS benefit (i.e., advantage of acoustic hearing in the implanted ear) for speech recognition in diffuse noise (S0N45-315). There was a significant relationship between EAS benefit and ITD thresholds (r = -0.54, p = 0.028), but no statistically significant relationship between EAS benefit and ILD thresholds (r = -0.21, p = 0.23).

Conclusions: The results of this study are not consistent with our previous study demonstrating significant binaural interference by a unilateral electrical “distractor" in simulated EAS for listeners with normal hearing (van Ginkel et al., 2019). The difference between studies suggests that chronic exposure to unilateral electrical stimulation combined with bilateral acoustic stimulation may reduce interference effects, perhaps because listeners adapt to the presence of the constant but binaurally incongruous CI stimulus. This study provides the first dataset demonstrating that the presence of a unilateral electrical stimulus does not preclude acoustic binaural sensitivity in a group of experienced adult EAS listeners.

The Utility of Low Frequency Hearing: Implications for Electroacoustic Stimulation

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Objectives: Cochlear implant (CI) recipients who are able to utilize residual acoustic hearing for electric-acoustic stimulation (EAS) are reported to have better outcomes for speech perception in noise, localization, and music perception compared to traditional CI users. However, not all patients see these benefits and the degree of improvement is variable and unrelated to simple audiometric thresholds. We sought to describe the quality of residual hearing beyond audibility to better predict speech perception outcomes.

Design: Normal hearing (NH, n=12) and hearing impaired (HI, n=23) listeners with steeply sloping audiograms participated. Spectral resolution was measured with the spectral-temporal modulated ripple test (SMRT), temporal resolution was measured using temporally modulated frequency discrimination (MDT), and speech perception was measured with AzBio sentences in quiet and noise. NH listeners heard stimuli through low pass filters designed to mimic steeply sloping hearing losses and at two levels (40 and 60 dBA) to simulate low and high audibility. HI listeners heard stimuli unaided at their most comfortable listening level.

Results: For NH listeners, speech perception performance degraded with increasing filter stopband frequency and an interaction was found between level and the introduction of noise. Spectral/temporal resolution was not affected by level and decreased only slightly with increasing filter stopband frequency. For HI listeners, SMRT performance was correlated with speech perception and duration of deafness. Mid-frequency thresholds (750-1000Hz) were most predictive of SMRT and speech perception scores.

Performance on SMRT was much poorer than predicted by even the most restrictive NH simulation; scores were also worse than previously published data for CI users listening electric-only despite appropriate audibility. The ranges for speech perception scores were similar between NH simulations and HI listeners. MDT scores for HI listeners showed a wide range of performance, with some users performing similarly to NH listeners.

Conclusions: NH simulations provide a "best-case" scenario for spectral resolution and speech perception with residual hearing. The degree of deviation from these simulations seen for SMRT may be a measure of the quality of the residual hearing. MDT scores suggest temporal resolution is largely intact in HI patients. Because SMRT correlated well with speech perception, this test can be used as a quick, non-linguistic measure to predict performance. The typical thresholds used for determining hearing preservation and EAS eligibility were not correlated with speech perception, suggesting that SMRT may be a better tool for predicting EAS benefit.

Temporal Pitch Explanation Limits for Cochlear Implant Users' Pitch Perception

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Objectives: Cochlear implant (CI) users often have difficulty accurately perceiving vocal pitch. However, the underlying cues that are used by CI users to perceive vocal pitch are unclear. Evidence suggests that temporal pitch likely plays a role in vocal pitch perception. The goal of this series of studies is to investigate whether temporal pitch, typically based on the amplitude modulations in the stimulation pattern, is sufficient to explain CI users' vocal pitch perception.

Design: Because CI users' vocal productions can provide evidence of what they perceive, Experiment 1 investigated differences in bilateral CI users vocal pitch while producing a sustained /a/ when using their left versus their right CI. Experiment 2 investigated if changing only the place of stimulation affected CI users' vocal pitch. Experiment 3 compared vocal pitch perception for natural vocalizations and a stimulus where the temporal modulations were independently manipulated.

Results: Experiment 1 results demonstrated that, despite no differences in the encoding of temporal modulations by the left and right processor, the vocal pitches produced when using the left versus the right CI often differed. Experiment 2 results demonstrated that, when only the place of stimulation was altered, CI users altered their vocal pitch. Experiment 3 found that F0 perception for natural stimuli and those with artificially added temporal modulations were similar for low frequencies. In contrast, perceived pitch continued to increase for higher F0s but not for higher artificially added temporal modulations.

Conclusions: Taken together these studies suggest that, while temporal modulations appear to play a key role in CI users' vocal pitch perception, they are not sufficient to fully explain CI users' vocal pitch perception.

Self-esteem in the Adult Cochlear Implant Users

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Objectives: Self-esteem is a good predictor of mental health and is crucial for well-being and psychological functioning. It is especially important in situations where there are potential mental health problems, such as in people suffering from hearing loss or total deafness. This study aims to gauge the level of self-esteem in adults who, in adulthood, had received a cochlear implant (CI). The association of self-esteem with other deafness-related variables (e.g. satisfaction with their CI or whether they also used a hearing aid) and sociodemographic factors was also investigated.

Design: The study group consisted of 120 CI users aged 22 to 60 years old. Data were obtained from questionnaires mailed to patients who, when adult, had received a CI. The subjects were divided into four subgroups: subjects with pre-lingual deafness, postlingual deafness, pre-lingual partial deafness, and post-lingual partial deafness. To evaluate their self-esteem, the Rosenberg Self-Esteem Scale (RSES) was used. For data on sociodemographic status and information related to deafness and CI, we used our own Information Inquiry form. For statistical analysis of the results, we compared means (t-test, ANOVA), investigated correlations, and applied linear regression.

Results: The self-esteem of deaf and partially deaf CI users was significantly lower than in the general population, especially for post-lingually deafened subjects. The only factor related to deafness and CIs that explained self-esteem was self-rated satisfaction with the CI - meaning that higher satisfaction was associated with higher self-esteem. The major sociodemographic factor that explained self-esteem was marital/partnership status (being in a relationship was helpful). Also men had higher self-esteem than women. Those with higher levels of education, and those working or studying, had higher self-esteem than those who did not.

Conclusions: Deafness and partial deafness appear to be risk factors for lower self-esteem, a finding that rehabilitation, medical, educational, and employment communities should be made aware of. Medical intervention in the form of a CI supplies the person with improved hearing, but it is not a panacea: their self-esteem is still vulnerable, and reinforcement of self-esteem is an aspect that professionals should focus on. Psychological, psycho-educational, and psychotherapeutic interventions have important roles to play for CI recipients.

Does Auditory Processing Predict Comprehension in Children with Language Disorders?

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Objectives: We examined the relation between auditory processing abilities and narrative language comprehension in children with developmental language disorder (DLD). Studies have suggested that children with DLD and children suspected to have auditory processing disorder are remarkably similar in

their cognitive-linguistic profiles. We predicted that auditory processing abilities in children with DLD may be compromised and may contribute to their language comprehension deficits.

