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

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Abstract Book

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Content

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Dear colleagues and guests of the „Future of Hearing" symposium,

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

On behalf of all members of the Cluster of Excellence we would like to welcome you to our international annual Symposium. After 11 years since the inauguration of our Cluster and 5 years into the second funding period, we are excited about all the highly successful work that has led us so far and about all the upcoming changes and preparations for the application for a third funding period. Please find out yourselves about all new developments by participating in the Symposium!
As usual, we will present keynote talks from international renown guest scientists as well as contributions from our own researchers, including overviews and highlights from the Research Threads and all other components of our cluster. In addition, a comprehensive poster session will allow you to go into more details by discussing recent developments with our staff – please see yourselves!

A number of coordinated actions (i.e. joint workshops, discussion rounds, writing days, consultation with external experts and the university boards as well as a scan of high potential researchers for the new group of principal investigators) has been pursued as a running process within the last year. Since both spokespersons of the Cluster will retire within the next three years, Prof. Dr. Christiane Thiel, Prof. Dr. Holger Blume and Prof. Dr. Andrej Kral will take over the spokesperson function of the cluster for the new application period. Moreover, a number of excellent scientists have accepted new professorship positions in the cluster within the last year in one of the supporting universities (i.e., Universität Oldenburg (UOL), Hannover Medical School (MHH) and Leibniz Universität Hannover (LUH)): Prof. Dr. Athanasia Warnecke (biological therapies for the inner ear, MHH), Prof. Dr. Jörg Albert (neurophysiology and behaviour, UOL), Prof. Dr. Jan Clemens (auditory neurophysiology, UOL), Prof. Dr. Maximilian Lenz (Neuroanatomy, MHH), and Prof. Dr. Pascale Sandmann (clinical auditory diagnostics, UOL). This all contributes to rejuvenating the cluster staff in a sustainable growth process like the "ever-skinning snake"!

Please use this opportunity to get into contact with our Cluster members 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. Dr. Dr. Birger Kollmeier
Spokesperson

Prof. Prof. h.c. Dr. med. Thomas Lenarz
Deputy Spokesperson

Thursday, 02.11.2023 | 09:00 - 18:30

Time	Topic
08:30 - 09:00	**Arrival and registration**
09:00 – 09:20	**Welcome and Introduction (Kollmeier, Lenarz)**
09:20 - 12:10	**Research Thread II: IT-based diagnostics and rehabilitation (Büchner, Kollmeier, Doclo)**
09:20 - 09:50	**Josef Chalupper** Finding the Self-Clinician-Balance: Hybrid Care of CI recipients
09:50 - 10:20	**Adele Diederich** Models of cognitive processing with relation to audiology
10:20 - 10:50	**Coffee Break**
10:50 - 11:10	**Overview and Highlights from Research Thread II** (including Poster Overview)
11:10 – 11:30	Alexey Demyanchuk Outcome Prediction in CI using Machine Learning
11:30 – 11:50	Anna Warzybok-Oetjen Matrix sentence tests: international application in diagnostics and research
11:50 – 12:10	Antje Wulff Towards Interoperable and FAIR Datasets in Audiology
12:10 - 13:10	**Lunch Break**

Thursday, 02.11.2023 | 09:00 - 18:30

Time	Topic
13:10 - 13:40	**TRC Highlight Talk** Jörg-Hendrik Bach ACALES - subjective listening effort scaling from basic research to viable product
13:40 – 16:30	**Research Thread I: Auditory processing deficits throughout the lifespan (Thiel, Kral, Klump)**
13:40 – 14:10	**Anja Hahne** Objective measurement of semantic learning processes in cochlear implant users: Evidence from longitudinal N400 studies in adults and young children
14:10 – 14:30	**Overview and Highlights from Research Thread I** (including Poster Overview)
14:30 - 14:50	Go Ashida Simulating the mammalian sound localization circuit - from auditory nerves to the superior olive
14:50 - 15:10	Andrej Kral Crossmodal Plasticity in Hearing Loss
15:10 - 15:30	Sebastian Puschmann Modulation of auditory cortex responses to speech in background noise by visual cues
15:30 – 16:00	**Coffee Break**

Thursday, 02.11.2023 | 09:00 - 18:30

Time	Topic
16:00 – 16:30 (online)	**Ladan Shams** The role of auditory-visual interactions in perception, memory and learning
16:30 - 17:00 (online)	**Tara Sainath** The Journey of E2E Models: From Research to Production
17:00 – 17:10	Announcements for the evening /next day
17:10 - 18:30	**Visit to the Poster Exhibition** **Open discussions with our poster authors**
19:30 - 21:00	**Evening Event:** **Windstärke 12 - Big Band concert**

