Hearing 4all

Cluster of Excellence in the Auditory Valley Future Hearing

Carl von Ossietzky Universität Oldenburg

MHH Medizinische Hochschule Hannover

Leibniz Universität Hannover

Hearing4all Symposium

The Future of Hearing

3/4 November 2022
Abstract Book

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Hearing4all 2.0

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Contact

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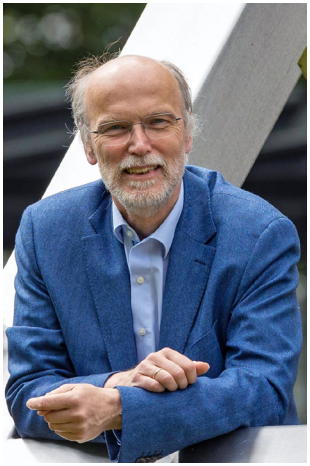
Dear participants, dear colleagues and friends of “Hearing4all",

On behalf of all members of the Cluster we would like to welcome you to our international annual Symposium. After its 10 years of successful existence, we are excited to celebrate this anniversary together with you.

As usual, we will present keynote talks from international scientists as well as highlight talks from our own researchers, talks from the Joint Research Academy and presentations from our Translational Research Center. Additionally, a widespread poster session will round up the event.

Please use this opportunity to get in contact with the members from our Cluster of Excellence and external guests and discover for yourself how we are all working towards the same goal: Hearing4all, for all people in all places at all times!

Prof. Prof. h.c. Dr. med. Thomas Lenarz
Clinical Spokeperson



Prof. Dr. rer.nat. Dr. med. Birger Kollmeier
Spokeperson

Thursday, 3rd November | 09:00 - 18:00

TIME	TOPIC
from 08:00	**Registration**
09:00 – 09:30	Welcome and Introduction (Thomas Lenarz, Birger Kollmeier)
09:30 – 10:15	**Alessia Paglialonga, Ph.d.** **National Research Council of Italy (CNR)** Self-administered hearing tests for screening at a distance
10:15 – 11:15	**Research Thread II:** **IT-based diagnostics and rehabilitation** **Overview and Highlights** (including Poster Overview)
	Overview by Andreas Büchner, Ph.D., Hannover Medical School
	Hanna Dolhopiatenko, M.Sc. Hannover Medical School Selective Attention Decoding to Predict Speech Understanding and Speech Integration in Bimodal Cochlear Implant Users
	Thomas Biberger, Ph.D. University of Oldenburg Auditory models in complex acoustical environments
	Lena Schell-Majoor, Ph.D University of Oldenburg On the way to a Virtual Hearing Clinic
11:15 – 11:45	**Coffee Break + Poster Session**
11:45 – 12:30	JRA Highlights
12:30 – 13:15	**Arianna Astolfi, Ph.D.** **Politecnico di Torino DENERG** Classroom acoustics: Comfortable speaking and listening in complex acoustic scenarios
13:15 – 13:45	**Lunch Break**
13:45 – 14:45	**Poster Session**

Thursday, 3rd November | 09:00 - 18:00

TIME	TOPIC
14:45 – 15:30	**Tobias Moser, Ph.D.** **University Medical Center Göttingen** Towards Optogenetic Hearing Restoration
15:30 – 16:30	**Research Thread I:** **Auditory processing deficits throughout the lifespan** **Overview and Highlights** (including Poster Overview)
	Overview by Andrej Kral, M.D., Hannover Medical School
	Christine Köppl, Ph.D. University of Oldenburg Perception and neural coding of temporal fine structure are impaired by aging but not by cochlear synaptopathy
	Angelika Illg, Ph.D. Hannover Medical School Outcome variability of language development following cochlear implantation within the early critical period of 2 years
	Arkan Al-Zubaidi, Ph.D. University of Oldenburg Human cortical auditory processing of naturalistic speech with simulated hearing loss: A data-driven fMRI approach
16:30 – 17:00	**Coffee Break + Poster Session**
17:00 – 17:45	**Monita Chatterjee, Ph.D. (online)** **Boys Town National Research Hospital** Spoken melodies: prosodic cues in emotional communication with cochlear implants
17:45 – 18:00	Announcements for the evening /next day
18:30	**Shuttle to Evening Event**
19:00 – 22:30	**Evening Event: Sprengel Museum**

Friday, 4th November 2022 08:25 – 16:45

TIME	TOPIC
08:25 – 08:30	Welcome (Thomas Lenarz)
08:30 – 09:15	**Henry Kennedy, Ph.D. (online)** **Stem-Cell & Brain Research Institute Lyon** The organizational Principals of the Primate Inter-areal Network
09:15 – 10:15	**Research Thread III:** **Auditory precision medicine: research-based novel intervention methods** **Overview and Highlights** (including Poster Overview)
	Overview by Thomas Lenarz M.D., Hannover Medical School
	Martin Mamach, Ph.D. Hannover Medical School Detection of inflammatory response in the cochlea after electrode implantation – an F-18-FDG PET study in guinea pigs
	Georg Böttcher-Rebmann, M.Sc. Hannover Medical School Towards intraoperative CI electrode array insertion force measurements
	Alexander Heisterkamp, Ph.D. Leibniz Universität Hannover Optoacoustic stimulation Sina Christoffers, M.Sc. Leibniz Universität Hannover Optogenetic regulation of BDNF expression in human cells
10:15 – 10:45	**Coffee Break + Poster Session**
10:45 – 11:15	**TRC Highlights** Karl-Heinz Dyballa, Ph.D. Hannover Medical School Regulatory Pathway in Translation of a Novel Electrical Hearing Prosthesis: the Auditory Nerve Implant (ANI)

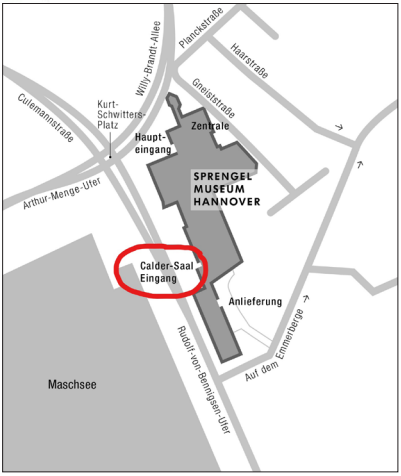
Friday, 4th November 2022 08:25 – 16:45

TIME	TOPIC
11:15 – 12:00	**Susan Scollie, Ph.D.** **Western Health Sciences School of Communication Sciences and Disoders** Using Self-Adjustment to Optimize Hearing Aid Shaping for Speech and Music
12:00 – 12:30	**Lunch Break**
12:30 – 13:30	**Poster Session**
13:30 – 14:15	**Lawrence R. Lustig, M.D. (online)** **Columbia University** Cochlear Gene Therapy – An Update for 2022
14:15 – 15:15	**Research Thread IV: The Hearing Device of the future** **Overview and Highlights** (including Poster Overview)
	Overview by Volker Hohmann, Ph.D., University of Oldenburg
	Peyman Goli, Ph.D. **University of Oldenburg** Human speaker localization and detection using deep learning approaches
	Tomas Gajecki, M.Sc. **Hannover Medical School** Coordinated Binaural Signal Processing for Bilateral Cochlear Implant
	Simon Klein, M.Sc. **Leibniz Universität Hannover** KUPEGA: Application Specific Integrated Circuit Design for Convolutional Neural Networks on Hearing Aids
15:15 – 15:45	Coffee Break + Poster Session
15:45 – 16:30	**Mounya Elhilali, Ph.D. (online)** **Johns Hopkins Whiting School of Engineering** Auditory Scene Analysis: Predictive processing in auditory perception
16:30 – 16:45	Farewell and closing remarks (Birger Kollmeier, Thomas Lenarz)
16:45	**End of Official Part of the Symposium**
17:00 – 19:00	**Scientific Advisory Board and Cluster Board Meeting**

Forum Niedersachsen
Feodor-Lynen-Str. 27
30625 Hannover

Map: HNO der MHH

Photos: Forum Niedersachen (3)



Prof. Alessia Paglialonga, Ph.D.
National Research Council of Italy (CNR)
Institute of Electronics, Information Engineering and Telecommunications(IEIIT)

Self-administered hearing tests for screening at a Distance

Age-related hearing loss has a high prevalence and, if left untreated, it can lead to cognitive decline, social isolation, and mental health problems that can translate into an increased access to care and higher costs. Despite this, hearing loss is frequently considered an inevitable component of aging. Adult hearing screening can help increase consciousness and subsequent early detection of hearing loss and help prevent the effects of undiagnosed hearing loss on quality of life.

The number and type of methods for adult hearing screening, particularly those using self-administered testing procedures, are growing. Self-administered hearing screening tests include, for example, pure-tone testing, validated questionnaires, and speech recognition tests. Speech-in-noise testing, in particular, has become a popular approach for adult hearing screening as the first difficulties experienced by adults with hearing loss are typically related to understanding speech in noisy environments. Furthermore, speech-in-noise tests can be performed in nonclinical settings in an unsupervised way, without a stringent need for calibrated equipment.

There is growing interest around the development of data-driven methods to support self-administered hearing testing, both in relation to testing procedures (e.g., optimization of adaptive procedures) as well as in relation to the development of hearing loss classification and prediction algorithms using multivariate approaches, as opposed to common univariate approaches using the speech recognition threshold (SRT) or the number/percentage of correct responses. Although widespread, univariate approaches to speech-in-noise screening may present limitations due to the well-known mismatch between hearing loss, as defined based on pure-tone detection thresholds, and speech recognition performance, as measured by the SRT. Multivariate approaches using machine learning on a set of features extracted from speech-in-noise testing may help improve the ability of speech-in-noise screening tests to identify hearing loss of mild degree or higher.

For example, features such as the subject's age or the average reaction time, when used in combination with SRT, can be accurate predictors of hearing loss in adults. The use of machine learning algorithms belonging to the eXplainable AI (XAI) area such as natively transparent models (e.g., decision trees, logistic regression) or post-hoc explainability techniques (e.g., implicit feature importance scores, SHapley Additive exPlanations, and partial dependence plots), can help improve efficiency and transparency of hearing loss screening models and may also help discover latent correlations and identify patients at risk of developing disease. More generally, multivariate, explainable approaches could be applied in different audiological applications to analyze the role of multiple variables and factors in determining a certain condition. For example, multivariate approaches might help address the factors leading to cognitive decline in older adults. Indeed, multiple measures from a battery of tests (e.g., pure-tone thresholds, cognitive measures from questionnaires of functional tests, self-assessment questionnaires of hearing handicap, electrophysiological measures, medical history, or even demographic and socioeconomic indicators) could be combined to gain a deeper knowledge about the factors that might lead to cognitive decline in individuals with hearing loss. The use of XAI in audiology can open new opportunities for a deeper understanding of the attributes and risk factors that can effectively characterize hearing loss and, in turn, can help building accurate methods to predict the risk of developing hearing loss in adults, thus being of substantial interest to researchers and developers of audiological instrumentation.