Design: Children with DLD (N=216) were assessed on multiple auditory processing and language measures as part of a larger randomized controlled intervention project. The children were recruited through informational flyers sent out through the schools. Children qualified for the study based on performance on a battery of tests. Inclusionary criteria were nonverbal IQ standard scores above 75 (to rule out intellectual disability) and standard scores of 81 or below on two or more clusters of the Test of Language Development. Exclusionary criteria were hearing loss, visual impairment, gross neurological impairment, oral-structural anomalies, or emotional/social disorders. Children with 3 or more episodes of otitis media within 12 months or history of neurological or other disorders were excluded. The participants were between 6- to 8 years 11 months (Mean = 7;6). Children were administered multiple language and auditory processing tests pre-intervention, immediately after intervention, and at 3- and 6-months post-treatment. For this study, children's data from pre-treatment were analyzed to model the relation between auditory processing ability and children's narrative comprehension. The dependent variable was children,Äôs score on the narrative comprehension subtest of the Test of Narrative Language. Auditory processing measures included three psychoacoustic tasks (tone detection in simultaneous masking noise, tone detection in non-simultaneous backward masking, frequency sweep discrimination) and three speech perception in noise tasks (Hearing In Noise Test for Children - speech perception in diotic noise, speech perception in dichotic noise to the right ear and to the left ear). A non-word repetition task indexed phonological short-term memory capacity. Age and nonverbal IQ were control variables.

Results: Correlation analysis revealed that children's narrative comprehension was positively correlated with all measures of auditory processing when controlling for age and nonverbal IQ. A multiple linear regression analysis was conducted to evaluate the extent to which the psychoacoustic and speech in noise tasks predicted language comprehension over and above age, nonverbal IQ, and phonological working memory. Age and nonverbal IQ contributed to 36.4 % variance in narrative comprehension ability and nonword repetition contributed 5.8 % of the total variance. The psychoacoustic tasks did not contribute significant variance, but speech perception in noise contributed significantly over and above all the other predictors (5.9%).

Conclusions: Auditory processing skills measured using psychoacoustic tasks were correlated with speech perception in noise but did not explain significant amounts of variance in children's narrative comprehension. However, speech perception in noise ability uniquely explained a significant amount of children's narrative comprehension ability even after controlling for developmental maturation (age and nonverbal IQ), working memory, and acoustic perception. These findings make a compelling case for the functional implications of adverse listening situations for children with DLD.

Auditory and Demographic Factors Affecting Word Learning in Children (and Adults)
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Objectives: To learn a new word, the acoustic properties of the word must be associated with a referent. In most cases, multiple exposures to the word and referent are necessary to encode a robust representation of the word in memory. The underdeveloped vocabularies of children with hearing loss suggests that the process of linking a word with its referent may be impaired or the representation of the

new word in memory may be degraded, or both. Adults with hearing loss may experience similar learning difficulty when encountering new information in daily life. In this presentation, the results of multiple experiments from the Pediatric Amplification Lab at Arizona State University will be reviewed to identify auditory and demographic factors that do and do not affect word learning in children and adults.

Design: In each of six studies, the same rapid-word learning task was used to assess listeners,Äô ability to correctly associate auditorily presented nonsense words with their referents (i.e., novel pictures) through a process of trial and error. Novel pictures were displayed on response buttons located below a reinforcement area on a computer screen. After presentation of a randomly sampled word, the listener selected one of the pictures. If the correct picture was selected, a video-type game in the reinforcement area advanced one step (e.g., a puzzle piece appears). If an incorrect picture was selected, no reinforcement was provided. To succeed at this task, the listener must hold the outcome of previous correct and incorrect responses in memory until they are able to pair each word with the correct picture.The correct/incorrect responses to 100 to 150 trials administered in each study were averaged in 10-trial bins and fitted with a regression function. Learning speed was expressed as the log of the number of trials needed to achieve the criterion performance. For each study reviewed, the number of trials require to achieve a criterion level of 71% correct performance was selected. This performance criterion represented the threshold of learning for this task. Trials to criterion was log-transformed and limited to no more than 1000 trials to express performance in terms of learning speed.

Results: No benefit was observed for: 1) word learning experience (adult vs. child), 2) enhanced auditory precision following extensive musical training, or 3) breadth of word-learning resulting from bilingualism. However, significant effects of bilateral hearing loss, unilateral hearing loss, and background noise were found as well as benefit from certain amplification features. Finally, preliminary data from a current study suggest that children with hearing loss have more difficulty recalling words they learned the next day than their normally hearing peers.

Conclusions: Together, these studies suggest that uncorrected hearing loss presents the greatest barrier to learning new words through auditory input while corrected hearing loss with amplification can improve learning significantly for both children and adults. However, corrected hearing loss does not yet appear to be sufficient to assist with word learning in noise or with retention of learned words.

Remote-Microphone Benefit in Noise and Reverberation for Children with Hearing Loss

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Objectives: The primary goal of this study was to determine if a recently developed remote-microphone system improved the signal-to-noise ratio for speech recognition in noise and in noise plus reverberation over hearing aids alone for children with hearing loss. Hypothesis: Noise plus reverberation will have a greater effect on speech recognition than noise alone and remote-microphone benefit would be evident in both conditions. A secondary goal was to examine the relationship in performance of children with hearing loss using hearing aids alone or hearing aids plus a remote-microphone system to that of peers with normal hearing in two acoustic environments. Hypothesis: Use of a remote microphone will result in performance for the children with hearing loss that is similar to that of children with normal hearing in the same condition.

Design: Twenty typically developing children with mild to severe hearing loss (7-18 years) participated. Data collection from 20 age-matched children with normal hearing is ongoing. Participants were recruited from the Boys Town National Research Hospital Human Research Subjects database and the Clinical Audiology Department. Each child was fitted with Oticon Opn Play hearing aids that were individually adjusted for their degree and configuration of hearing loss. An Oticon EduMic remote-microphone system was used with the hearing aids for that portion of the test procedure.Testing was conducted in a sound-treated booth. Eight loudspeakers were arranged around the participant every 45o. Speech was presented from the loudspeaker at 0o azimuth and speech-shaped noise was presented from the remaining seven loudspeakers. An adaptive task was used to evaluate the signal-to-noise ratio at which the children scored 50% on a sentence recognition task (SNR50). Testing was completed under two device conditions (hearing aids only; hearing aids plus remote microphone) in two simulated acoustic environments (noise only; noise plus reverberation). Speech was presented at 60 dB SPL. A reverberation time of 400 ms was used for testing in noise plus reverberation.

Results: Children with hearing loss had poorer sentence recognition in noise plus reverberation than in noise alone. Sentence recognition in both acoustic environments improved with the remote microphone relative to hearing aids alone. Children with better audibility through the hearing aids exhibited better performance overall. There was a significant interaction between reverberation and audibility, suggesting that children with better audibility had an even lower SNR50 in noise plus reverberation relative to those with poorer audibility than in noise alone. The absence of a significant interaction between audibility and use of the remote microphone suggested that its benefit was similar across degree of hearing loss. Comparisons between children with hearing loss and peers with normal hearing will be reported.

Conclusions: Results from this study support the extant literature indicating positive speech understanding benefits from the use of remote-microphone technology for children with hearing loss. This benefit can be seen in noise alone and in noise plus reverberation. For these children, the benefit from a remote microphone is similar across degree of hearing loss.