Friday, 03.11.2023 | 09:00 - 16:00

Time	Topic
09:00 - 09:10	**Welcome (Birger Kollmeier)**
09:10 – 11:30	**Research Thread IV: The Hearing Device of the future (Hohmann, Blume, Büchner)**
09:10 – 09:40	**Dorothea Kolossa** Audio-visual hearing support: Harnessing machine learning to support hearing beyond acoustics
09:40 – 10:00	**Overview and Highlights from Research Thread IV** (including Poster Overview)
10:00 – 10:20	Ragini Sinha Subjective Performance Evaluation of Single-channel Speaker-conditioning Target Speaker Extraction Systems
10:20 – 10:50	**Coffee Break**
10:50 – 11:10	Marc-Nils Wahalla Online EEG-Signal Processing within the CereBridge mobile Brain-Computer Interface system
11:10 – 11:30	Sreekari Vogeti Modulating near-threshold auditory perception using transcranial alternating current stimulation
11:30 - 12:30	**Visit to the Poster Exhibition** **Open discussions with our poster authors**
12:30 - 13:20	**Lunch Break**

Friday, 03.11.2023 | 09:00 - 16:00

Time	Topic
13:20 – 15:40	**Research Thread III: Auditory precision medicine: researchbased novel intervention methods (Lenarz, Kollmeier, Behrens)**
13:20 – 13:50	**Akira Ishiyama** Human temporal bone histopathology and molecular analysis of intracochlear changes following cochlear implantation
13:50 – 14:20	**Paul Avan** From genetic models to an improved characterization of age-related hearing loss
14:20 - 14:40	**Overview and Highlights from Research Thread III** (including Poster Overview)
14:40 - 15:00	Eugen Kludt Personalized Cochlear Implantation Using Fluoroscopy and Intraoperative ECAP Measurements
15:00 - 15:20	Heike Schmitt Towards molecular treatment strategies: possibilities of molecular perilymph diagnostics in patients with inner ear diseases
15:20 - 15:40	Maximilian Lenz Investigating synaptic transmission and plasticity in the human neocortex
15:40 – 15:50	**Poster award ceremony (Birger Kollmeier, Thomas Lenarz)**
15:50 – 16:00	**Farewell and closing remarks (Birger Kollmeier, Thomas Lenarz)**

Friday, 03.11.2023 | 16:30 - 18:30

16:30 – 17:30	Scientific Advisory Board Meeting (internal)
17:30 – 18:30	Cluster Board Meeting (internal)

Anja Hahne
Technische Universität Dresden & University Clinic Dresden

Objective measurement of semantic learning processes in cochlear implant users: Evidence from longitudinal N400 studies in adults and young children

Cochlear implants enable the (re)acquisition of hearing through electrical stimulation. However, there are technical limitations compared to natural hearing. In addition, the CI encounters an acoustically deprived system. What are the consequences for speech understanding with a CI? All of the studies presented in this talk investigate word processing using the N400 effect in the event-related potential. The high temporal resolution of the event-related potentials allows detailed analysis of word processing. The focus will be on EEG studies with adult CI users in silence and in the particularly challenging situation of background noise. In several longitudinal studies, starting as early as 3 days after initial activation of the speech processor and continuing for up to one year, the learning processes that CI users have to go through in order to understand words again are investigated. Surprisingly, very rapid learning effects are shown for word comprehension in quiet. Understanding in noise, however, develops rather slowly. In addition, studies on early implanted children who have to establish their language system based on electrical stimulation are also discussed. The focus here is on vocabulary development. Is brain plasticity sufficient to compensate for deprivation and reduced input? What is the time course of semantic learning compared to normal hearing children?

Ladan Shams
Multisensory Perception Laboratory at University of California, Los Angeles, USA

The role of auditory-visual interactions in perception, memory and learning

Humans are often referred to as "visual animals" and the saying "seeing is believing" is frequently invoked. I will present an illusion that demonstrates how auditory input can radically alter what we see. I will also present findings that show visual learning can be facilitated and enhanced substantially by sound. Some of our findings point to the critical role played by the auditory cortex in processing perceptions, even when the tasks and stimuli are visual. Conversely, visual information can exert a substantial influence on auditory processing. While the influence of vision on auditory perception has been well-documented, our recent findings shed light on the role of auditory-visual integration in shaping auditory memory. Our results also uncover individual differences in how visual inputs impact the encoding of auditory information, ultimately giving rise to distinct memory styles. Collectively, these findings underscore the intricate and reciprocal functional relationship between hearing and vision across all stages of information processing, encompassing perception, learning, and memory.