Prof. Arianna Astolfi, Ph.D.
Politecnico di Torino DENERG
TEBE GroupDepartment of Energy Turin, Italy

Classroom acoustics: Comfortable speaking and listening in complex acoustic scenarios

In the last decade several studies have started to consider the complex speech communication scenario in classrooms, where acoustic requirements are needed for both teachers and pupils. The voice monitoring of teachers has revealed challenging conditions for speaking as a result of bad acoustics, with consequences on vocal health. Research has underlined the importance of voice support from the room, which has led us to reconsider the optimal reverberation time in classrooms, whose tendency is towards higher values than those for listening. On the other hand, it has been proved that a high reverberation increases the listening effort and decreases reading abilities. Thus, the question of the optimal reverberation time for speaking and listening arises, as well as the need to optimize the design of classrooms to support voice and control the sound tail. Results from a large measurement campaign in occupied classrooms suggest that more convenient parameters, like clarity in the central position of the classroom, can be used instead of reverberation time to classify classroom acoustics. Clarity is also better related to reading abilities of pupils.

Reverberation also amplifies the noise produced by pupils themselves and affects their well-being. To cope with this, a new device has been introduced to inform pupils on the need to lower their voices and respect others.
Noise and reverberation degrade speech intelligibility, but the combined effect of reverberation, informational noise and position of target, listener and noise source on speech intelligibility still needs to insights. Competitive listening scenarios are even more challenging for children with cochlear implants and if the teacher is wearing a face mask, as during the Covid-19 pandemic.

A summary of the newest outcomes on classroom acoustics is given in this lecture where it is evident that a new paradigm on speech communication is needed that should involve both teaching and learning. Further work is required to investigate the factors that underpin this complex communication scenario.

Prof. Tobias Moser, Ph.D.
University Medical Center Göttingen
Institute for Auditory Neuroscience & InnerEarLab

Towards Optogenetic Hearing Restoration

When hearing fails, cochlear implants (CIs) provide open speech perception to most of the currently half a million CI users. CIs bypass the defective sensory organ and stimulate the auditory nerve electrically. The major bottleneck of current CIs is the poor coding of spectral information, which results from wide current spread from each electrode contact. As light can be more conveniently confined, optical stimulation of the auditory nerve presents a promising perspective for a fundamental advance of CIs. Developing optogenetic stimulation for auditory research and future optical CIs requires efforts toward design and characterization of appropriate optogenetic actuators, efficient and safe viral gene transfer to the neurons, as well as engineering and characterization of multichannel optical CIs. The presentation will summarize the current state of optogenetic hearing restoration and report on recent breakthroughs on achieving high temporal fidelity and frequency resolution and establishing multichannel optical CIs.

Monita Chatterjee, Ph.D. (online)
Center for Hearing & Speech Perception Research
Boys Town National Research Hospital

Spoken melodies: prosodic cues in emotional communication with cochlear implants

Despite several advances in the field, cochlear implants are still limited in the extent to which they convey information about the complex harmonic pitch of sounds such as the human voice or musical instruments to patients. This results in limitations in how cochlear implant patients perceive speech prosody. To what extent neural plasticity based on age at implantation or experience with the device may benefit child patients in identifying prosodic cues is not well understood. At the other end of the lifespan, the effects of aging in adult patients' processing of prosodic cues remain unexplored. In spoken communication, emotional prosody dominates our perception of our conversational partners' intended emotions and is an important aspect of social communication. Deficits in emotional prosody perception have been shown in both children and adults with cochlear implants. In children, a lack of access to perceptual prosodic cues may be associated with impaired production of these cues. Deficits in understanding emotional prosody have been linked to poorer quality of life in cochlear implant patients. Currently, evidence-based clinical protocols to assess or treat deficits in prosody perception and production do not exist. In this talk, I will describe our findings on the factors that predict outcomes in emotional prosody perception and production by prelingually deaf children with cochlear implants and postlingually deaf adults with cochlear implants.

Prof. Henry Kennedy, Ph.D. (online)
Stem-Cell & Brain Research Institute Lyon, France

The organizational Principals of the Primate Inter-areal Network

While some 50 years of cortical neuroanatomy have revealed many features of the cortex, it is only in the last 10 years that quantitative techniques have been used to obtain a consistent directed and weighted matrix in the none-human primate that allows exploring the principals of the inter-areal network. This work has shown that the cortical network is spatial embedded meaning that weight distance relations determine the numerous organizational principals such as wire minimization, and local and global efficiency. An unexpected feature of the NHP empirical data is the unexpected high-density of the cortical graph, which poses new challenges for determining network heterogeneity such as the core-periphery structure. We shall discuss the limitations of diffusion MRI tractography and the challenges that are posed to extrapolate the findings using invasive techniques in the macaque to the human brain. This will lead us to speculate on the importance of the macaque model for understanding the human brain. We shall briefly review the important aspect of the structural network for understanding function in the hierarchical processing of information in the cortex and this relates to future challenges of resolving predictive processing.

Prof. Susan Scollie, Ph.D.
Western Health Sciences
School of Communication Scienes and Disorders

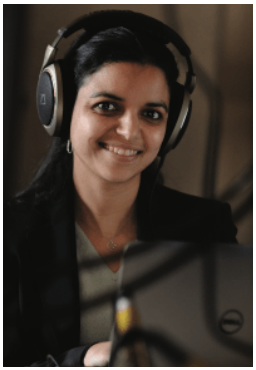
Using Self-Adjustment to Optimize Hearing Aid Shaping for Speech and Music

Individual differences in preference for frequency shaping may lead to different fitted frequency responses in hearing aids, compared to hearing aid prescriptions. In this study, we sought to understand the magnitude of these differences, both for speech and for music stimuli. A specific self-fitting algorithm was implemented, and linked to a multi-channel wide dynamic range hearing aid simulator within the Open Master hearing aid, with high-power extended bandwidth insert transducers to provide output in the ear. In-ear verification measures were obtained before and after self-fitting to quantify the degree of change in aided sound levels. Twenty-two listeners who have hearing loss completed the task, completing the self-tuning in less than 5 minutes on average. Self-fitting adjustments differed from prescribed targets more for music than for speech. Results will be examined for reliability, impact of stimulus, and effect on perceived sound quality.

Prof. Lawrence R. Lustig, MD (online)
Columbia University
Department of Otolaryngology Head and Neck Surgery

Cochlear Gene Therapy – An Update for 2022

The first successful gene therapy study occurred in the 1990's. Since this pivotal time period, many diseases have explored gene therapy as a means of correcting genetic defects and regenerating normal function. With the diversity of genetic mutations that have been implicated in hearing loss, cochlear gene therapy has long been studied to fulfill this potential. Today our field now stands at the precipice of treating some forms of genetic deafness with cochlear gene therapy. This talk will highlight the gene therapy research from our lab and collaborators, tracing our original studies of vesicular glutamate transporter 3, then Usher Syndrome IIIa, and lastly to Otoferlin. Each of these examples provides clues into the promises and pitfalls of treating genetic deafness using virally mediated gene therapy. An overview of these 3 lines of research will also lead to a broader context of current efforts to treat genetic deafness with cochlear gene therapy.



Prof. Mounya Elhilali Ph.D. (online)
Johns Hopkins Whiting School of Engineering

Auditory Scene Analysis: Predictive processing in auditory perception

The brain's ability to extract statistical regularities from sound is an important tool in auditory scene analysis, necessary for object recognition, structural learning (in speech or music), texture perception, and sound event detection. In this talk, we explore perceptual, neural and computational principles underlying the brain's ability to collect complex and non-deterministic patterns in echoic memory. These processes underlie statistical inference in auditory perception and guide our ability to delineate salient changes in our acoustic environment. We will explore the acoustic dimensionality and statistical granularity of this inference space using complex soundscapes; and discuss theoretical interpretation of perceptual and neural findings in terms of coding mechanisms in the brain.

Research Thread I:
Auditory processing deficits throughout the lifespan

Christine Köppl Ph.D.
University of Oldenburg
School of Medicine and Health Sciences, Department for Neuroscience

Perception and neural coding of temporal fine structure are impaired by aging but not by cochlear synaptopathy

Friederike Steenken, Rainer Beutelmann, Henning Oetjen, Christine Köppl, Georg M. Klump*Symposium speaker*

Despite an absence of hearing deficits in the clinical audiogram, many people of age 50 and above have compromised supra-threshold perception (e.g., of speech or tones in noise), a condition referred to as hidden hearing loss (HHL). It has been suggested that HHL is associated with a reduced number of synapses at the inner hair cells due to aging processes or to cumulative noise-induced damage over the life time (e.g., see review by Liberman 2015). Such synaptopathy was postulated to cause compromised processing of temporal stimulus features, in particular of the temporal fine structure (TFS) of sounds (for a review see Moore 2014). However, in humans, it is impossible to directly assess synaptopathy, which limits the ability to convincingly relate problems in TFS perception to inner-ear function.

The most commonly used psychoacoustic test for probing temporal fine structure perception in humans is the TFS1 test (Moore & Sek 2009). It investigates the discrimination of harmonic and inharmonic tone complexes that differ in TFS but not in the envelope of the waveform. Using the TFS1 test, we determined the sensitivity of Mongolian gerbils for processing the temporal fine structure of sounds in a behavioral Go/NoGo task. We compared the performance of five groups of animals: (1) young-adult, normal-hearing gerbils, (2) three-year old gerbils with age-related synaptopathy, (3) young-adult gerbils with 40µM ouabain-induced synaptopathy, (4) young-adult gerbils with 70µM ouabain-induced synaptopathy, and (5) a control group of young-adult gerbils sham-treated with saline only (no ouabain). Compared to young-adult, untreated gerbils, we observed reduced numbers of synapses in old gerbils and in gerbils treated with 70µM ouabain. Both these groups showed a similar extent of synaptopathy. Compared to young-adult, normal-hearing gerbils, however, only the group of old gerbils showed reduced sensitivity and increased thresholds in the TFS1 test. This finding strongly argues against synaptopathy causing deficits in TFS perception. Responses of auditory-nerve fiber recordings from gerbils of all five groups to the TFS1-test signals suggest that fibers with low spontaneous rates do not represent TFS as well as fibers with high spontaneous rates. Low-spontaneous-rate fibers primarily represented the stimulus envelope. Auditory-nerve fiber spontaneous rates are reduced in old gerbils (Heeringa et al. 2020), which may explain their compromised ability to discriminate TFS1 stimuli that differ only in TFS but not in their envelopes.