Family Functioning Differentially Influences Language in DHH and NH Children

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Objectives: Dimensions of family functioning that influence developmental outcomes in children have been widely acknowledged for nearly 30 years. The dimensions are similar in families with typically developing children and with chronically-ill children (Kronenberger & Thompson, 1990). Because the mode through which family dynamics are conveyed - communication - is disrupted in families of deaf and hard-of-hearing (DHH) children, we hypothesize that family functioning dimensions might be differently organized in families of DHH children. Moreover, we hypothesize that the contribution of family functioning to spoken language outcomes will be stronger in DHH than normal-hearing (NH) children, because of DHH children's higher risk for spoken language delays, similar to findings on parental stress and child language.

Design: Primary caregivers of 65 NH (mean child age = 5.8 yr) and 63 DHH (mean child age = 6.3 yr) children completed the Family Environment Scale (FES), a psychometrically rigorous 90-item, true-false questionnaire of family functioning consisting of 10 subscales. There were no significant or meaningful differences between the two groups on child age and gender, or parental gender and education. Children's receptive vocabulary and spoken language were measured with the Peabody Picture Vocabulary Test (PPVT-4), the Following Directions/Concepts and Following Directions subscale of the Clinical Evaluation of Language Fundamentals (CELF-5/P), and the Sentence Comprehension subscale of the Comprehensive Assessment of Spoken Language (CASL-2) in their home.

Results: Three FES components were extracted using principal components analyses with promax rotation of the 10 FES subscale T-scores separately for the NH and DHH samples. Within each sample, the three components resembled those derived by Kronenberger and Thompson (1990) - Controlling, Supportive, and Conflicted - with some differences in component composition between the NH and DHH samples. FES components based on data from families of NH children were more similar to Kronenberger and Thompson's FES components than were FES components based on data from families of DHH children. Regression analyses revealed that for NH children, the FES factors only contributed to CASL-2 sentence comprehension scores (p = .008), with higher scores on the Conflicted dimension accounting for the significant association (Œ≤ = .400, p = .008). In contrast, regression models predicting PPVT-4 and CASL-2 scores were statistically significant for the DHH sample (ps&l .004), with all three FES components contributing to the significant association (ps< .039). Two FES components contributed significantly to CELF-5/P scores in the DHH sample (ps< .041).

Conclusions: The specific composition of three well-established dimensions of family functioning differed in families of DHH children relative to NH children. Moreover, family functioning was more strongly associated with spoken language outcomes in DHH children compared to NH children. In this population of vulnerable spoken-language learners, family environment played a particularly important role in fostering the development of spoken language.

PODIUM SESSION V: TRAUMA, TINNITUS, ETC.

Effectiveness of Three Telephone Hearing Screening Protocols in Primary Care

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Objectives: Hearing loss affects millions of Americans with prevalence increasing with age. Recent estimates indicate that 25% of adults aged 65-74 years and 50% of adults 75+ years of age have hearing loss that interferes with communication. Untreated hearing loss has been shown to be associated with increased communication difficulties, increased risk of dementia and cognitive decline, increased falls risk, depression, social isolation, and reduced quality of life. Despite the known impacts of untreated hearing loss, hearing screenings are not routinely performed in primary care (PC) clinics due to lack of established effectiveness, time constraints, uncovered cost, and other unknown reasons. The goals of this NIH-funded study were to compare compliance and follow-through using three screening protocols that

differed in levels of clinic support (i.e., physician encouragement and access to in-clinic or at-home self-administered telephone screening tool). It was hypothesized that screening compliance and follow-through would be highest in the group that received PC physician encouragement and given access to complete the hearing screening in the office.

Design: Three groups of participants 65-75 years of age without a previously diagnosed hearing loss (n = 220 each) were recruited from 6 PC clinics around Durham, NC. Group 1 participants were provided printed information about the phone screening to do at home, but no PC physician encouragement; Group 2 participants were provided printed information about the phone screening with PC physician encouragement to complete at home; and Group 3 received PC physician encouragement and access to complete a telephone hearing screening in the office. The primary outcome for each group was the percentage of patients who completed screening. Secondary outcomes were the percentage of screening failures who scheduled and completed (1) diagnostic evaluations and (2) intervention plans.

Results: Among enrolled participants, 99.5% of Group 3 participants completed the hearing screening whereas compliance was 25.5% and 19.5% of Group 2 and Group 1, respectively. Among participants who completed screening, 97.6% failed the screening in Group 1, 93.0% in Group 2, and 54.7% in Group 3. The percentage of those who failed the hearing screening and subsequently scheduled and completed a diagnostic evaluation was 59.5%, 41.5% and 49.2% in Group 1, 2, and 3 respectively. Of those, the percentage who completed intervention plans was 33%, 29%, and 41%, respectively. Treatment recommendations were at the discretion of the hearing healthcare professional and could include no treatment. Interestingly, when hearing aids were recommended, audiologists recommended them nearly twice as often as otologists.

Conclusions: The study results showed that PC physician encouragement was not a significant factor on follow-through with hearing screenings protocols analyzed or the proportion of patients who failed the screening who 1) scheduled and completed a formal diagnostic evaluation, or 2) implemented a treatment plan. Thus, physician encouragement was not an important driver of compliance with these hearing healthcare recommendations for Group 1 or Group 2, although nearly all Group 3 participants completed the in-office hearing screenings. Clinical implications of this work support the availability of hearing screenings for older adults in PC offices.

Blast Exposure and Self-Reported Hearing Difficulty: Mediating Role of PTSD

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Objectives: There is evidence that military blast exposure leads to self-reported hearing difficulties even among individuals with audiometrically normal hearing, yet research identifying potential mechanisms remains limited. Understanding speech in noise requires an intact auditory system and top-down cognitive processing including working memory and attention. Veterans exposed to blasts are often diagnosed with post-traumatic stress disorder (PTSD), which involves alterations to these cognitive processes. Thus, PTSD may mediate (i.e. an intermediate mechanism explaining) the effects of blast on

self-reported hearing difficulty among Service members and Veterans with normal hearing. The objectives of this study were to examine, in a group of normal hearing Service members and Veterans: a) the association between blast exposure and self-reported hearing difficulty; b) the association between PTSD and self-reported hearing difficulty; and c) the extent to which the effects of blast exposure on self-reported hearing difficulties are due to PTSD.

Design: Participants in the Noise Outcomes in Servicemembers Epidemiology (NOISE) Study completed baseline questionnaires to assess demographic and military service characteristics, blast exposure, PTSD symptoms, self-reported hearing difficulty, and auditory function. The analytic cohort was limited to individuals with normal pure tone thresholds (<20 dB HL) from 250-8000 Hz (n=411). Using logistic regression, we examined associations between blast exposure and self-reported hearing difficulty and between PTSD symptoms and self-reported hearing difficulty. Next, we performed a formal causal mediation analysis to estimate the effect of blast exposure on self-reported hearing difficulty and the extent to which the effects are mediated by PTSD. Based on an a priori causal model, logistic regression models were adjusted for key demographic and military service characteristics. Adjusted odds ratios (OR) with 95% confidence intervals (CI) are reported, along with the estimated percent of the observed association mediated through PTSD.

