THURSDAY, FEBRUARY 15, 2024
8:00 am – 9:00 am, Translational Research I

Voice and Speech Perception in Children with Hearing Devices
Deniz Baskent, PhD
Professor, University Medical Center Groningen, University of Groningen, Groningen, The Netherlands

Objectives: While hearing aids and cochlear implants aim to provide best speech perception, there are other important aspects of communication that the hearing devices may also help. Examples are perception of a speaker's voice or vocal emotions, or segregating target speech from background speakers, enhancing speech-in-noise perception. These perceptual mechanisms are essential for overall development of children. Yet, studies with children with hearing devices can be complicated, due to the interactions of developmental aspects with hearing-related factors. In our research, we aim to address this complexity by conducting studies on voice perception systematically, using speech synthesis techniques in a variety of voice-related tests, testing children with differing hearing device configurations, and taking into account developmental effects by using baseline normal-hearing developmental trajectories.

Design: Our study participants are school-age children (5-6 years onwards) with hearing aids or cochlear implants. Our control participants are school-age children and adults with normal hearing. For producing stimuli with different voices, we use STRAIGHT speech synthesis to vary two voice cues, voice pitch (F0; related to the glottal pulse rate) and vocal tract length (VTL; related to the resonance cavity, and hence speech formants). Using synthesized speech with varying voice cues, we determine the voice cue sensitivity (the just noticeable difference), voice gender identification (voice perceived as male/female), vocal emotion (happy, sad, angry), and speech-on-speech perception (using coordinate-response measure). We use game-like interfaces, or at times even a humanoid robot, to collect reliable data, even with youngest children tested.

Results: Results with children and adults with normal hearing indicate that, in general, voice-related perceptual mechanisms require many years to develop. However, the age that the scores become adult-like varies across the tests. Even in normal hearing, within the same age group there is a large variation in scores, indicating individual developmental trajectories. Children with hearing aids and cochlear implants also show a large variation per age, with some scores overlapping with children with normal hearing. For group data, and for some tests, there seems also a developmental trajectory for children with hearing devices. For the few children with hearing devices whose scores fall outside the age-typical range, there is no clear hearing-related or demographic factor that can explain this difference. The exception is the low-frequency hearing thresholds, which show a significant effect in some tests. In general, vocal emotion perception seems to be a great challenge for children with hearing devices, requiring long developmental periods even in normal hearing. On the other hand, the prelingually deafened and implanted children with cochlear implants seem to produce better scores in general than the postlingually deafened and implanted adults.

Conclusions: The overall impression from our many studies combined is that, when age-adjusted, we can see the benefits of hearing devices for children with hearing loss for many aspects of voice

perception. Many children perform very well with their devices, and the few who have deviating scores, or the tests that seem especially challenging for this group, need further attention to identify what factors can be improved in hearing devices or hearing rehabilitation.

THURSDAY, FEBRUARY 15, 2024
5:00 pm – 6:15 pm, Carhart Memorial Lecture

The Ear: In Search of Solutions for Engineers and Clinicians
Hideko Heidi Nakajima, MD, PhD
Associate Professor, Department of Otolaryngology-Head and Neck Surgery, Harvard Medical School, and Mass Eye and Ear, Boston, MA

Learning control theory in an electrical engineering course taught by Dave Mountain sparked my interest in hearing research. This led me to study the control mechanisms involved in cochlear tuning. With continued learning in medicine and engineering, and supportive and kind mentors helping to open opportunities, I was able to focus and delve deeply on studying the acoustics and mechanics of human hearing. Our lab studies how the human ear transmits sound up to the nervous system, yet keeping in mind what is relevant for the human nervous system. This focus, supported by lab members with diverse expertise, including biologists, engineers, and clinicians, also lends itself to clinical applications. Close collaborative efforts of our lab members utilize decades of research and theoretical findings by others together with new ideas to work towards understanding normal and pathological mechanisms and develop diagnostic techniques and treatments.