Angelika Illg Ph.D.
Hannover Medical School
Department of Otolaryngology

Outcome variability of language development following cochlear implantation within the early critical period of 2 years

Illg A, Adams D, Schedel L, Lesinski-Schiedat A, Lenarz T, Kral A

Outcome variability is an ongoing unresolved issue of cochlear implantation. Also in pediatric cochlear implantation, further shift in the implantation age below two years improved performance, but did not eliminate the variability. Children's language acquisition is subject to high variability even if the temporal order of psycholinguistic features is known.

Standardized, age-appropriate language acquisition tests have been performed for children with cochlear implants (CI) in our clinic. These are the "Speech Acquisition Test for Two to Five Year Old Children" (SETK 2-5) (N= 142), and the "Marburg Speech Comprehension Test for Children" (MSVK) (N=84). In addition, there are data on speech comprehension in quiet and in noise like monosyllables (MST) and sentences. The data have been statistically evaluated and analyzed.

The overall test results (SETK and MSVK) show age-appropriate receptive and expressive language abilities that are comparable to the normal-hearing age norm on average (T-values of 50 ± 10). T-Values of "Phonological Memory for Non-Words" is just below 40 in three year old children with CI and is below average compared to normal-hearing three-year-olds. In the next year of life, the results improve to 50 ±10 and are within the age norm. The overall SETK results are significantly higher in children implanted under the age of 12 month ($p=0,02$). The MSVK overall score correlated with age ($r=-0.309$; $p=0.005$) and monosyllables test results ($p<0.000$). Two-way ANOVA shows age effects in most subtests but no effects on additional disabilities without cognitive involvement or anatomical nature.

Congenitally deaf children, provided with bilateral CI within the first year of life, can build up age-appropriate linguistic abilities until school enrolment, while there are lower chances for bilaterally congenitally deaf children, provided with CI on both sides in their second year of life. The reasons for the high variability of the results of spoken language development can not be explained enough with the current knowledge. In order to find explanations, the development of cognitive processes e.g. Phonological Memory" must be further analyzed intensively.

Arkan Al-Zubaidi
University of Oldenburg
Department of Psychology Applied Neurocognitive Psychology Lab

Human cortical auditory processing of naturalistic speech with simulated hearing loss: A data-driven fMRI approach

Arkan Al-Zubaidi, Leo Michalke, Jochem W. Rieger

We investigate the cortical auditory processing of realistic speech in natural soundscapes with clear and degraded naturalistic stimuli using voxel-wise encoding models (VWEMs). Our approach develops and derives machine learning models to characterize which acoustic features drives are used to model brain activity and the functional organization of the underlying brain networks (Boos et al. 2021).

We used an audio description of the movie "Forrest Gump" soundtrack as a clear naturalistic stimulus (CS) and two additional versions with different levels of acoustic degradation (low (S2) and high (N4), Bisgaard et al., 2010) at higher frequencies to simulate common types of hearing loss. We measured fMRI responses while normal-hearing participants listened to the full movie in each session but in eight segments at different levels of degradation and the three repetitions at different degradation levels (CS, S2, or N4) were distributed over three sessions. We separately estimated VWEMs for the sound Mel-frequencies spectrogram of CS, S2, and N4 stimuli.

In parallel, we also develop novel and more efficient methods for characterizing brain function across individuals based on multiset canonical correlation analysis (M-CCA) and demonstrate the considerable improvement of across-individual generalization of information in brain imaging data. In the future, we plan to use these methods to improve further the characterization of acoustic or language encoding in the human brain.

Applied Neurocognitive Psychology Lab and Cluster of Excellence Hearing4all, Oldenburg University, Oldenburg, Germany

Boos, M., Lücke, J., & Rieger, J. W. (2021). Generalizable dimensions of human cortical auditory processing of speech in natural sound scapes: A data-driven ultra high field fMRI approach. NeuroImage, 237, 118106. Bisgaard, N., Vlaming, M. S., & Dahlquist, M. (2010) Standard audiograms for the IEC 60118-15 measurement procedure. Trends in amplification, 14(2), 113-120.

Research Thread II:
IT-based diagnostics and rehabilitation

Hanna Dolhopiatenko M.Sc.
Hannover Medical School
Department of Otolaryngology Auditory Prosthetic Group

Selective Attention Decoding and its Potential as an Objective Measure of Integration between Electric and Acoustic Stimulation in Bimodal Cochlear Implant Users

Hanna Dolhopiatenko, Waldo Nogueira

This work focuses on bimodal hearing which consists of electric stimulation through a CI and acoustic stimulation on the opposite side through the subject's residual hearing. Bimodal CI users can combine electric and acoustic information to improve speech understanding. However, the observed benefit presents high variability across subjects and some subjects even experience worsened speech performance with bimodal stimulation. This variability may be associated with the effectiveness of the integration between electric and acoustic stimulation. However, there is a lack of established methods to assess electric acoustic integration and consequently to adequately program bimodal devices. For this reason, we investigated methods to assess bimodal integration.

Previous studies have shown that it is possible to track the envelope of an attended speech source using high-density electroencephalography (EEG) (Ding and Simon, 2012; O'Sullivan et al. 2015; Mircovic et al. 2015). Neural tracking can also be measured in a competing talker situation using a so called selective attention paradigm. In this case, the listener is asked to attend to one speaker and ignore all others. Previous studies in our group have shown that it is possible to decode selective attention in bilateral CI users when the two speech streams are presented independently to each ear using high density EEG (Nogueira et al 2019a), using a mobile EEG device (Nogueira et al, 2019b) and using the CI electrodes as sensors (Aldag et al. 2022). Moreover, the possibility to predict speech intelligibility from selective attention decoding has been shown in NH listeners (Vanthornhaut et al, 2018) and in CI users (Nogueira and Dolhopiatenko, 2022).

The main goal of this work is to investigate integration between electric and acoustic stimulation electrophysiologically. For this purpose, a selective attention decoding paradigm has been designed and its potential as an objective measure of electric acoustic integration in bimodal CI users has been investigated.

The study included a behavioral paradigm based on speech understanding performance and an electrophysiological paradigm based on selective attention decoding from EEG. Speech material for both paradigms were presented to the CI side (CIS) alone, the acoustic side (AS) alone and to both sides simultaneously (CIS+AS). We propose a novel integration measure between electric and acoustic stimulation in bimodal CI users based on the EEG selective attention decoding paradigm. This measure subtracts the correlation coefficients of selective attention decoding obtained with CIS+AS from the sum of correlation coefficients obtained with CIS only and AS only. This integration measure showed a significant correlation with speech understanding score calculated in the same way.

Thomas Biberger, Ph.D.
University of Oldenburg
Medical Physics Section

Auditory models in complex acoustic environments

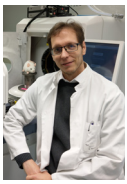
Daily-life acoustic environments are often complex, typically comprising one attended target sound in the presence of other interfering sounds (e.g., disturbing talkers) and reverberation. To better understand hearing and consequences of hearing impairment in such complex acoustic environments (CAEs), different perceptual measures such as detectability, speech intelligibility, audio quality, and loudness can be assessed. The resulting data are also important for the development of auditory models, which have often been applied under optimal conditions (i.e. without reverberation and maskers). Moreover, auditory models have often been developed or "tuned" to account for specific experiments. Here, a unified modelling approach, the Generalized Power Spectrum Model (GPSM), is suggested, using power and envelope power SNRs in combination with a task-dependent decision stage to predict psychoacoustic masking, speech intelligibility and audio quality. To model was initially "calibrated" using basic psychoacoustic experiments before it was applied to the more complex perception tasks. Despite its simplicity, results demonstrated that the power and envelope power metric within the GPSM is appropriate to predict audio quality for a variety of signal distortions in addition to speech intelligibility and psychoacoustics. This talk gives an overview about current GPSM developments and their application to CAEs.

Lena Schell-Mayoor Ph.D.
University of Oldenburg
Department of Medical Physics and Acoustics Psychoacoustics, speech perception and audiology

On the way to a Virtual Hearing Clinic

The Virtual Hearing Clinic (VHC) is a key concept in Hearing4all. Integrating various application modules, it aims at offering low-threshold hearing diagnostics and rehabilitation on mobile devices to reduce the barrier for individuals to test their hearing, get information about possible treatments and their potential outcomes. Current work addresses adapting and validating test procedures and interfaces for use on mobile devices, calibration of individual hardware, psychological and audiological profiling and defining and setting up the technical infrastructure. This talk gives an overview about the current status and further perspectives of the VHC.

Research Thread III:
Auditory precision medicine: research-based novel intervention methods



Martin Mamach Ph.D.
Hannover Medical School
Department of Radiation Protection and Medical Physics

Positron emission tomography-based in-vivo imaging of tissue responses in the cochlear implanted guinea pig

Martin Mamach[1,2], Jana Schwieger[2,3], Jens P. Bankstahl[4], Claas-Tido Peck[2,3], Thomas Lenarz [2,3], Georg Berding[2,4], Verena Scheper [2,3]

The perceptive performance varies widely between cochlea implant (CI) patients. Due to the limited accessibility of the cochlea, diagnosing reasons such as insertion trauma-based inflammation is challenging. The use of non-invasive positron emission tomography (PET) imaging combined with computer tomography (CT) using F-18-FDG (F-18 fluorodeoxyglucose) could overcome the diagnostic deficits.

Methods: CI were implanted unilaterally in 4 normal hearing guinea pigs after initially setting an electrode insertion trauma (EIT). Subsequently, PET-CT imaging under general anesthesia was performed with F-18-FDG at different time points: (i) acute reactions were observed after 7, 14, and 21 days post operation (CI acute) and (ii) chronic reactions were imaged 1 year post (CI chronic). 2 normal hearing non-implanted animals (nCI) were scanned as reference. F-18-FDG imaging indicates the metabolic activity of cells, e.g. is increased for inflammation. Volumes-of-interest (VOIs) of the cochlea were defined based on CT data to evaluate the respective mean standardized uptake value (SUV) from the inherently co-registered PET image.