Results: Of the 411 participants, 26% reported a military blast exposure, 24% had PTSD symptoms, and 11% were identified with both. Another 22% reported hearing difficulty (Hearing Handicap Inventory for Adults score > 16). Compared to study participants without military blast exposure, those with blast exposure were 2.7 times (95% CI: 1.4-5.1) more likely to report difficulty hearing. Compared to study participants without PTSD symptoms, individuals with PTSD symptoms were 4.5 times (95% CI: 2.5-8.2) more likely to report difficulty hearing. Approximately 39% (8-70%) of the blast exposure effect on self-reported hearing difficulties could be attributed to PTSD symptoms (p=0.01).

Conclusions: We identified a greater proportion of Service members and Veterans with self-reported hearing difficulty among those with PTSD symptoms, compared to those without PTSD symptoms, while controlling for potential confounders. Formal causal mediation analysis suggests that some of the self-reported hearing difficulty in Service members and Veterans with blast exposure may be in part due to PTSD. However, the percent mediated confidence interval is wide; more data and longitudinally structured data would yield a more precise estimate. Nonetheless, our current findings have implications regarding mental health screening and treatment needs among Service members and Veterans with normal hearing but self-report hearing difficulty.

Impact of Noise on Manganese Uptake Following Otolith Stimulation

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Objectives: Loud noise impacts a variety of systems and has a broad range of effects often dependent upon the frequency, duration, and level. Pervasive noise can damage auditory, cardiovascular, and vestibular pathways with subsequent increased risk for hearing loss, tinnitus, high blood pressure, as well as trips, and falls, each of which can decrease the quality and/or length of life. Not only can noise-induced injury occur peripherally, but central pathways can also be affected. Specifically, loud noise can impact vestibular pathways and function but frequently may go unnoticed because people do not often relate vestibular symptoms (ie., dizziness, imbalance, poor postural control) with noise exposure or

symptoms may not appear until challenged. Measuring changes in central pathways and identifying individual nuclei that may play a role in noise-induced dysfunction can be challenging. We have previously used manganese-enhanced magnetic resonance imaging (MEMRI) to evaluate neuronal activity in central pathways related to linear acceleration. This study applies MEMRI to the assessment of the effect of loud, low-frequency noise on the activity of neurons responsive to linear acceleration.

Design: Baseline MRIs (no manganese) were obtained for each adult male Sprague Dawley rat (n = 10). Additionally, baseline functional assessment of vestibular pathways was collected (vestibular short latency evoked potentials -- VsEPs) during linear acceleration. Animals were divided into noise and no noise groups. The noise group was exposed to a 3 octave band noise centered a 1.5 kHz at 120 dB SPL for 6 hours. After 24 hours noise exposed animals and age matched controls were anesthetized and administered manganese chloride (66 mg/kg i.p.). Immediately afterward they were exposed to linear acceleration (jerk stimulus 3,000 up and 3,000 down) in the naso-occipital plane at either 500g/s or 2500 g/s, over a period of 30 minutes. Manganese uptake is quick (within 45 minutes) while efflux from cells is slow (1 - 2 weeks). In vivo imaging was performed (Bruker 7T MRI scanner) 24 hours after manganese chloride administration and vestibular stimulation. Regions of interest were assessed for five rostral nuclei (LVe - lateral vestibular, MVeMCr - magnocellular medial vestibular, MVePCr - parvocellular medial vestibular, SuVe - superior vestibular, VeCb - vestibular cerebellar) and three caudal nuclei (MVeMCc - magnocellular medial vestibular, MVePCc - parvocellular medial vestibular, SpVe - spinal vestibular).

Results: After the noise exposure, each vestibular region took up manganese. The milder stimulus (500 g/s) resulted in significantly more manganese uptake in the noise-exposed group when compared to the stimulated non-noise exposed group. Conversely, the stronger stimulus (2,500 g/s) resulted in less Mn2+ uptake in the noise-exposed group compared to the non-noise exposed group ($p < 0.05$). In seven of the eight brain regions analyzed, the 500 g/s stimulated noise-exposed group took up significantly more Mn2+ than the 2,500 g/s stimulated noise-exposed group ($p < 0.05$. The SuVe nucleus was the exception with no significant difference between stimulation groups that had been noise exposed.

Conclusions: Loud noise differentially affects manganese uptake depending upon the intensity of the linear acceleration and region of interest. Our results suggest that noise can change neuronal activity in central vestibular related pathways. The duration of these changes in neuronal activity and how they correlate with VsEP amplitude and latency remain to be determined.

Sound-Evoked Cortical Activity Suggests Incomplete Adaptation to Hearing Loss in Tinnitus

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Objectives: Hearing loss and tinnitus have been associated with plasticity in the central auditory system. Specifically, tinnitus has been related to changes in the tonotopic maps of auditory brain centers. This

study investigates sound-evoked activity and tonotopy in the auditory cortex in relation to hearing loss and tinnitus.

Design: A functional magnetic resonance imaging (fMRI) study was conducted in 90 participants. Three groups were included: (1) participants with tinnitus and high-frequency sensorineural hearing loss (n=35). (2) participants with hearing loss matched to group 1, but no tinnitus (n=17), (3) control participants with neither tinnitus nor hearing loss (n=38). Sound-evoked activity was measured in response to tones with frequencies from 0.25 to 8 kHz, in 1 octave steps. For each participant, the tone levels were matched in loudness to a 1-kHz tone at 40 dB SPL. Brain activity was assessed in the left and right auditory cortex using fMRI.

Results: In both hearing loss groups, the response to the 8-kHz tone was larger than in the control group. The 8-kHz responses were largest in the hearing-impaired subjects without tinnitus. No significant differences were present at lower frequencies. Correspondingly, higher frequencies were over-represented in tonotopic maps of the cortex in the groups with hearing loss compared to controls, more so in the group without tinnitus than in the group with tinnitus. Thus, both in terms of response amplitudes and tonotopic map layout, the tinnitus subjects were intermediate to the controls and the hearing-impaired participants without tinnitus.

Conclusions: Tinnitus is often considered to be associated with exacerbated plasticity in the central auditory system. In contrast, our results suggest that tinnitus may be associated with incomplete cortical adaptation to hearing loss. Thus, tinnitus treatments may need to promote plasticity.

Combined Sound and Trigeminal Nerve (Tongue) Stimulation to Treat Tinnitus

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Objectives: Tinnitus affects 10-15% of the population. Unfortunately, there are limited treatment options. Recent animal research and pilot human studies have demonstrated the ability to drive extensive auditory plasticity and potentially treat tinnitus by pairing sound with trigeminal or somatosensory nerve activation, such as with tongue stimulation. A non-invasive device (Lenire) using auditory and tongue (bimodal) stimulation was evaluated in two large randomized and blinded clinical trials in over 500 participants with tinnitus in Ireland and Germany.