FRIDAY, FEBRUARY 16, 2024
8:00 am – 8:30 am, Early Career Research Award Presentation

Personalized Evidence-Based Adult Cochlear Implant Care Using the CIQOL Instruments
Teddy R. McRackan, MD, MSCR
Associate Professor, Medical Director Cochlear Implant Program, Director Skull Base Center, Department of Otolaryngology-Head and Neck Surgery, Medical University of South Carolina, Charleston, SC

Since initial FDA approval, cochlear implant (CI) outcomes have been assessed primarily using measures of speech recognition, which persists despite years of research demonstrating poor associations with patients' self-reported benefits. The Cochlear Implant Quality of Life (CIQOL) instrument suite (including the CIQOL-35 Profile and CIQOL-Expectations with associated CIQOL Functional Staging System) was developed and validated to address this limitation in CI care and enhance the understanding of the real-world functional benefits from cochlear implantation, to advance pre-CI counseling, and to improve how patients are monitored after implantation. This presentation will first describe the development of the CIQOL instruments and then demonstrate through the following two studies their application to provide personalized adult CI care.

In study 1 we sought to determine the degree to which CI users' pre-CI expectations were or were not met after implantation. To accomplish this, we compared CI users' pre-CI CIQOL-Expectation domain scores (patients' expected outcomes) to their 12-month post-CI CIQOL-35 Profile domain scores (actual outcomes). Overall, patients' pre-CI expectations exceeded their 12-month post-CI CIQOL outcomes. Moreover, larger differences between pre-CI expectations and post-CI CIQOL outcomes were associated with higher rates of CI-related decisional regret, but no associations with post-CI speech recognition outcomes were observed.

For study 2 we sought to determine the association of pre-CI CIQOL Functional Stage (with a higher stage meaning better pre-CI abilites) on the degree of improvement at 12-months post-CI. We enrolled a prospective cohort of adult CI users who were grouped based on their pre-CI functional stage for each CIQOL domain. These and other outcomes were monitored at 3/6/12 months post-CI. The degree of improvement after cochlear implantation varied based on CI users' pre-CI functional stage. Specifically for the communication domain, CI users with pre-CI stage 3 communication abilities were over two times less likely to demonstrate improvement after implantation compared to patients in pre-CI stage 1 and 2.

Application of the CIQOL instrument suite in these two studies demonstrates that (1) post-CI functional abilities as assessed by the CIQOL-35 Profile fall short of pre-CI expectations for a substantial percentage of adult CI users, and this mismatch appears to be associated with increased CI-related decisional regret and (2) patients at higher pre-CI CIQOL functional stages may be at increased risk of not obtaining improved functional benefit after cochlear implantation compared to their baseline abilities. Results of these two representative studies provide examples of how the CIQOL instruments can be used to enhance CI counseling by applying patient-specific data using an evidence-based, patient-centered approach.

FRIDAY, FEBRUARY 16, 2024
8:30 AM – 9:30 AM, Translational Research II - Killion Lecture

New Models of Human Hearing Via Machine Learning
Josh McDermott, PhD
Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, Cambridge, MA

Humans derive an enormous amount of information about the world from sound. This talk will describe our recent efforts to leverage contemporary machine learning to build neural network models of our auditory abilities and their instantiation in the brain. Such models have enabled a qualitative step forward in our ability to account for real-world auditory behavior and illuminate function within auditory cortex. They also open the door to new approaches for designing auditory prosthetics and understanding their effect on behavioral abilities.

SATURDAY, FEBRUARY 17, 2024
8:00 am – 9:00 am, Translational Research III

Auditory Olivocochlear Efferent Feedback System Changes with Aging and Noise Exposure
Amanda M. Lauer, PhD
Associate Professor, Johns Hopkins University School of Medicine, Baltimore, MD

Objectives: The role of the medial olivocochlear system in perception has been debated by psychophysicists for many years due to conflicting and variable results in human and animal studies, often violating hypotheses that are based on well-characterized physiological anti-noise masking mechanisms in the auditory nerve. Studies in lesioned animals also produced mixed perceptual outcomes, sometimes showing recovery of performance with continued practice. The emergence of genetically engineered mouse models has provided new opportunities for the investigation of increased or decreased olivocochlear activation in intact animals that can be tested across the lifespan under controlled experiential conditions. We can also study the effects of noise and age in these models housed under controlled acoustic conditions.