Results: The VOI sizes (voxels) of the analyzed cochleae did virtually not differ between implanted (2289 ± 167) and non-implanted (2301 ± 126) cochleae. In contrast, the SUVs were significantly increased in implanted cochleae (0.953 ± 0.196) compared to non-implanted cochleae (nCI: 0.636 ± 0,066 [Mann–Whitney U test $p < 0.001$]). A comparison of the F-18-FDG SUVs at the different time points after CI-surgery still showed significant differences between implanted and non-implanted cochleae (CI vs. nCI early: $p < 0.05$, late: $p < 0.01$). However, the values between implanted ears in acute and chronic phase did not differ significantly (CI acute: 0.897 ± 0.027, CI chronic: 1.008 ± 0.293).

Conclusions: F-18 FDG-PET-CT imaging showed increased radiotracer uptake after CI-insertion with EIT consistent with acute and chronic inflammatory tissue responses in the guinea pig cochlea. This non-invasive diagnostic tool allows longitudinal observation of ongoing processes in the implanted cochlea. Further preclinical studies with other specialized radiotracers (e.g. targeting microglia activation or fibrosis) and the translation to patients may result an improved understanding and specific therapy for one sort of reasons for outcome variability in CI-patients.

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Towards intraoperative CI electrode array insertion force measurements

Georg Böttcher-Rebmann[1], M. Geraldine Zuniga[1], Viktor Schell[1], Rolf Salcher[1], Thomas Lenarz[1], Thomas S. Rau[1]

Soft-surgery aims to preserve residual hearing after cochlear implant (CI) surgery by reducing trauma during electrode array (EA) insertion. Insertion forces have been correlated with the occurrence of trauma and are influenced by the surgical approach. While this has been shown in ex vivo experiments, insertion forces have never been measured in vivo. We designed a surgical tool that enables the measurement of insertion forces during conventional CI surgery.

In a first step, the tool was compared to the current gold standard in insertion force measurement to assess its accuracy and performance when inserting into an artificial cochlea model. Subsequently, surgeons performed insertions with real EAs into human temporal bone specimen using our tool to evaluate its applicability in a realistic setting. Lastly, we developed concepts for intraoperative force visualization to provide force feedback to the surgeon and evaluated them experimentally.

Measurements with the tool were equivalent to the gold standard measurements. An algorithm implemented to remove gravitational disturbances originating in the variable tool orientation reliably removed these disturbances. All EAs were successfully inserted in the temporal bone trials and the surgeons evaluated the usability and patient safety with the tool to be equivalent to conventional surgery. The measurements were reliable and recorded force profiles comparable to the literature. However, contact between bone and the tool introduced artefacts to the signal. Visual force feedback could successfully aid users in performing different tasks with the tool. While preferences varied, there were significant differences in user performance depending on the specific visualization concept.

The experimental evaluation proves that intraoperative insertion force measurement is feasible from a technical point of view and can be included into the conventional surgical workflow easily and without added risk to the patient. In addition to the measurement of insertion forces for postoperative evaluation, force feedback can be an additional source of information for the surgeon, further reducing the risk of intracochlear trauma during CI surgery. Strongly increased regulatory hurdles due to the new MDR are the last remaining obstacle to introducing insertion force measurement to conventional CI surgery.

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Optoacoustic sound generation by nanosecond laser pulses over the entire hearing range

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The aim of this work is to generate defined tones that cover the human hearing range in aqueous media for a later application in middle or inner ear implants. In our experiments, we investigated the characteristics of single laser pulses and pulse trains with different laser repetition rates of nanosecond laser pulses that were focused into aqueous media in a small volume. The frequency of the generated tones was limited by the spectral properties of the single acoustic pulses, which depended on the medium. Tones with fundamental frequencies above 8 kHz were generated using laser pulses focused into water. By replacing water with gel, tones between 500 Hz and 20 kHz could be produced. The generation of tones in the low-frequency range was only possible when laser pulse trains with pulse density modulated pulse patterns were applied in gel. This enabled the generation of tones between 20 Hz and 2 kHz. Consequently, the combination of different pulse patterns for the different frequency ranges allows generating optoacoustic tones between 20 Hz and 20 kHz in gel. Thus, we can cover the complete range of human hearing through optoacoustically generated tones.

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Optogenetic regulation of BDNF expression in human cells

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Background: Optogenetic systems may serve as therapeutic applications providing temporally and spatially controlled protein regulation such as light-induced release of brain-derived neurotrophic factor (BDNF). Stem cells may thus create an optimal milieu in the inner ear to support healing processes of the neural network after cochlea transplantation [1]. Optogenetics are based upon the photosensitive receptor cryptochrome 2 (CRY2) interacting with the transcription factor CIB1 upon blue light activation for targeted gene and protein expression.

Methods: The system was optimized with human epithelial kidney carcinoma cells (HEK cells) in terms of different plasmid ratios and illumination patterns. HEK cells were co-transfected using cationic lipids with high efficiency (25 %). Kinetics of BDNF-mRNA-expression was examined using qT-PCR for optimization of time patterns of light induction. Blue light pulses with duration and frequency of 20 seconds per 80 seconds were administered over 3-12 hours using a LED array. Afterwards, illuminated cells were lysed for qT-PCR and supernatant was collected and examined for BDNF protein expression by an ELISA assay kit. Non-illuminated cells (continuously kept in the dark) were used as control.

Results: The CRY2/CIB-system was able to switch on a stable blue light induced protein production after transfection of human cells. Illuminated cells produced over 1000 ng/ml BDNF with a 100-fold increase as compared to non-illuminated control cells.

Conclusion: This was the first time, that BDNF was optogenetically turned on upon light activation in human cells. In the future, this optogenetic approach is to be transferred to human mesenchymal stem cells using laser illumination to get closer to the clinical application in the inner ear. An optimization of transfection efficiency is further aimed by use of nucleofection.

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[1] Dieter, A.; Klein, E.; Keppeler, D.; Jablonski, L.; Harczos, T.; Hoch, G.; Rankovic, V.; Paul, O.; Jeschke, M.; Ruther, P.; Moser, T. µLED-based optical cochlear implants for spectrally selective activation of the auditory nerve. EMBO molecular medicine, 2020, 12, e12387

Research Thread IV:
The H4A hearing devices of the future

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Deep learning-based speech source detection and localization in hearing aids

We will present two deep learning-based methods for joint speech-source detection and localization in hearing aids. Speech source detection and localization algorithms can provide essential localization information for beam forming algorithms in hearing aids to steer and amplify target speech among interfering sources. The first proposed method uses either a binaural or only a monaural microphone array of a hearing aid. Motivated by the human auditory system, peripheral preprocessing is applied on the microphone signals to obtain auditory subband signals that serve as input to a deep model that is trained to detect and localize speech sources. In addition, the proposed models are extended with learnable peripheral processing instead of the fixed peripheral front-end. The proposed methods show better performance compared to several baseline methods. In the second method, we propose two new interaural features for deep learning-based speech source detection and localization by using two binaural microphones of a hearing aid. Two spectral-temporal features are proposed based on the interaural cross correlation between the complex auditory subband signals, and generalized cross correlation with phase transforms (GCC-PHAT) weighted with gammatone filter shapes. In addition, some spectral power-based features are utilized to improve the performance of the deep model in detecting speech sources from nonspeech sources, in adverse acoustic conditions. Results show that the extended new feature set outperforms a deep-learning approach based on a more classical feature set.

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Coordinated Binaural Signal Processing for Bilateral Cochlear Implants

Tomas Gajecki & Waldo Nogueira

Introduction: Bilateral cochlear implant (BiCI) users do not benefit as much as normal hearing listeners from a bilateral input when it comes to speech understanding in noise and sound source localization. There is consensus that the reason is multifactorial, and that different mechanisms and causes are involved. One potential reason is related to the fact that both CI speech processors are physically and algorithmically independent. This may cause the delivery of distorted interaural cues and suboptimal front-end algorithmic binaural speech enhancement performance, which could be improved by leveraging potentially rich sources of information contained in the acoustic redundancy of the bilateral input.

Methods: In this study, we propose a fully coordinated BiCI processing strategy. This strategy relies on bilaterally synchronizing the electrical stimulation and on linking specific processing blocks of each CI. Specifically, we link the N-of-M band selection block performed by the CI located in the best signal-to-noise-ratio (SNR), artificially enhance interaural level differences (ILDs), and look into deep learning-based binaural speech enhancement by sharing latent information contained in each listening side by means of fusion layers.

This work is divided onto three different studies. In the first study we examine the effect of bilaterally synchronizing the CI electrical stimulation and linking the band selection is assessed with behavioral speech tests in 10 BiCI subjects. In the second study, we also investigate the effect that linked band selection and artificial enhancement of ILDs have on the lateralization abilities of 10 BiCIs. Finally, in the third and last study, we explore the effect that deep latent fusion layers have in the context of
speech denoising. We specifically examine the generalization abilities these layers provided the model with and how different encodings affect the overall enhancement performance.

Results: Speech perception results obtained in the first study show that the tested BiCI listeners benefit from bilaterally linked band selection and bilaterally synchronized electrical stimulation when compared to standard clinical BiCI setups. Sound source lateralization results gatehred in study number two indicate that three out of the 10 participants largely benefit from synchronized linked band selection for large azimuths and that all tested BiCIs benefit from the artificial ILD enhancement at smaller azimuths when compared to using natural ILDs. Finally, in in the third study we observe
that the proposed fusion layers seem to have the potential to improve speech enhancement performance on unseen data, with respect to the independent models, and that latent encodings are necessary in order for the model to exploit the bilateral input information.

Conclusions: In this work, we investigate a coordinated deep learning-based sound coding strategy for BiCIs. This work shows that coherent bilateral CI and deep learning-based speech processing have the potential to improve speech intelligibility and sound source lateralization of BiCIs.

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KUPEGA: Application Specific IntegratedCircuit Design for Convolutional Neural Networks on Hearing Aids

Simon Christian Klein[1], Holger Blume[1]

Neural networks (NN) offer great opportunities in hearing aid research, but their use on a hearing aid is still limited by memory and processing power. To enable their use, custom Application Specific Integrated Circuits (ASICs) need to be designed and manufactured. The ASIC should be suited to the computational needs of the different layer types present in typical neural networks. The main two layer types oppose different challenges: fully con-nected layers are very memory demanding, while convolution layers are very compute intensive. While the memory demand can be reduced by advanced quantization techniques (Klein, Kantic, & Blume, 2021), in order to improve computation performance different measures are needed.