Josef Chalupper
Advanced Bionics GmbH, Hannover, Germany

Finding the Self-Clinician-Balance: Hybrid Care of CI recipients

In a hybrid care model, digital and physical experiences are fused together to provide flexible, accessible patient-centric care. Potential benefits of hybrid care in the provision of cochlear implants include increased capacity at clinics and improved individual fitting outcomes and less travelling efforts for the CI recipient. In order to make the potential benefits a reality, self-administered variants of clinical tasks like speech and tone audiometry are required. Moreover, the integration of self-administered tasks into the clinical workflow and interactions of all involved players (healthcare provider, recipient, hearing device) must be considered. Across the individual patient journey from getting awareness of hearing impairment to surgery and acclimatization to stable performance the optimum mix of digital/virtual vs. physical/personal experiences must be customizable to satisfy needs of professionals and recipients. While the surgery presumably will remain a primarily physical/personal experience at the clinic, during the acclimatization and maintenance phase the "Self-Clinician-Balance" might shift from clinician-administered tasks to self-administered tasks. Involving the recipient into the individual fine-tuning of 1) global fitting parameters like coding strategy and frequency allocation table or 2) situation-specific parameters like noise reduction settings might increase individual benefit as oftentimes clinicians do not have enough time for such time-consuming tasks. Once a stable fitting achieved, self-administered speech tests might help to reduce the amount of personal annual visits to the clinic. First results from respective studies will be presented in this contribution.

Adele Diederich
Department of Psychology, University of Oldenburg

Models of cognitive processing with relation to audiology

Modeling the processes involved in speech and hearing are fundamental, not only for understanding the underlying mechanisms but also for diagnosing hearing deficits and therapy. While sophisticated models on signal processing in the auditory system have been developed and possible places identified where degradations in the signal processing may occur leading to hearing impairment, less is known about the underlying decision processes that lead to a specific response. The prevalent decision model is signal detection theory (SDT) accounting for response biases and deviations from an ideal observer. Some modifications of SDT seek to account for attention lapses in the search of an ideal psychometric function. Cognitive models are predominately qualitative. For instance, in the context of speech the influential Ease of Listening and Understanding (ELU) model by Rönneberg and colleagues is descriptive and closely related to experimental design manipulations, but it provides no formal mechanism allowing for quantitative predictions and rigorous testing.

The present cognitive model seeks to incorporate the stochastic-dynamic components inherent in any decision making. It originates from preferential decision making and provides a computational framework for complex decisions. It incorporates the so-called mechanical model for speech perception proposed by Uslar et al (2015) assuming bottom-up and top-down and processes framed as dual-process. It includes signal-triggered components (e.g., output of the signal processing stage) but also cognitive components like attention and motivation.

Akira Ishiyama
David Geffen School of Medicine at University of California,
Los Angeles, USA

Human temporal bone histopathology and molecular analysis of intracochlear changes following cochlear implantation

There is a growing focus on short term audiometric outcomes rather than the long-term hearing outcomes enabled by cochlear implants and effective electrical stimulation. When considering a patient's outcome with cochlear implant, it is important to define performance as measured over the "lifetime of the patient", rather than concentrating on the short-term benefit of hearing preservation in the low frequencies.

With numbers of cochlear implant recipients increasing worldwide, an understanding of how to minimize intracochlear changes following cochlear implantation is important. Therefore, it is important to consider factors that can maintain the long-term cochlear health by minimizing the intracochlear injury from surgery and secondary changes due to host response. Cochlear implantation can lead to insertion trauma and foreign body reaction resulting in intracochlear new tissue formation, which can detrimentally affect implant performance.

Transforming growth factor beta-1 (TGF β-1) and connective tissue growth factor (CTGF) are pro-fibrotic proteins implicated in various pathologic conditions, but little is known about their role in the cochlea. Archival human temporal bone specimens obtained from 12 patients who received cochlear implantation were used in this study. Histopathologic analysis of fibrosis and osteoneogenesis was conducted. Protein expression was characterized using immunofluorescence and co-localization studies were conducted using laser confocal microscopy. TGF β-1 was expressed diffusely within the fibrous capsule while CTGF was expressed in the thickened portion towards the modiolus. There was also strong expression of CTGF at the junction between fibrosis and new bone formation.

Fibrosis and osteoneogenesis following CI placement can lead to implant malfunction and loss of residual hearing. To our knowledge, this is the first study to demonstrate increased expression of TGF β-1 and CTGF in the human implanted cochlea and may provide better understanding of the mechanism behind this pathogenic process for future therapies.