Design: We use a variety of conditioned and reflexive behavioral assays, non-invasive physiological tests, and quantitative anatomical analysis techniques to investigate how genetic manipulations of the olivocochlear system affect hearing outcomes in young, middle aged, and old mouse models exposed to varying acoustic conditions.

Results: In this talk, I will summarize our findings obtained over the years from various controlled mouse models. One might expect mouse models to yield more clear-cut behavioral disruptions, but these animals do not always perform as expected on behavioral sound detection and discrimination tasks. In contrast, acoustic startle reflex-based and evoked potential measurements have identified several functional effects of diminished or enhanced olivocochlear activity, including abnormal reactivity to loud sounds and temporal processing deficits. Newer techniques such as optogenetics and gene therapy show promise for revealing the specific effects of acute olivocochlear activation or deactivation provided that appropriate controls are implemented.

Conclusions: Contributions of the ascending peripheral and central auditory pathways to age-related and noise-induced hearing deficits have been well-characterized, but we know comparatively little about how the descending projections from the brain to the cochlea contribute to hearing deficits. Early-life deficits observed in mouse models with deficient olivocochlear function may reflect abnormal central auditory system development rather than overt peripheral olivocochlear modulation of afferent activity. Diminished olivocochlear efferent function appears to be most detrimental to hearing in aged and aged, noise-exposed auditory systems which are already working with reduced afferent input to the brain. However, plasticity in remaining neurons in this system may compensate for some aspects of this decline and may explain the variable behavioral outcomes reported in animals and humans.

SATURDAY, FEBRUARY 17, 2024
1:30 pm – 4:00 pm, Special Session: Artificial Intelligence and Hearing Healthcare

Digital Patient Clones for Individualized Clinical Inference

Dennis Barbour, MD, PhD
Professor of Biomedical Engineering, Washington University, St. Louis, MO

Traditional frameworks in evidence-based and precision medicine are deeply rooted in etiological diagnosis, aiming for a mechanistic understanding of diseases. While effective for conditions with universal, identifiable, and predictive mechanisms, this approach struggles to cope with the complexity and heterogeneity inherent in disorders of brain and behavior. I will present an alternative clinical inference methodology that retains the predictive power of conventional diagnostic methods but is engineered to adapt to variable population traits. Central to this new approach are "digital clones"—generative models that recapitulate a patient's clinical history and current findings. These models offer the flexibility to contribute to robust outcome forecasts in both homogeneous and diverse populations. I will demonstrate the application of this framework in auditory and cognitive assessments, discuss its potential for broader medical applications, and highlight how this approach is designed to be intrinsically equitable, thereby better serving outliers, minorities, and patients with rare diseases.

Generating, Handling, and Drawing Inferences from Big Data in Hearing Healthcare
Vinaya Manchaiah, AuD, MBA, PhD
Professor and Director of Audiology, University of Colorado School of Medicine, Aurora, CO

Objectives: Big data refers to a large and diverse set of structured and unstructured data that grows exponentially over time. Artificial Intelligence and Machine Learning (AI/ML) tools have made it possible to generate and analyze big data, especially those generated from the internet quickly and meaningfully. This talk presents some examples of how big data is being used in healthcare to generate new theories and draw inferences. Challenges and limitations of using big data will also be discussed.
Design: A literature review was performed to examine the type of big data used within the field of hearing science and the AI/ML methods used to analyze them. Examples of studies with big data (i.e., structured, semi-structured, and unstructured) and the type of AI/ML methods used will be presented to illustrate the applications within hearing healthcare.

Results: The use of big data and AI/ML models within hearing healthcare is still in its infancy. In the past, the use unstructured and semi-structured publicly available data was common. However, more structured big data is being generated through hearing device manufactures, through ongoing panel studies as well as within the healthcare systems. In general, earlier big data studies within hearing healthcare were exploratory and hypothesis-generating. However, current and future studies are likely to enhance hypothesis testing and experimentation, complementing the traditional research methods.

Conclusions: AI/ML methods will continue to improve and expand as well as impact the future of hearing healthcare. It is likely that the generative AI will be used more and more in the future both by the researchers as well as the industry to be able to improve efficacy. However, efforts are needed to develop good quality big data within hearing healthcare to train the AI/ML models effectively.