While convolution layers have very few weights, up to several hundered operations for every weight have to be computed. That offers huge possibil-ities through parallelisation, but requires a careful data orchestration, to ac-count for the complex computation pattern. Most accelerators solve this problem by defining a low level dataflow and increase the bandwidth when scaling the accelerator. This works well for layers with certain dimensions (e.g. wide input, few channels), but suboptimal for others (e.g. narrow input, many channels). In contrast to other architectures the KUPEGA Architec-ture introduces a top-down approach, by splitting the workload along the six convolution dimensions spatially and temporally. This allows executing different dataflows by reconfiguration of each layer, adapted to the current dimension sizes.

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References: Klein, S. C., Kantic, J., & Blume, H. (4. Oktober 2021). Fixed Point Analy-sis Workflow for efficient Design of Convolutional Neural. 55th Annual Conference of the German Society for Biomedical Engineering.

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Dynamics of Cortical Neural Processing under Sensory-Perceptual and Auditory-Cognitive Load in Young Listeners

Brilliant[1*], Yifat Yaar Soffer[2,3*], Yael Henkin[2,3] and Andrej Kral[1]

Most communication in everyday life takes place in adverse listening conditions. The impact of sensory-perceptual (S-P) (e.g., background noise, competing talkers) and/or auditory-cognitive (A-C) loads (i.e., the task specific burden related to cognitive functions, such as working memory and attention) on this process remains unclear. In this study electroencephalographic recordings have been obtained from young normal hearing adult listeners to identify the neural markers related to specific S-P and A-C load effects. Two auditory tasks, a vowel identification task and an auditory Stroop task, were presented in two listening conditions, quiet and noise. Time-frequency representations using wavelet analysis were derived and both evoked and induced responses were analyzed. Stimuli evoked responses mainly in delta-theta bands. In addition to this evoked activity, alpha desynchronization and theta and beta synchronizations were observed in the induced domain, indicating extensive post-perceptual processing even after the behavioral response. These post-perceptual manifestations were not evident in the evoked potentials.
Comparison between the impact of S-P and A-C load separately revealed that higher S-P load (noise vs. quiet condition decreased the evoked theta power and induced activations in alpha and beta frequency band. Higher A-C load (auditory Stroop task vs. vowel identification task) resulted in increased, long-lasting (up to 2 seconds) theta activity. Taken together, the present methodology exposed neural markers in frequency domain of high-level auditory processing during an adverse listening condition.

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Effects of acute ischemic stroke on binaural perception

Anna Dietze[1,2*], Peter Sörös[3,4], Matthias Bröer[3], Anna Methner[3], Henri Pöntynen[1,2], Benedikt Sundermann[4,5], Karsten Witt[3,4], Mathias Dietz[1,2,4]

Stroke-induced lesions at different locations in the brain can affect various aspects of binaural hearing, including spatial perception. Previous studies found impairments in binaural hearing, especially in patients with temporal lobe tumors or lesions, but also resulting from lesions all along the auditory pathway from brainstem nuclei up to the auditory cortex. Currently, structural magnetic resonance imaging (MRI) is used in the clinical treatment routine of stroke patients. In combination with structural imaging, an analysis of binaural hearing enables a better understanding of hearing-related signaling pathways and of clinical disorders of binaural processing after a stroke. However, little data are currently available on binaural hearing in stroke patients, particularly for the acute phase of stroke. Here, we sought to address this gap in an exploratory study of patients in the acute phase of ischemic stroke. We conducted psychoacoustic measurements using two tasks of binaural hearing: binaural tone-in-noise detection, and lateralization of stimuli with interaural time- or level differences. The exact location of the stroke lesion was established by previously acquired MRI data. An additional general assessment included three-frequency audiometry, cognitive assessments, and depression screening. Fifty patients participated in the experiments, on average five days after their stroke onset. Patients whose lesions were in different locations were tested, including lesions in brainstem areas, basal ganglia, thalamus, temporal lobe, and other cortical and subcortical areas. Lateralization impairments were found in most patients with lesions within the auditory pathway. Lesioned areas at brainstem levels led to distortions of lateralization in both hemifields, thalamus lesions were correlated with a shift of the whole auditory space, whereas some cortical lesions predominantly affected the lateralization of stimuli contralateral to the lesion and resulted in more variable responses. Lateralization performance was also found to be affected by lesions of the right, but not the left, basal ganglia, as well as by lesions in non-auditory cortical areas. In contrast, binaural tone-in-noise detection was unimpaired in most patients, regardless of the lesion site.

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Dendritic Complexity of Layer III and V Pyramidal Cells in the Congenitally Deaf Auditory Cortex

Lea Sollmann[1, 2], Ana Bedalov[3, 4], Damir Kovacic[5], and Andrej Kral[1, 2]

The absence of peripheral stimulation in the auditory cortex leads to structural as well as functional changes in the brain (Kral et al., 2019, Ann Rev Neurosci). A reduction in thickness of cortical layers IV-VI in primary and secondary auditory areas have been observed in congenitally deaf cats (CDCs) when compared to normal-hearing controls (HCs) (Berger et al. 2017, J Comp Neurol).

In this study, we quantified structural neuromorphological changes at the cellular level in pyramidal neurons using the (i) Sholl method (Sholl, 1953) and (ii) additional somatic and dendritic parameters obtained from digitally identified and automatically reconstructed neuronal trees. A comparison in layer III and V pyramidal cells was performed in primary and secondary auditory fields (AI, AII, and DZ) and in the associated Brodmann area 7 from the same sections. Brain tissue was collected from adult CDCs (n=6) and HCs (n=6) that were perfused transcardially. The brain was cut with a cryostat and digitized using a KEYENCE BZ-9000E microscope. For analysis, 50µm thick frontal brain sections were stained with SMI-32 antibody (Mellott et al., 2010, Hear Res). Quantitative analysis was performed using KARMENstudio, a fully automated machine learning based software that was applied on digitized neuronal images. 3450 pyramidal neurons in layers III and V were analyzed in the present study. We found systematic significant differences between layer III and layer V pyramidal neurons, particularly pronounced in basal dendritic length in the deaf cats not present in the HC group. In addition, we found significant differences in dendritic lengths in layer V between deaf and hearing cats. All together, these data support the previous study on reorganization of deep cortical layers (Berger et al., 2017, J Comp Neurol) and demonstrate that a part of these differences is due to changes in the dendritic trees. Our data confirm that neurons developmentally deprived of their adequate input reorganize their dendritic tree and thus loss of sensory input has implications for morphology of the auditory cortical neurons.

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Development of an implant-associated drug delivery system for the cochlear implant based on a silicone matrix

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One critical issue of the cochlear implant is the relatively large gap between the cochlear electrode and the remaining spiral ganglion neurons (SGNs). For a better acoustical experience, an improvement of the electrode-nerve contact is necessary.[1] For this purpose, a growth factor-based drug delivery system is developed which will be established on the cochlear implant.

The system is based on nanoporous silica nanoparticles (NPSNPs). The growth factors neurotrophin-3 (NT-3) and brain-derived neurotrophic factor (BDNF) are attached to these nanoparticles. They are known to foster the growth and differentiation of neurons.[2] Also, it is known that gradients of NT-3 can guide outgrowing neurites.[3]
After incubation, it could be shown that the particles are capable to function as a release system.

The attachment of NPSNPs to the cochlear implant is a major issue due to the inert nature of the used materials (silicone/platinum). A polymer coating is attached to the silicone via a UV-initiated radical reaction to bypass this.

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[1] N. Schmidt, J. Schulze, D. P. Warwas, N. Ehlert, T. Lenarz, A. Warnecke, P. Behrens, PloS one 2018, e0194778.
[2] A. K. Wise, R. Richardson, J. Hardman, G. Clark, S. O'Leary, The Journal of comparative neurology 2005, 487, 147–165.
[3] K. Moore, M. MacSween, M. Shoichet, Tissue engineering 2006, 12, 267–278.

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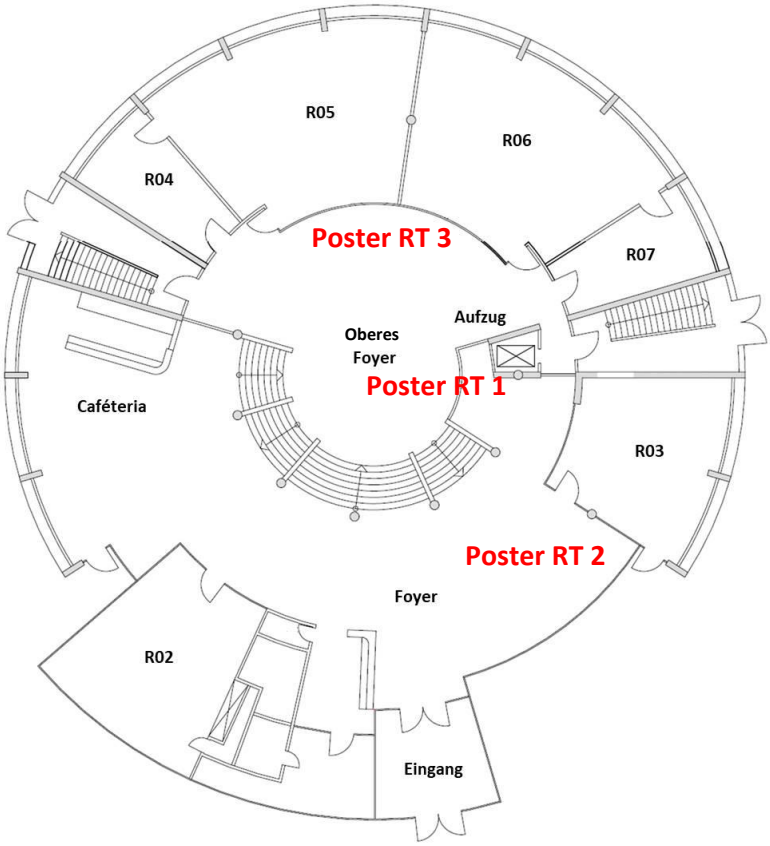
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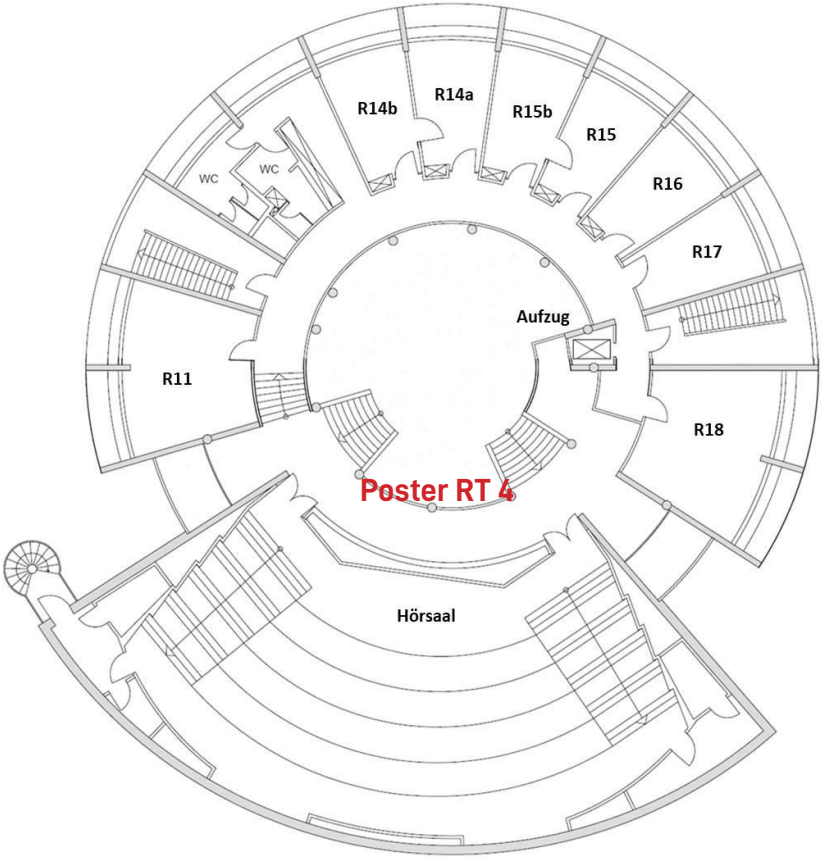
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Research Thread I:
Auditory processing deficits throughout the lifespan