Paul Avan
Center for Research and Innovation in Human Audiology
Institut Pasteur, Paris, France

From genetic models to an improved characterization of age-related hearing loss

Pilot studies conducted in the laboratory have shown that in a sample of about 200 volunteers, recruited France-wide, with untimely age-related hearing loss, almost one quarter presented with an ultra-rare variant in one gene already known for being causative for congenital sensorineural hearing loss (SNHL) of type DFNA (non syndromic, dominant). Each of the 53 ultra-rare variants described from this study was shown to be causative of a late-onset form of SNHL, based on a set of cues such as genealogy, predicted protein shape and similar effect when expressed in a murine model. In the remaining 75% volunteers, monogenic causes could not be excluded, perhaps due to variants of 'unknown significance' (unknown, yet).

One interest of this observation stems from the fact that the genes of interest are expressed in selected auditory cells functionally involved only in precise stages of peripheral auditory processing. Thus we assume the existence of audiological signatures of their defect. These signatures might help define optimal objective and subjective audiological tests, also able to disentangle the complex disorders expected in regular (non monogenic) ARHL. The study that we are now conducting is a replication of the pilot one based on the same inclusion criteria, in which pure-tone audiometry is completed by a broad set of electrophysiological and perceptive tests. The studied disorders lead to expect a Schuknecht-like categorization into sensory, neural or metabolic types of SNHL, and a Plomp-like description of hearing loss in terms of loss in sensitivity and sensory distortions that a systematic study of audiological profiles in monogenic ARHL will help better characterize. Current tests in volunteers last 6 hours and combine many stimuli, pure-tones, clicks, noise and speech sounds. In addition, a comprehensive evaluation of balance is carried out as several genes of interest are expressed in the vestibule. Machine learning using the collected data should contribute to an evidence-based definition of the minimum set of tests allowing optimal (short and efficient) categorization. The first set of results using customized version of electrocochleography and distortion-product otoacoustic emissions will be discussed.

Acknowledgments: we warmly acknowledge the collaboration with Birger Kollmeier's laboratory (Anna Warzybok; Andeas Radeloff in the ENT department), University of Oldenburg, supported by a grant from DFG -ANR (ANR-21-CE14-0075 on the French side, plus support from grant FPA-IDA1 and 10).

Tara Sainath
Google LLC, Mountain View, California, USA

The Journey of E2E Models: From Research to Production

End-to-end (E2E) speech recognition has become a popular research paradigm in recent years, allowing the modular components of a conventional speech recognition system (acoustic model, pronunciation model, language model), to be replaced by one neural network. In this talk, we will discuss a multi-year research journey of E2E modeling for speech recognition at Google. This journey has resulted in E2E models that can surpass the performance of conventional models across many different quality and latency metrics, as well as the productionization of E2E models for Pixel 4, 5 and 6 phones. We will also touch upon future research efforts with E2E models, including multi-lingual speech recognition.

Dorothea Kolossa
Electronic Systems of Medical Engineering Group
Technische Universität Berlin, Germany

Audio-visual hearing support: Harnessing machine learning to support hearing beyond acoustics

Speech communication plays a central role in human connection and daily life. Hearing impairments have far-reaching consequences that extend beyond their immediate impact on speech perception. They can result in social isolation, affect emotional well-being, and are even associated with cognitive decline. Despite recent advancements in speech technology, individuals relying on hearing aids and cochlear implants (CIs) continue to face challenges in understanding speech, particularly in noisy or reverberant environments.

One promising avenue for improving speech comprehension in such adverse conditions involves the inclusion of alternative sensory modalities. Extensive research has shown that visual cues, i.e., observing a speaker's mouth, significantly enhance speech understanding. Likewise, as we have also shown in our work, integrating video information of a speaker's moving face into computer-based speech recognition systems can yield substantial improvements.

Nonetheless, the application of visual information for speech enhancement in hearing aids and CIs remains relatively unexplored, despite its evident potential. In this presentation, I will examine this concept from two angles: firstly, by discussing the current understanding of audio-visual speech perception in human listeners, and secondly, by exploring audio-visual integration in machine listening and speech enhancement. Via a hybrid approach that combines statistical and machine learning approaches, I will outline how a consistent enhancement of machine speech perception can be obtained, even if the video information of the speaker's lips may only be available intermittently or in poor quality.

However, both the issues of latency and of privacy can form obstacles to the wider adoption of audio-visual speech enhancement. Thus, in the final part of this talk, I will address these two challenges, together with a few potential avenues for mitigating both issues in future research.