Design: The first study (TENT-A1) investigated three stimulation settings (PS1, PS2, PS3) presented for 12 weeks (60 minutes recommended per day) and evaluated during treatment and up to 12 months post-treatment (326 enrolled participants). Primary outcome measures included the Tinnitus Handicap Inventory (THI) and Tinnitus Functional Index (TFI). The second study (TENT-A2) investigated different stimulation settings over time across four treatment arms (191 enrolled participants). The first treatment arm consisted of the most effective stimulation setting from TENT-A1 during the first 6-weeks

(PS1) followed by a new bimodal stimulation setting during the second 6-weeks (PS4). The second and third arms consisted of different bimodal settings than the first arm, while the fourth arm consisted of an acoustic only condition during the first 6-weeks followed by a bimodal condition during the second 6-weeks.

Results: All three stimulation settings in TENT-A1 resulted in statistically significant improvements in tinnitus for THI ($p<0.0001$) and TFI ($p<0.0001$) that were also clinically significant (>7 THI points, >13 TFI points). Post-treatment, PS1 resulted in persistent improvements lasting 12 months after treatment ceased ($p<0.0001$). The treatment was safe and well-tolerated with a high compliance rate (84%; >36 hours of usage). The largest therapeutic effects occurred within the first 6-weeks. In TENT-A2, similar results were observed for PS1 during the first 6-weeks as in TENT-A1. Changing the stimulation setting from PS1 to PS4 led to a greater improvement ($p<0.001$) than observed in TENT-A1 that also persisted for 12 months post-treatment. Post-hoc analyses showed that different bimodal stimulation settings over time could be as effective as the PS1-to-PS4 condition and that specific bimodal stimuli consistently outperformed the acoustic only condition for both THI and TFI.

Conclusions: Overall, these findings demonstrate that the Lenire bimodal treatment provides safe, fast-acting (within 6 weeks) and reproducible therapeutic effects that can last at least 12 months. Furthermore, adjusting the stimulation settings over time can drive greater therapeutic effects.

Internet-based Cognitive Behavioral Therapy (ICBT) for Tinnitus in the U.S.

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Objectives: Although tinnitus is one of the most commonly-reported symptoms in the general population, patients with bothersome tinnitus are challenged by issues related accessibility of care, and intervention options that lack strong evidence to support their use. Therefore, creative ways of delivering evidence-based interventions are necessary. This presentation focuses on the adaptation of an Internet-based Cognitive Behavioral Therapy (ICBT) intervention, originally used in Sweden and in the UK, for individuals with tinnitus in the United States. Elements of the ICBT program requiring consideration included (a) adaptations to the platform's features and functionalities, (b) translation into Spanish to extend the reach of the program (c) user acceptability and satisfaction of the program, (d) outcomes from a pilot trial from which it was hypothesized that patients would demonstrate a reduction in tinnitus distress and associated difficulties as measures using standardized self-reported outcome measures, and (e) discussion of the relative merits and appropriateness of the intervention.

Design: The iTerapi platform developed in Sweden was adopted for use in the US. The platform required functional and security features modifications to confirm its compliance with both institutional and governmental regulations, and to ensure it was suitable for the US population. Acceptability and suitability of the materials were evaluated by both hearing healthcare professionals (n=11) and

individuals with tinnitus (n=8). A pilot study followed as adults with bothersome tinnitus completed the 8-week program (n=30).

Results: Cultural adaptations included word substitutions, adapting counseling examples for a US population, and modifying the spelling of certain words. The materials were then translated into Spanish and cross-checked. Professional review ensured the suitability of the chapters. Literacy level analysis confirmed all chapters were within the guidelines to be below the 6th grade level for readability. Healthcare professionals and individuals with tinnitus reported favorable acceptance and satisfaction ratings regarding the content, suitability, presentation, usability and exercises provided in the ICBT platform. Preliminary analyses of pilot data indicated a reduction in tinnitus distress and associated difficulties (i.e., anxiety, depression, insomnia) and an improvement in quality of life.

Conclusions: Ensuring that the ePlatform offers the appropriate features and functionalities for the intended population is an essential part of developing Internet-based intervention. The user evaluations and pilot trial outcomes indicated that clinical trials can be performed to assess the effectiveness of ICBT for tinnitus in the US.

Text-mining for Cohort Ascertainment and Analysis of Patients with EVA

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Objectives: To develop text-mining approaches to ascertain patients with enlarged vestibular aqueduct (EVA) and to use computational methods to analyze the cohort.

Design: A significant source of clinical data can be found in clinical notes that are difficult to access using traditional computer approaches. Not only do these text fields pose technical challenges to data input, they are typically rife with personal health information (PHI) that needs to be protected. To overcome this limitation, new technologies are being developed that liberate the data from the challenges of data entry and privacy concerns. The science team of the Audiological and Genetic Database (AudGenDB) is developing text-mining techniques using regular expression (regex) and natural language processing to extract knowledge from clinical notes for hearing researchers. Here, we discuss text-mining approaches developed to identify and analyze patients with EVA. Normally, specific diagnoses can be searched by a designated code in the International Classification of Diseases (ICD) vocabularies. However, because EVA is not identified by a specific code, our team has taken two approaches to identifying EVA patients: 1) maintaining a list, which is labor intensive; and 2) developing a regex algorithm to search radiology reports that describe EVA. The challenge for identifying EVA patients from radiology reports is the diversity of language used to describe the condition. Even the term for the structure that is enlarged is not consistent; both "vestibular aqueduct" and "endolymphatic sac" are used. As a general solution to these search challenges, computer scientists have developed regex, which uses a functional vocabulary of search terminology that can accommodate several alternative word structures.

Results: By assembling a search library of regex terms specific for EVA, we have succeeded in identifying 206 radiology reports from 190 patients with EVA within a library of 13,289 anonymized radiology

impressions from 6,255 patients from the Children's Hospital of Philadelphia in the AudGenDB resource. Together with the lists maintained at Boston Children's Hospital and Vanderbilt University, we assembled an EVA cohort of 344 patients, the largest that we have found in a single study of this condition. To identify patients with progressive hearing loss (PHL) within the EVA cohort, we developed algorithms that examine PTA4 as a function of patient age and found that 37% of our EVA cohort progressed. Algorithms were also developed to identify patients with fluctuating hearing thresholds. We will discuss the outcomes of these fluctuating patients, who constituted 23% of the cohort. Finally, we have developed mathematical models of hearing as a function of age in this population and used K-means clustering to categorize these hearing progression curves.

Conclusions: We are using text-mining approaches to facilitate EVA cohort ascertainment and analysis; we will present details of the approach and analyses of this large EVA cohort at the meeting. These data represent the first steps in our long-term goal to develop computational methods to evaluate hearing outcomes and machine learning approaches to predict outcomes in EVA - and more broadly - PHL patient cohorts.

A Community Health Worker (CHW)-Led Initiative to Support Children with SNHL

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Objectives: Early detection and follow up for children with hearing loss prevent delays in speech, language, and social/emotional development. Developed in 2018, the Pediatric CHW program is a collaboration between an academic-medical center and a community-based organization (CBO). The program's objective is to connect children with hearing loss to a bilingual CHW that will identify challenges with adherence and connect families to resources.

Design: Eligible caregivers that have challenges with appointment adherence are referred to the program by a pediatrician, audiologist, or speech pathologist. CHWs, employed by a CBO, are trained in early intervention (EI), special education, and cochlear implants. The program includes longitudinal support from diagnosis to enrollment in EI. CHWs asses for social determinants during a home visit, accompany caregivers to medical and school appointments, and meet with providers to inform care plans.