I.01
The perception of Spanish vowels in adverse listening conditions: An investigation of children with typical hearing and children with hearing impairment

Marcel Schlechtweg (CvO Universität Oldenburg) & Mark A. Gibson (Universidad de Navarra, Spain)

I.02
Perception of non-native vowel contrasts in clear speech and in noise

Stephanie Kaucke & Marcel Schlechtweg

I.03
Hearing loss in juvenile rats leads to hyperactivity and pronounced social play-fighting during development and in adulthood, together with altered neuronal activity in frontal regions.

Jonas Jelinek, Marie Johne, Mesbah Alam, Joachim K. Krauss, Kerstin Schwabe

I.04
Neural mechanisms of contingency learning: the role of contingency awareness and cognitive control

Dorota Sznabel, Rüdiger Land, Bruno Kopp, Andrej Kral

Research Thread I:
Auditory processing deficits throughout the lifespan

I.05
OLANA: The Oldenburg Auditory Neuroscience Archive

Sebastian Puschmann, Rebekah Brückner, Stefan Debener, Andrea Hildebrandt, Christiane M. Thiel

I.06
Lexical access in children with normal hearing and children with cochlear implants

Bénédicte Grandon & Esther Ruigendijk

I.07
Molecular classification of SGN in ageing gerbils based on a comprehensive single cell transcriptome dataset

Schinzel, Leyk, Nothwang

I.08
fMRI Sampling Rate Effects on Estimating Voxel-wise Encoding Parameters

Funda Yilmaz, Arkan Al-Zubaidi, Leo Michalke, Jochem W. Rieger

I.09
Inter-subject alignment and single-trial classification using multiset canonical correlation analysis

Niloofar Sedaghatgouyanrad, Leo Michalke, Jochem W. Rieger

Research Thread II:
IT-based diagnostics and rehabilitation

II.01
Automated Speech Audiometry in Voice over IP calls

Tobias Bruns, Jasper Ooster, Matthias Stennes, Jan Rennies

II.02
Speech in Noise Tests on modern Smartphones. Can you hear the Noise?

Florian Kanzler, und Tobias Bruns

II.03
Development and Verification of Smartphone-Based Methods for Assessing Pure-Tone Audiometry and Loudness Growth Functions

Chen Xu, Lena Schell-Majoor, and Birger Kollmeier

II.04
Psychological profiling in a Virtual Hearing Clinic

Giulia Angonese, Inka Kuhlmann, Birger Kollmeier, Mareike Buhl & Andrea Hildebrandt

II.05
Relation Between Amplitude Modulation and Speech Perception in Cochlear Implant Users – An EEG Study

Nina Aldag

II.06
Predicting Cochlear Implant Performance with a decision tree approach

Alexey Demyanchuk

Research Thread II:
IT-based diagnostics and rehabilitation

II.07
Speech Intelligibility Prediction for Hearing-Impaired Listeners with Phoneme Classifiers based on Deep Learning

Jana Roßbach, Rainer Huber, Saskia Röttges, Christopher F. Hauth, Thomas Biberger, Thomas Brand, Bernd T. Meyer, Jan Rennies

II.08
Measuring day-to-day hearing variability in young and old

Inka Kuhlmann, Giulia Angonese, Christiane Thiel, Birger Kollmeier & Andrea Hildebrandt

II.09
How to measure the matrix test on a smartphone

Samira Saak, Mareike Buhl, Birger Kollmeier

II.10
Hearing aid gain self-adjustment and noise reduction trait estimation

Jonathan Gößwein, Jan Rennies und Birger Kollmeier

II.11
A Demonstrator for the Virtual Hearing Clinic

Chen Xu, Samira Saak, Lena Schell-Majoor, Birger Kollmeier

Research Thread III:
Auditory precision medicine: researchµbased novel intervention methods

III.01
Cable-bound recording of neuronal activity allows analysis of event related potentials in the three-tone auditory oddball paradigm

Jonas Jelinek, Marie Johne, Franck Fogaing Kamgaing, David Rotermund, Mesbah Alam, Joachim K Krauss, Elvis J Hermann, Kerstin Schwabe

III.02
Anodic polarity reduces cochlea implant facial nerve stimulation

Peter Baumhoff, Andrej Kral, Wiebke Konerding

III.03
Relation of electrophonic responses to hearing thresholds in cochlear implant stimulation

Mika Sato, Jochen Tillein, Andrej Kral

III.04
Mouse models with cell-type specific dysfunction in the inner ear as models of individual pathologies

Maike Claußen, Lena Ebbers, Janina Leyk, Andrej Kral, Hans Gerd Nothwang

III.05
The amyloid proteinopathy linked to Alzheimer´s disease increases oxidative stress and inflammation in the cochlea. A vicious circle?

José M. Juiz, T. H. Lenarz

Research Thread III:
Auditory precision medicine: researchμbased novel intervention methods

III.06
Balanced armature microactuator for round window stimulation

K. Bethmann, E. Müller, M. Prediger, A. Glukhovskoy, M. Wurz, H. Maier

III.07
Possibilities of Molecular Perilymph Diagnostics in Patients with Cochlea Implant Surgeries

Heike Schmitt

III.08
Fibre-based Neuronal Guidance Scaffold for the Inner Ear

Monika Seegers, Jennifer Harre, Thomas Lenarz, Athanasia Warnecke, Peter Behrens

III.09
Development of a drug delivery system based on silica nanoparticles and silicone

Luisa Vanessa Steingrube, Jörn Baumgarten, Arne Klaus Schierz, Jennifer Harre, Madeleine Goblet, Athanasia Warnecke, Thomas Lenarz, Peter Behrens

III.10
Development of a Nanocomposite Coating for Implant-Associated Local Drug Delivery from Neural Electrodes

M. Habib, T. Herrmann, K. Hindricks, T. Lenarz, A. Warnecke, P. Behrens

Research Thread IV:
The Hearing Device of the future

IV.01
Supervised Learning-Based Multi-Frame Filtering for Binaural Speech Enhancement

Marvin Tammen, Simon Doclo

IV.02
Exploiting an external microphone for binaural direction of arrival estimation for multiple speakers

Daniel Fejgin, Simon Doclo

IV.03
Spatial Coherence-Based RTF Vector Estimation for Acoustic Sensor Networks in a Diffuse Sound Field

Wiebke Middelberg, Simon Doclo

IV.04
AIKAPU: A Low-Power Mobile Hardware Platform for Integration of Online EEG-signal Processing into Hearing Aid Systems

Marc Wahalla, Holger Blume

IV.05
KUPEGA: Application Specific Integrated Circuit Design for Convolutional Neural Networks on Hearing Aids

Simon Klein, Holger Blume

IV.06
Portable Research Platform for Exploring Bio-Sensor-Based Hearing Devices

Steffen Dasenbrock, Volker Hohmann, Hendrik Kayser

Research Thread IV:
The Hearing Device of the future

II.07
Sensor fusion efforts on a mobile research platform: An Overview of past and future work

Paul Maanen, Stefan Debener, Hendrik Kayser, Volker Hohmann

II.08
Advanced fitting for spatially complex listening environments with a portable hearing aid research platform

Hendrik Kayser, Volker Hohmann

II.09
Oscillatory phase, not polarity alone modulates near-threshold auditory perception in transcranial alternating current stimulation studies

Sreekari Vogeti, Maryam Faramarzi and Christoph S. Herrmann

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Deep Real-time Improvement of Speech Signals after Packet Loss Using a Short Temporal Context

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II.11
Enhancement of Hearing Aid Processing via Spatial Spectro-Temporal Post-Filtering with a Prototype Eyeglass-Integrated Array