Driving Hearing Devices Using Conversation and Communication Statistics
Christi Miller, PhD, CCC-A
Meta, Reality Labs Research, Seattle, WA

An Augmented Reality (AR) platform is a system of interdependent technologies (e.g., audio, eye-tracking, computer vision, etc.), which enable digital objects to be placed in our real-world surroundings. These digital objects may provide assistance by overlaying enhancements to natural auditory objects in the scene, but the classic hearing device problems of estimating listener effort and identifying signals-of-interest remains. An AR platform in the form of glasses could support a large number of widely spaced microphones, forward and eye-facing cameras, inertial measurement units and other motion tracking hardware, and many other sensors. These sensors could be used to shed light on what sounds a listener wishes to hear, and whether they are having difficulty hearing them, but only if this information is optimally combined with a deeper understanding of natural conversation behavior.

To this end our team has taken advantage of an AR glasses platform to create a number of egocentric datasets capturing conversation in difficult listening situations, utilizing similar types of data that future AR hearing devices could be able to capture. In a recent study, we used this approach to study the effects of noise level and hearing loss on communication behaviors. Communicators with and without hearing loss were recruited in groups (i.e., they were familiar with one another), and participated in a 1-hour conversation while background levels randomly varied in a mock restaurant space. A glasses research device, Aria, collected egocentric data with a variety of sensors (i.e., microphones, forwardfacing cameras, eye-tracking cameras,inertial measurement units), combined with close-talk microphones. Hypotheses were established a-priori about how behavior would change with increases in noise level and/or hearing loss, and regarded metrics from voice activity, head motion/position, and eye gaze. The data is being analyzed using human and automated annotations, combined with statistical and machine learning approaches with the eventual goal of leveraging these statistics to better understand what signals listeners wish to hear and how much difficulty they are having in understanding and communicating.

Potentials of and Barriers to the Use of Artificial Intelligence in Hearing Aids

Brian C.J. Moore, PhD
Cambridge Hearing Group, Department of Psychology, University of Cambridge, UK

Objectives: To review potential benefits of the use of artificial intelligence (AI) in hearing aids and to consider barriers to the implementation of AI and how those barriers might be overcome.

Design: Literature review and personal experience with hearing aids.

Results: AI is currently being applied in hearing aids in two main ways: (1) to determine the nature of the sound scene (e.g. speech in quiet, music, in a restaurant) and to select appropriate signal processing based on the identified scene; (2) to process the incoming signal directly so as to attenuate some sounds (e.g. background noise) while preserving the signal of interest (usually speech). AI in the form of deep neural networks has shown great promise in laboratory studies for enhancing speech in background noise and reverberation. However, there are several barriers to the effective implementation of AI in hearing aids, including:

(1) Many of the most effective AI schemes require processing power and memory capacity exceeding what is currently available in hearing aids. This barrier is likely to be overcome by technical advances, but the timescale is uncertain.

(2) Some AI schemes introduce a time delay exceeding the maximum acceptable delay of 10-20 ms. Further development of low-latency AI schemes is needed.

(3) Many AI schemes have been trained with only a limited number of types of background sounds. Training with a great variety of types of backgrounds is needed to ensure appropriate generalization.

(4) A common and important listening situation is when several people are talking at once. While AI can be quite effective at separating two or more talkers, adequate methods for selecting the talker that the person wants to listen to are not available. Such methods are needed but will be difficult to develop. Probably they will require the combination of information from several sources (using AI), for example evoked electrical potentials, eye gaze, head movements, and information from the auditory and visual scene. This will require multiple sensors, making the whole system "clunky" and potentially reducing acceptability to the user.

(5) To get the benefits of AI in situations with high sound levels, the ear canal needs to be sealed; the commonly used open fitting would allow unprocessed sound to leak to the eardrum, reducing or eliminating any potential benefits of AI signal processing. Closed fittings create problems with occlusion (the person's own voice sounding loud and boomy) for hearing-impaired people who have

reasonably good hearing at low frequencies, which is common. Possible solutions are "active vents" or active own-voice cancellation.

Conclusions: Much research on potential applications of AI to hearing aids has been done in laboratory studies, considering only the effectiveness of the signal processing using sounds delivered via headphones or loudspeakers. A more wholistic approach is needed, where the barriers described above are considered and addressed.