Results: A multidisciplinary team (CHWs, otolaryngologists, audiologists, and speech/education specialists) have developed referral workflows and implemented rounding processes. To date, CHWs have worked with 22 families. Of these 59% (n=13) were referred to EI connecting children to preschool education. Additionally, 27% (n=6) were found to have food insecurity. CHWs assisted 45.5% of families (n = 10) with SSI.

Conclusions: Integration of CHWs into a multidisciplinary team working with children with hearing loss improves outcomes and aids in overcoming social impediments to care.

PODIUM SESSION VI: POPULATION HEARING HEALTH

Associations Between Dementia and Hearing-aid Use in 100,000 Hearing-aid Users

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Objectives: To examine associations between rates of incident diagnosed dementia post hearing-aid fitting and long-term persistence vs. non-persistence with hearing-aid use.

Design: All (N=375,379) patients fitted with hearing aids in the VA healthcare system between April 2012 and September 2013 formed the initial sample. Of these, 100,071 were first-time hearing-aid users with PTA data and free of a dementia diagnosis at October 1, 2015. For these patients, we examined rates of incident diagnosed dementia between October 2015 and December 2017. Logistic regression analysis was used to predict the probability of receiving a diagnosis of dementia, using factors including age, average pure-tone threshold, persistence of hearing-aid use on October 1 2015 (i.e., at least one battery order in the period 2014/01/01-2015/09/30), and other previously identified risk factors for dementia (obesity, depression, bipolar disorder, stroke, hypertension, diabetes).

Results: After controlling for other major risk factors, persistence of hearing-aid use was associated with reduced post-fitting incidence of dementia (Odds Ratio 0.86; CI 0.80-0.93, p=0.0001).As a control, we carried out the same analysis for a separate (non-overlapping) patient sample, created by shifting the sampling and observation dates. The results were very similar.The prevalence of dementia in our initial sample was markedly lower than that reported for VA patients as a whole, suggesting that patients with (and thus potentially also those approaching) a dementia diagnosis are less likely to be fitted with hearing aids than those without a dementia diagnosis.

Conclusions: This is an observational study, therefore we cannot conclude there is a causal relationship between persistent hearing-aid use and risk of dementia. The alternative explanation ‚Äì that patients with or approaching dementia are less often fitted with hearing aids ‚Äì cannot be dismissed.Whichever explanation is correct (and both may be), this analysis provides the justification to carry out further research. While large-scale studies are ongoing to determine whether hearing-aid use can mitigate cognitive decline, it may be equally important to consider how access to amplification might be encouraged, and then be provided in a more dementia-friendly form, for those already suffering cognitive decline.

Assessing Hearing Loss-Specific Health Literacy May Improve Access to Healthcare

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Objectives: Although hearing loss is the third most common chronic condition in older adults, it is often neglected as part of aging. Many people, especially those with low health literacy, are not aware of the serious negative outcomes associated with untreated hearing loss, which places them at risk for increased health burden and reduced quality of life. Health literacy is a key parameter to measure individuals' ability to "obtain, process, and understand basic health information and services needed to make appropriate health decisions." Low health literacy is a significant barrier to the use of existing effective healthcare services. While measures of general health literacy exist, there are no such measures available to assess hearing loss-specific health literacy. A condition-specific health literacy assessment

tool will be advantageous when it is applied to individuals who need to obtain further education and care for a certain condition. The purpose of the study is to provide pilot data for developing a comprehensive health literacy assessment tool specific to hearing loss for adults (Hearing Loss Health Literacy Assessment Tool; HL-LAT).

Design: This is a cross-sectional study. Preliminary data were collected from adults throughout Metro Detroit (n = 55; age range:18-82 yrs; female = 31). We expect to collect approximately 200 participants for the study to rigorously test the psychometric properties of the HL-LAT. The preliminary tool has both self-assessed and professional-assessed components. We used a conceptual framework of health literacy to design the self-assessed component of HL-LAT. This component has a total of 34 items with four subscales to self-rate the ability to obtain, understand, appraise, and apply hearing health information to manage hearing loss. The total score is the average score across all items with item responses ranging from 0 to 10. We further adapted the Rapid Estimate of Adult Literacy in Medicine (REALM) to create the professional-assessed component - the Rapid Estimate of Adult Literacy in Audiology (REALA). The REALA is a reading recognition test that requires participants to read hearing health/audiology-related terms aloud. Each item on the REALA is scored 'correct' or 'incorrect' based on the participant's ability to accurately pronounce the target word. We will use two established instruments to measure general health literacy to cross check the validity of the HL-LAT.

Results: Based on the preliminary data, it appeared that the ability to obtain hearing health information was rated the lowest compared to other abilities. The Cronbach's coefficient Œ± and the item-total correlation coefficients will be reported to assess the internal reliability. The difficulty and sensitivity of individual words for discrimination of hearing health literacy will be analyzed across participants.

Conclusions: The preliminary results highlighted the weak areas that hearing health professionals need to target for improving access to hearing health care. We expect the results of the proposed study to provide a solid foundation to develop the final version of the HL-LAT. Once the tool is fully developed, it will allow hearing health professionals to identify patients with needs and provide individualized service for those with hearing loss.

Patient Education Materials for Age-Related Hearing Loss: Issues and Solutions

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Objectives: Age-related hearing loss (ARHL) introduces a considerable public health burden. However, treatment of ARHL is often neglected as part of aging. There is an urgent need to increase public awareness of hearing loss and associated serious negative outcomes associated with this chronic condition. Both electronic health record (EHR) systems and professional organizations which specialize in communication sciences and disorders (CSD) can provide relevant information for individuals with hearing loss. Particularly, EHR systems have been equipped with easily accessible patient education materials (PEMs) for dispensation to patients at the point of care to help support primary care providers with referrals and education. It should be noted that the average adult in the United States reads at the eight- or ninth-grade level and only an estimated 12 percent of adults can effectively read and understand health information. Therefore, it is vital to provide appropriate and effective educational materials that highlight the risk factors, signs, symptoms and treatment options of ARHL. We speculated that the lack of accessible and effective educational materials could be a key contributing factor to explain why individuals with ARHL are underserved. The effectiveness of written health materials can be

analyzed using readability and suitability tools. As a result, an investigation of the readability and suitability of the materials supplied by popular EHRs is warranted, as health care providers often rely on and dispense these materials without enough time to carefully review the information. In addition, it is also important to evaluate the readability and suitability of the materials from the CSD professional organizations as well. The objective of this study was to explore and compare the readability and suitability of PEMs on topics of ARHL supplied by both EHR systems and CSD organizations.

Design: PEMs on ARHL were identified through a computerized search of EHR databases and CSD organization websites. Selected PEMs were assessed using three readability indices as well as the Suitability Assessment of Materials (SAM), which is a standardized tool to assess the content and design of written materials. Ten PEMs from EHR databases and 17 PEMs from CSD organizations were analyzed.