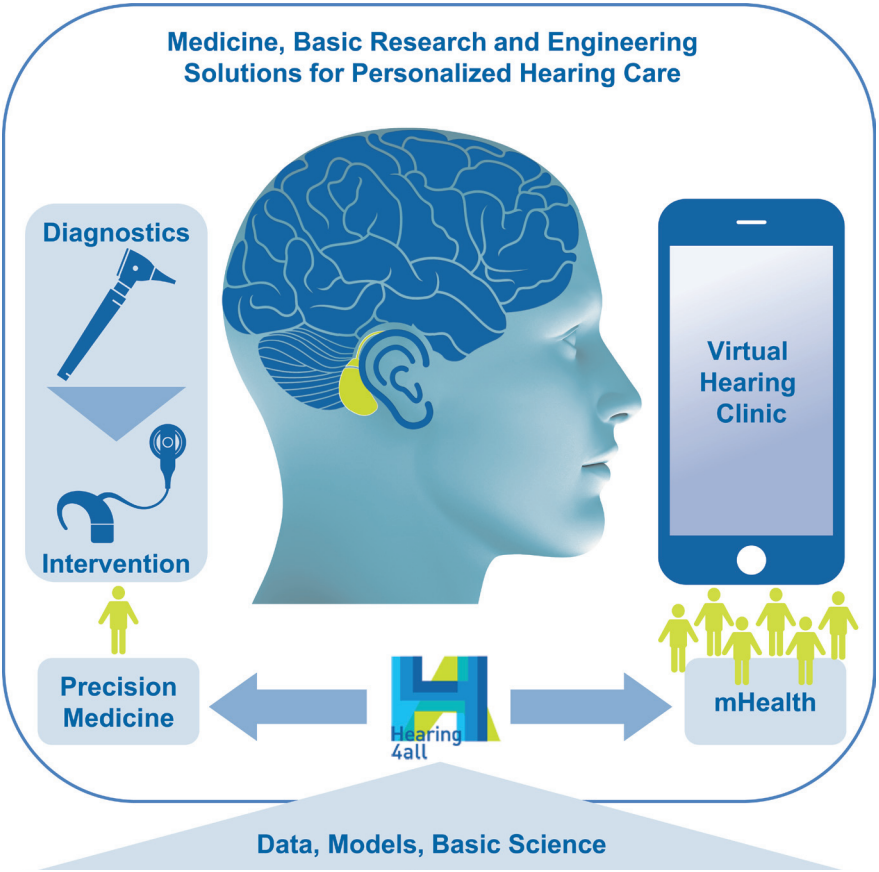
Marcos Cantu, Volker Hohmann

Hearing4all 2.0 –
Medicine, Basic Research and Engineering Solutions for Personalized Hearing Care

The long-term aim of Hearing4all is to solve the major problem of hearing impairment in our communication-oriented, ageing society by providing research-driven solutions to improve hearing for all listeners, i.e., for all kinds of hearing impairments, in all acoustical situations, and for all domains of everyday life. Hearing impairment is the most frequent chronic neurosensory disease (progressively affecting 17% of our population); it has one of the highest impacts on the quality of life and often leads to social isolation. Hearing aids, auditory implants and other treatments therefore need to become more effective than the currently unsatisfactory state-of-the-art. Hearing4all encompasses all the research expertise needed to fulfil patients´ needs through groundbreaking, individually tailored hearing solutions for all kinds of hearing impairment, ranging from near-normal listeners to deaf patients. By combining science-based functional auditory diagnostic methods with models of auditory processing in the normal and hearing-impaired auditory system, the most effective hearing solutions and medical treatment for the future will be sought, based on highly innovative algorithms, biomaterials and architectures for future generations of individually tailored hearing devices. The wide spectrum of combined expertise from basic science, engineering, and machine learning oriented towards clinical medicine allows a personalized approach to identify the causes of hearing impairment and of its amelioration. The research consortium from universities, non-university research institutions, and industry in the "Auditory Valley" network is in an internationally leading position to achieve solutions for the long-term goal of the Cluster of Excellence and to attain a paradigm shift in rehabilitative audiology from a descriptive empirical discipline towards a quantitative, model- and data-driven science.

Hearing4all 2.0 builds on the achievements and unique innovations from the current first funding period of the cluster. These include multilingual speech recognition tests, auditory mid-brain implants or precise, aided patient performance prediction with machine learning, which aim at better diagnosis, better hearing devices and better assistive technology in hearing support. To further advance Hearing4all into mobile Health solutions with a "virtual hearing clinic" for everyone - that includes a "software hearing device" and builds up auditory precision medicine with groundbreaking hearing device technology - we will pursue four ambitious and comprehensive research threads. These span two orthogonal dimensions: "Development chain: from basic research to solutions" and "Severity of hearing loss". The Excellence Centre for Hearing Research (Oldenburg/Hannover), the Joint Research Academy, and the Translational Research Centre will be developed as sustainable joint structures across the participating universities, coordinating basic, clinical and translational research.

Basic research on auditory brain function and on hearing devices is connected with medical research on precise diagnostics and treatment. This paves the way for hearing devices of the future and for mobile health (mHealth) apps in a data-driven and model-based approach.



Auditory processing deficits throughout the lifespan

Coordinators
Christiane Thiel (UOL), Andrej Kral (MHH), Georg Klump (UOL)

Objectives: Auditory deficits will be traced to structural and functional changes in the developing and ageing brain in a comparative approach focussing on three areas of research: multisource perception, hearing loss and compensation, and the relationship between hearing and cognition. An unprecedented array of neuro-scientific methods will be applied to understand the complex interplay throughout the lifespan between audition, the brain and cognition as the basis for developing auditory diagnostics and therapy.

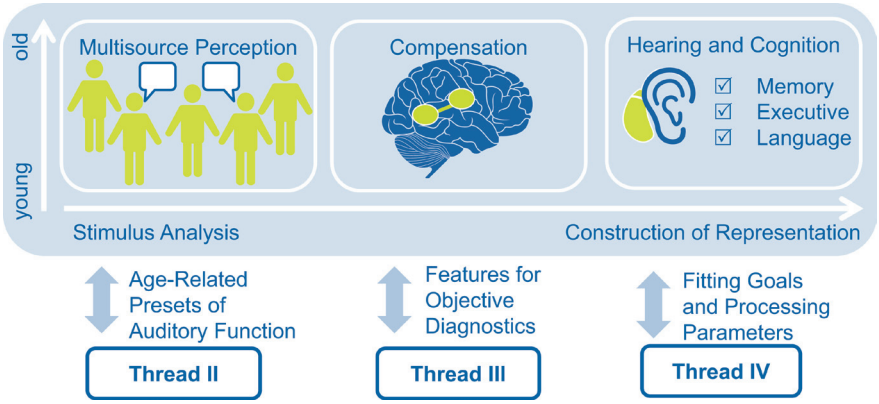
We will concentrate on the three most important aspects of characterising individual hearing ability across the lifespan that are especially important for diagnostics and treatment with hearing devices: Hearing in complex, multisource environments (including better understanding of source segregation and of temporal processing deficits), plasticity as a compensatory function in hearing impairment (including cross-modal plasticity) and interaction between hearing and cognition (including the relationship between hearing impairment and cognitive decline). These fields highlight different representation levels in the auditory system from stimulus analysis to the internal reconstruction of the outer world (representation construction) and provide the relevant knowledge on central physiological mechanisms to the other research threads (see Fig.), for example:

- Physiological signatures of source segregation, temporal processing and central auditory representation and compensation will provide objective measures to Research Thread II to diagnose impairments typical of multisource environments. Moreover, easily accessible and validated diagnostic methods will be shared with Research Thread II. Research Thread I will provide normative data from these measures to be inserted into the "virtual hearing clinic" for a better interpretation of the outcomes.

- Cognitive fingerprints and research methods will be shared with Research Thread III, to support rehabilitation strategies in the young and old.

- The most important changes observed with ageing in interaction with hearing devices and their consequences for the fitting and functioning of hearing devices will be provided to Research Thread IV, which will deliver prototype hearing devices for testing the interaction between aided performance, age and the performance domains considered in Research Thread I.

Research Thread I analyses auditory and cognitive performance across development and ageing, comparing stimulus-driven vs. cognition-driven processes linked to the construction of (internal) representation. It delivers results and data for the other research threads and receives input from them.

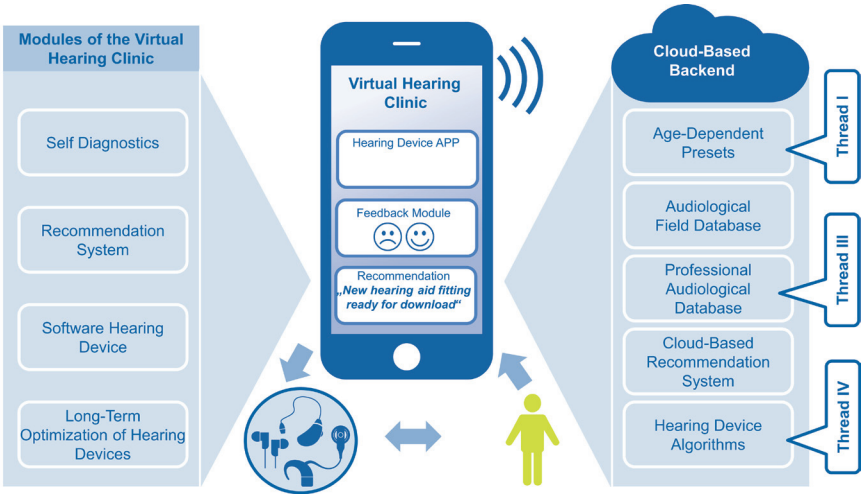


IT-based diagnostics and rehabilitation

Coordinators
Andreas Büchner (MHH), Birger Kollmeier (UOL), Simon Doclo (UOL)

Objectives: Groundbreaking data- and model-driven approaches towards self-controlled hearing tests and fitting of hearing devices will be advanced for listeners with a beginning, a mild or a moderate hearing impairment. Using machine learning techniques and professional databases, the aim is a multilingual "virtual hearing clinic" providing a low-threshold, affordable access and basic hearing support for every smartphone user (see Fig.).

To achieve this, we strive to develop a comprehensive system of multilingual diagnostic methods, functional auditory models, and hearing-aid fitting tools for smartphone-based devices in combination with data-driven, machine-learning-supported inference techniques. We aim at generating and exploiting a suitable "big" audiological data pool to quantify any possible relationships between audiological screening, diagnostic and hearing-aid benefit parameters and hence to verify or falsify the auditory model predictions



Functionality of the virtual hearing clinic approach from Research Thread II. A cloud-based backend with knowledge-based decision making provides treatment recommendations and settings for the subject's hearing device based on the individual user data obtained through the app.

developed in Hearing4all. The aim is to be able – by machine learning techniques employing probabilistic (Bayesian) approaches – to automatically deduce from an incomplete, error-prone individual diagnostic data set not only a potential diagnosis, but also the optimum treatment option and a related prediction of the benefit with the lowest possible uncertainty. Research Thread II will interact with the other research threads in various ways:

- Research Thread I will provide age-related expectations to be used for the various auditory functional parameters as well as ways to interpret the relationships between auditory functions across age.

- Research Thread III will manage and analyse the professional, clinical database and will provide access to it in order to classify patients as far as possible using their self-assessed data obtained within the virtual hearing clinics. Moreover, a common set of diagnostic methods and a classification and recommendation system for best treatment will be jointly developed with Research Thread III.