Results: 66.7% of PEMs were written above the 8th grade readability target. PEMs from CSD organizations were significantly more difficult to read compared to those from EHR databases. 85.2% of PEMs were classified as 'adequate' using the SAM analysis. No significant SAM score differences were found between PEMs from CSD organizations and those from EHR databases. Common areas of weakness among PEMs were 1) failure to include a summary of key information, 2) reading level and 3) vocabulary too advanced for the intended audience, and 4) limited subdivision of complex topics.

Conclusions: The readability and suitability of PEMs on topics of ARHL supplied by EHR providers and CSD organizations are not supportive of the health literacy skills of the average U.S. adult. It is critical to improve the readability, suitability, and comprehensibility of PEMs on ARHL to make information about hearing healthcare more accessible and usable.

Affordability of Hearing Aids for Hearing Help-Seekers with Low Incomes

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Objectives: Only one out of five with hearing loss seeks assistance for communication problems through amplification. Although more than half of the states in the US provide some hearing healthcare coverage for adults, Oklahoma does not provide hearing aids through Medicaid or Medicare leaving the elderly and the disadvantaged to pay out-of-pocket for amplification and associated services. Our aim was to apply healthcare economic analyses to applicant income data reported to a community hearing aid bank to determine the affordability of amplification for unserved and underserved hearing help-seekers. We hypothesized that average-priced hearing aids at $2,372/each and even lower would not be affordable for this population.

Design: The impoverishment and catastrophic economic analyses were applied to income data reported by a cross-section of 396 applicants to a community hearing aid bank in Central Oklahoma from 2015 to 2018. Briefly, the impoverishment approach calculated the proportion of the sample that would enter poverty (e.g., 1.0, 1.3, and 1.5 times the United States Federal Poverty Level [FPL]) for the year after deducting the hearing aid purchase price from annual income (adjusted for # in household).

Alternatively, the catastrophic approach determines the proportion of the sample for which the purchase would exceed a predetermined percentage of income (i.e., 3%, 5%, and 10%).

Results: The median annual income of the sample was $13,778 (Inter-Quartile Range: $9,645; $19,107). Ten observations were removed for the impoverishment analysis due to missing household data. The impoverishment analysis found that most applicants were below the FPL (51%, N = 201) and another 11.5% would fall below for the year as a result of the hypothetical purchase of an average price hearing aid at $2,367. Hearing aids priced at $1,500 and $1,000 would result in an additional 7.1% and 5.3% falling below the FPL as a result of purchase. Affordability of hearing aids improved at a price of $400 with only an additional 2% falling below the FLP.Using the catastrophic approach, an averaged priced hearing aid would be affordable for only a few applicants to the community hearing aid bank (99%, N=394) with the hypothetical purchase exceeding 3% of their annual incomes. Similarly, hearing aids priced at $1,000 and $1,500 would not be affordable for 94.9% (N = 378) and 98.7% (N = 391) of the sample, respectively. However, only about 50% (N = 198) and 67% (N = 265) would face financial catastrophe if having to purchase a hearing aid at $400 or $500, respectively.

Conclusions: The hearing-help seekers with low incomes could not afford a hearing aid at an average price of $2,372 per device. Additionally, they would not be able to afford hearing aids priced at $1,000 or $1,500. Affordability of hearing aids improved at price points of $500 and below. The State of Oklahoma and others without assistance should provide entry-level digital hearing aids for adults with hearing loss through their Medicaid/Medicare programs. Moreover, these data indicate that over-the-counter, direct-to-consumer devices be priced at $500 and below in order to improve the affordability of and accessibility to amplification.

RCT and Longitudinal Study of Entry-Level Amplification for Low-Income Adults

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Objectives: Untreated sensorineural hearing loss (SNHL) can result in the reduction of health-related quality of life, isolation, depression, and cognitive decline. Only one in five with SNHL seeks assistance for their communication problems through amplification. Some states do not provide hearing aids through Medicaid/ Medicare programs requiring disadvantaged adults to pay out-of-pocket for amplification and associated services. We conducted a three-year, randomized clinical trial and longitudinal study to determine the benefits from entry-level digital hearing aids for adults with low incomes (Median income = $13,778; Inter-Quartile Range: $9,645; $19,107) who participated in a community hearing aid bank. We hypothesized that these adults would achieve benefits from and satisfaction with these devices.

Design: The RCT randomly assigned 70 adults with mild and moderate SNHL to treatment and waiting list control groups who were administered at baseline (pre-fitting) the following outcome measures: Expected Consequences of Hearing Aid Ownership (ECHO), the World Health Organization Disability Assessment Schedule 2.0 (WHO-DAS 2.0), the Hearing Handicap Inventory for the Elderly (HHIE), and the Abbreviated Profile of Hearing Aid Benefit (APHAB). These outcome measures in addition to the

International Outcome Inventory for Hearing Aids (IOI-HA) and the Satisfaction with Amplification in Daily Life (SADL) were also administered at 8-weeks, 6-months, and 1-year post-fitting of hearing aids for all participants. Patients in the waiting list control group were fit with hearing aids after the RCT portion of the study. Variables were assessed for normality using Shapiro-Wilks tests.

Results: Seventy patients (35 control; 35 treatment) (M = 64.1 y) with mild and moderate SNHL (Four-Frequency PTA = 46 dB HL), roughly equivalent gender representation, and varied experience with amplification participated in the study. Patients with low-income had unrealistic expectations of hearing aids (ECHO). Analysis of Covariance with amplification experience as a covariate indicated significant interactions between group and measurement period indicating that those with entry-level digital hearing aids had significant reductions of participation restrictions (HHIE; $p<0.01$) and acoustic benefits (APHAB; $p<0.01$) compared to the control group. No significant interactions between group and measurement period were found for the WHO-DAS 2.0 composite scores. All 70 participants were satisfied (SADL) with and achieved significant benefit (IOI-HA) from their hearing aids. Positive outcomes were maintained at 6-months and 1-year post fit, although some outcome measures showed a slight decrease over time. Participants consistently wore their hearing aids between 4 and 8 hours/day. Self-efficacy for these patients for the advance handling of hearing aids and aided listening in noise was low.

Conclusions: Patients with low incomes need counseling regarding the realistic benefits derived from the use of amplification. Qualitative data indicated that counseling from a hearing healthcare provider during the trial period was important for these patients. Entry-level digital hearing aids provide a significant reduction of participation restrictions and acoustic benefits for these patients with mild and moderate losses. Patients were satisfied with their hearing aids. Benefits were maintained at 6-months and 1-year, although some outcome measures showed a slight decrease over time.

Hearing Loss, Cognition & Disparities in Care: Findings from ARIC-NCS

New Investigator Presentation

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Objectives: Although dementia and hearing loss are age-related and highly prevalent, little is known regarding the prevalence of hearing loss and hearing aid use among persons with dementia (PwDs). Current understanding is based on convenience samples primarily from specialized memory clinics. As hearing loss is increasingly recognized as a potentially modifiable risk factor for incident dementia with hearing care as a potential form of primary prevention, we must also consider the role of hearing care as tertiary prevention of dementia sequela. The Atherosclerosis Risk in Communities Neurocognitive Study (ARIC-NCS) is a large, prospective study of a population-based cohort from 4 U.S. community sites with audiometric and neurocognitive testing and bi-racial representation. We examined the prevalence of hearing loss and hearing aid use among older adults with cognitive impairment and whether cognitive status influences hearing aid use. We hypothesized that the prevalence of hearing loss is higher among older adults with cognitive impairment while hearing aid use is lower.