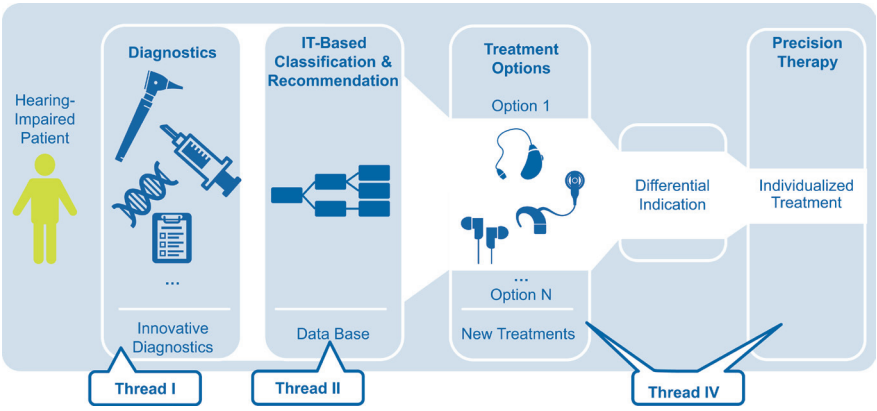
- The interface between auditory diagnostics and (virtual) hearing devices with respect to hearing device fitting and functioning will connect Threads II and IV.

Auditory precision medicine: research-based novel intervention methods

Coordinators
Thomas Lenarz (MHH), Birger Kollmeier (UOL), Peter Behrens (LUH)

Objectives: The precision of the auditory diagnostic procedure for patients with hearing loss will be substantially advanced. This will allow for an innovative, precisely individualized rehabilitative treatment, also involving newly developed therapeutic measures.

Prevention, diagnosis and treatment of hearing loss with respect to the wide variety of the different causes will require the development of novel approaches for extensive and in-depth diagnosis and targeted novel therapy options for precision treatment that supplement the technological and clinical interventions achieved in H4A 1.0. The goal is to determine the patient-specific, functional hearing deficit and to provide innovative therapies for individualized treatment as well as prevention strategies in a highly optimised way. The diagnostic methods (organized in a rational diagnostic decision tree, see Fig.) will be developed to yield the most relevant information and provide unprecedented precision in selecting the best treatment options, the most accurate prognosis and predicting a valid outcome for each individual patient. The aspired therapy options will supersede current treatment concepts by providing novel auditory implants including superselective electrodes, multimodal stimulators of the inner ear with additional bio-



Research Thread III provides auditory precision diagnostics and therapy and interacts with results and data from the other research threads.

logical components including local drug delivery to enhance the electrode-nerve interface, gene therapy to stop progression of hearing loss, and cell therapies to improve the neurobiological substrate for stimulation of the auditory system. The interaction with the other research threads is characterized as follows:

- Diagnostical methods, their results and interpretation throughout the lifespan is shared with Research Thread I that provides suggestions and data for objective diagnostics derived from auditory brain functions and cognition across developmental stages and ageing.

- The patient-centred database with statistical and knowledge-based methods to connect different patient's parameters for model-based diagnostics and interpretation will be shared with Research Thread II, thus creating a close link between the subclinical population, persons with a mild to moderate hearing loss (primarily covered by Research Thread II) and the moderate-to-severe hearing-impaired patients to be considered in Research Thread III.

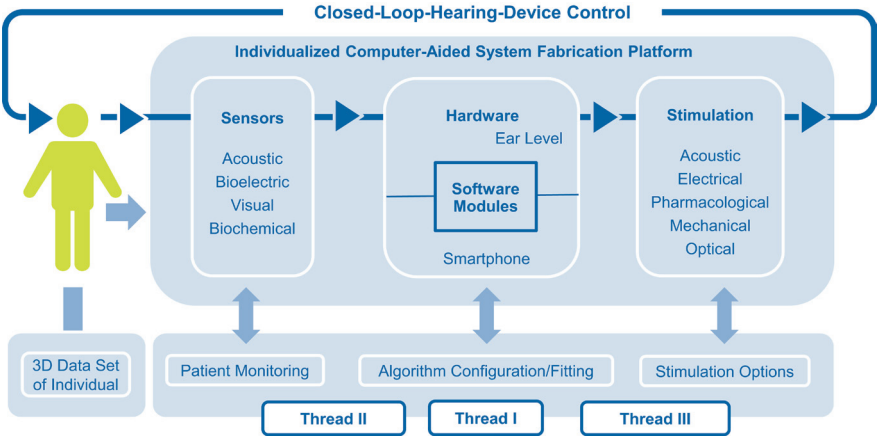
- The technology of the "hearing device of the future" and the options to simulate and predict aided performance, as pursued by Research Thread IV, underlies to the development of actuators and biological components for precision therapy performed in Research Thread III.

The H4A hearing devices of the future

Coordinators
Volker Hohmann (UOL), Holger Blume (LUH), Andreas Büchner (MHH)

Objectives: Based on the solutions from H4A 1.0, unprecedented, highly integrated system concepts, hardware and software solutions for research and applications will result from interdisciplinary research on comprehensive system technology. This translational research focus will enable the cluster to serve all degrees of hearing impairment and to achieve its ultimate goal of Hearing for All in the future.

The fourth research thread integrates research and development towards functional concepts, novel stimulation principles, hardware, software and algorithms for a groundbreaking hearing device system technology. This will enable the cluster to achieve its ambitious goals, i.e., to implement the "IT-based diagnostics and rehabilitation" and "auditory precision medicine" research threads utilizing the most advanced hearing device technology available worldwide. Devices of the future will be "human-centred", i.e., the subject will be the centre of all technology. In particular, closed-loop concepts utilizing biosignals for device adaptation and the empowerment of the patient, giving them control over their own device through the use of intelligent software interfaces, will define a new era of hearing devices (see Fig.).

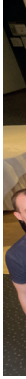


Research Thread IV develops hearing devices of the future and interacts with the other research threads by exchanging concepts, results and data.

To this end, device concepts based on the research results from H4A 1.0 and from the results of Research Thread I will be employed to design innovative functional principles and algorithms of next-generation devices while covering the whole range of acoustic, electric and alternative modes of stimulation including any combinations thereof. The connection to the other research threads are as follows:

The technology of the "hearing device of the future" and the options to simulate and predict aided performance, as pursued by Research Thread IV, underlies to the development of actuators and biological components for precision therapy performed in Research Thread III.

- The characterisation of the patient throughout their life time and its consequences for hearing device system design is shared with Research Thread I.
- The connection between the virtual hearing device developed and maintained in Research Thread IV and its integration into the virtual hearing clinic (Research Thread II) is shared by both Threads.
- The clinical parameters, experience and application data to specify and modify hearing devices will be received from Research Thread III, which will receive technical solutions (prototypes) to be used within clinical rehabilitative audiology.



Staff

The groups contributing to the cluster provide a unique set of competencies in basic science, applied and translational research, and clinical medicine in a transdisciplinary structure from physics, chemistry, engineering, biology, physiology, psychology as well as the clinical specialties otology, audiology, and neurology. Likewise, the whole range of research expertise required for the developmental chain from patient needs via diagnostics, models, devices and clinical applications towards comprehensive hearing solutions is covered.

Spokespersons

Birger Kollmeier (Authorised Spokesperson)
Carl von Ossietzky University of Oldenburg

Thomas Lenarz (Clinical Spokesperson)
Hannover Medical School

Principal investigators

Peter Behrens (LUH)
Georg Berding (MHH)
Holger Blume (LUH)
Andreas Büchner (MHH)
Stefan Debener (UOL)
Simon Doclo (UOL)
Theodor Doll (MHH)
Alexander Heisterkamp (LUH)
Christoph Herrmann (UOL)
Volker Hohmann (UOL)
Georg Klump (UOL)
Birger Kollmeier (UOL)
Christine Köppl (UOL)
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Jutta Kretzberg (UOL)
Thomas Lenarz (MHH)
Jörg Lücke (UOL)
Hannes Maier (MHH)
Hans Gerd Nothwang (UOL)
Jochem Rieger (UOL)
Esther Ruigendijk (UOL)
Kerstin Schwabe (MHH)
Christiane Thiel (UOL)
Steven van de Par (UOL)
Athanasia Warnecke (MHH)

Research Focus
Diagnostics – Models – Devices – Clinical Applications

Research Expertise
Clinical – Translational – Applied - Basic

Ruigendijk	Thiel	Kretzberg	Rieger	Herrmann
Köppl	Klump	Lücke	Kral	Debener
van de Par	Doclo	Heisterkamp	Blume	Maier
Nothwang	Behrens	Kollmeier	Doll	Hohmann
Berding	Schwabe	Warnecke	Büchner	Lenarz

In addition to the PIs, a number of internationally visible, non-PI researchers participate as members of H4A 2.0 with financial support. They qualify for a prominent role within the cluster either by a professorship or a group leader position in one of the institutions supporting the cluster or have shown a high potential for a future leadership position or professorship. Their involvement in the projects of H4A 2.0 also secures the close interaction with non-university research institutions that provide strategic advantages in some of the fields to be addressed by H4A 2.0, e.g.:

- Access to the hearing-aid manufacturers worldwide through their strong collaboration with Hörzentrum Oldenburg GmbH and HörTech gGmbH
- Access to the cochlear implant manufacturers worldwide through Deutsches Hör-Zentrum Hannover (DHZ) at the Hannover Medical School, Hörsys GmbH, Fraunhofer ITEM and Hörzentrum Oldenburg GmbH
- Access to the consumer electronic industry and to IT-market global players via the Fraunhofer IDMT/HSA
- Access to international research networks and organizations in neuroscience and the social sciences relevant for technology follow-up research through the Hanse-Wissenschaftskolleg, Delmenhorst

Contact:

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Medizinische Hochschule Hannover (MHH)
Leibniz Universität Hannover (LUH)

Cooperation Partners

Hörzentrum Oldenburg gGmbH (HZO)

Fraunhofer Institute for Digital Media Technology IDMT, Project Group Hearing, Speech and Audio Technology (IDMT/HSA)

Fraunhofer Institute for Toxicology and Experimental Medicine ITEM (ITEM)

Jade University of Applied Sciences (Jade HS)

Laser Zentrum Hannover e.V. (LZH)

Hanse-Wissenschaftskolleg (HWK) – Institute for Advanced Studies

Deutsches Institut für Kautschuktechnologie e.V. (DIK)

HörSys GmbH

KIZMO GmbH - Klinisches Innovationszentrum für Medizintechnik Oldenburg