Design: We analyzed audiometric and hearing care data from ARIC-NCS Visit 6 (2016-2018). Participants underwent a full neurocognitive battery at visit 6, the same visit at which audiometric data were also collected. Participants with complete audiometric data and an adjudicated diagnosis of cognitively normal, mild cognitive impairment (MCI), or dementia were included in the analytical cohort (N=3,385). The primary reason for missingness was lack of complete audiometric data (N=375). Differences in participant characteristics by cognitive status were descriptively compared using Chi-square tests or one-way ANOVAs. We performed a series of logistic regression models to estimate the odds of hearing aid non-use by cognitive status.

Results: Prevalence of hearing loss was greater with increasing cognitive impairment (cognitively normal:64.7%; MCI:71.3%; dementia:83.3%). Prevalence of hearing aid use among those with hearing loss and cognitive impairment varied substantially by race (African Americans 7.2%; whites 32.8%). In a multivariable-adjusted model, cognitive impairment was independently associated with higher odds of non-use of hearing aids (MCI odds ratio (OR):1.4 (95% CI: 1.0-1.8); dementia OR:1.8 (95% CI: 1.2-2.9) versus cognitively normal). The strongest risk factor for non-use of hearing aids was race, where African American participants have almost a 5 times higher odds of not using hearing aids compared to whites (95% CI: 2.9-7.4).

Conclusions: Hearing loss is highly prevalent but vastly untreated among older adults with cognitive impairment, particularly African Americans. These estimates are some of the first population-based estimates of audiometric hearing loss among diverse older adults with adjudicated diagnoses of MCI or dementia. We found that cognitive impairment was independently associated with hearing aid use and that African Americans with cognitive impairment had the lowest rates of hearing aid use. With increased calls to address ethnic/racial disparities in Alzheimer's disease and related dementias, we must include hearing loss, as one of the most common co-morbidities among PwDs, to optimize the health and well-being of PwDs. Future research is needed to understand the role of hearing loss, specifically hearing care as a nonpharmacological intervention, in the prevention and management of behavioral and psychological symptoms among diverse PwDs.

Population-based Study of Hearing Impairment, Cognitive Performance and Beta-amyloid Deposition

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Objectives: Hearing impairment is a risk factor for dementia but the mechanism underlying this association is unknown. We investigated the relationship between hearing and cognitive performance and brain -amyloid deposition.

Design: Population-based cross-sectional study of 253 adults aged 72-93 years (38% black race, 61% female) without dementia from three U.S. communities. To measure amyloid deposition, standardized uptake value ratios (SUVRs) were calculated from florbetapir-positron emission tomography scans. A global cortical measure of florbetapir uptake was calculated as a weighted average of the orbitofrontal, prefrontal, and superior frontal cortices; the lateral temporal, parietal, and occipital lobes; the precuneus, the anterior cingulate, and the posterior cingulate. Amyloid deposition was defined as an elevated SUVR > the median value of the global cortical measure (median value=1.2), as well as the temporal lobe (median value=1.1), the location of the primary auditory cortex. A composite cognitive score was created from ten neuropsychological tests summarized using latent variable methods. Air conduction hearing threshold levels for the frequencies of 0.5, 1, 2 and 4 kHz were obtained by pure tone audiometry and averaged for the better-hearing ear to yield a pure tone average (PTA) in decibels hearing level (dB HL). Multivariable-adjusted linear and Poisson regression with robust standard errors were used to estimate the average difference in cognitive scores and prevalence of elevated SUVR, respectively, by hearing impairment status.

Results: 120 participants (47%) had elevated global cortical SUVR, and 124 participants (49%) had elevated temporal lobe SUVR. 157 participants (62%) had hearing impairment (PTA >25 dB HL). In analyses adjusted for age, sex, education and APOE 4 status, hearing was not associated with elevated global cortical SUVR [prevalence ratio per 10 dB increase (worse hearing) = 0.99 (95% CI: 0.90, 1.07)] or elevated temporal lobe SUVR [prevalence ratio per 10 dB increase (worse hearing) = 0.95 (95% CI: 0.87, 1.04)]. Results did not differ by race. Each 10 dB increase in hearing impairment was associated with 0.06 standard deviation (95% CI: -0.003, 0.11) lower global cognitive score, after adjustment for demographic and cardiovascular factors.

Conclusions: Poorer hearing is associated with poorer cognitive performance but not with amyloid deposition, suggesting that the mechanism underlying the relationship between hearing and cognition may be independent of Alzheimer's-related pathologic brain changes.

Influence of Age and Hearing Loss on Speech Understanding

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Objectives: Audiologic assessment is crucial in managing patients with hearing loss across the lifespan. In routine audiologic assessment, monosyllabic word-recognition in quiet (WRQ) has been the default test of speech perception for over 60 years. The continued use of WRQ scores is noteworthy in part because difficulties understanding speech in noise (SIN) is perhaps the most common complaint of individuals with hearing loss. Such complaints have led to increasing awareness that audiologic assessment should include measures of the ability of patients to understand speech in noise. Recent work from our lab indicates that SIN abilities 1) can largely predict categories of excellent vs. poor WRQ scores, 2) are more accurate at flagging the presence of vestibular schwannomas than WRQ scores, and 3) are more likely to predict deficits on questionnaires of perceived patient handicap than WRQ scores. Taken together, these data provide support for the idea that SIN measures can replace WRQ in the routine audiologic test battery. To make such changes, however, audiologists and physicians need a better understanding of how SIN performance is influenced by other key demographic variables, such as age. It is widely assumed by clinicians and researchers that performance on both WRQ and SIN both decrease with age. However, the effect of age can vary widely depending on the assessment tools and the degree of hearing loss. Our current objective was to characterize the effects of age and hearing loss on the ability of patients to perform tests of monosyllabic word-recognition in quiet, and speech understanding in noise.

Design: Retrospective data from 5084 patients who completed audiometric testing were examined. All patients completed pure-tone audiometry, word-recognition in quiet, the QuickSIN, and the SSQ12. Pure-tone audiometry and WRQ are staples of the standard audiologic test battery. The QuickSIN determines the signal-to-noise ratio needed to repeat 50% of key words in low-context sentences and is sometimes used in clinical environments when SIN abilities are assessed.

Results: Our results indicate that WRQ scores decrease on average with advancing age. However, these decreases appear to be due almost exclusively to the effects of increased hearing loss with age. Within a given range of hearing loss, we observed little to no effects of age when measuring WRQ scores. In contrast, QuickSIN scores decreased with advancing age for all degrees of hearing loss. Moreover, as the degree of hearing loss increased, the QuickSIN score became increasingly affected by advanced age.

Conclusions: Performance on the QuickSIN was affected by both the age of the patient and the degree of hearing loss, while performance on word-recognition in quiet was affected only by the degree of hearing loss. This suggests that tests of speech in noise are more sensitive to the effects of aging, and may therefore better reflect the difficulties faced by individual patients. These data appear to have direct clinical implications, and provide further support for the concept of making speech in noise the default test of speech perception in routine audiometric testing.