Research Thread I:

Auditory processing deficits throughout the lifespan

Research Thread I aims at understanding the neural mechanisms supporting source segregation and auditory processing throughout the lifespan by combining an unprecedented array of neuroscientific methods and modelling approaches in both animals and humans to feed into evidence-based development of auditory diagnostic tools and therapy. The cluster strives to understand central plastic changes in young and old hearing-impaired individuals and provide strategies to reverse detrimental changes. In addition, the causal impact of hearing loss in young and old age on cognition and brain connectivity and the changes induced by hearing devices (hearing aids or cochlear implants) is investigated.

Go Ashida: Simulating the mammalian sound localization circuit - from auditory nerves to the superior olive

The ability of sound localization, or detecting the direction of a sound source, is one of the most fundamental functions of the auditory system. It is essential, for example, for speech perception in a noisy environment. Mammals including humans possess a specialized neuronal circuit in the hindbrain that is devoted to the processing and detection of binaural sound localization cues such as the interaural time and intensity differences. Since the start of the Excellence Cluster Hearing4all, we have developed a computer model framework to simulate the responses of biological neurons in the sound localization circuit. Such a "physiological modeling" approach has been found useful in understanding the underlying biophysical mechanisms of binaural acoustic information processing, in simulating the performances of subjects in psychophysical measurements, and in assessing possible functional degradations associated with pathological changes in relevant neurons and synapses. To illustrate these points, this talk will focus on the following topics: (1) a brief review on the physiology and anatomy of the sound localization circuit; (2) our modeling of the lateral superior olivary nucleus and simulating its robustness against age-related changes; (3) collaborative approach in predicting perceived lateralization of amplitude-modulated sounds; (4) enhancement of binaural coding by bushy cells in the cochlear nucleus that lies in between the auditory nerve and the superior olivary complex. Future improvements of our modeling framework will also be discussed.

Andrej Kral: Crossmodal Plasticity in Hearing Loss

Crossmodal plasticity is a textbook example of the ability of the brain to reorganize based on use. The congenitally deaf cat is a unique model that recapitulates many reorganizations of the brain related to deafness, including critical periods, changes in brain connectivity and cross-modal reorganizations. Using this model it has been possible to study the neuronal mechanisms behind cross-modal plasticity in this extreme deprivation condition (complete and congenital). The data demonstrate a high areal specificity of the reorganization, a moderate anatomic substrate and correspondingly a limited electrophysiological substrate of cross-modal rewiring. The data are compatible with a mechanism exploiting pre-existing circuitry and top-down interactions (review in Kral and Sharma, 2023, Trends Neurosci). The data disprove the hypothesis that crossmodal reorganization is responsible for closing critical periods in deafness or that it interferes with cochlear implant therapy. In consequence crossmodal plasticity does not affect the neuronal preconditions for successful hearing restoration and given its dynamic and versatile nature. Crossmodal plasticity can be effectively exploited for improving clinical outcomes after neurosensory restoration.

Supported by Deutsche Forschungsgemeinschaft (Exc 2177) and European Union (ITN Comm4Child)

Sebastian Puschmann: Modulation of auditory cortex responses to speech in background noise by visual cues

Audiovisual binding is an integral aspect of natural speech processing in face-to-face situations. Visual speech provides important cues on the timing and rhythmic properties of an ongoing acoustic signal as well as on its content, and facilitates the perception of speech, especially in noisy listening settings. The neural correlates underlying this enhancement have been widely investigated, showing that visual input shapes neural activity at different levels of language processing. How audio-visual interactions modulate early speech representations in the auditory sensory cortex, is however not clear at present. To explore this question, we conducted an fMRI experiment using naturalistic and continuous (audiovisual) speech in background noise. In this talk, I will describe how neural responses to continuous (audiovisual) stimulation can be assessed using between-brain analysis methods. Based on this approach, I will demonstrate that visual input enhances stimulus-driven activity at different stages of the auditory cortex processing hierarchy, starting as early as in the primary auditory cortex. Furthermore, I will provide evidence that the observed enhancements are related to functional interactions between higher-order auditory and visual sensory regions.

Research Thread II:
IT-based diagnostics and rehabilitation

The aim of Research Thread II is the development of ground-breaking data- and model-driven approaches towards self-controlled multilingual hearing tests, automatic initial hearing loss diagnostics, and fitting of hearing devices. The cluster seeks to develop an app-based multilingual "virtual hearing clinic" for interactive use which on the one hand provides low-threshold, entry-level hearing support for smartphone users through readily available hearables, and on the other hand offers hearing device users the possibility to optimise their hearing sensation through simple-to-use interfaces and inferences from large databases.

Alexey Demyanchuk: Outcome Prediction in CI using Machine Learning

Hearing loss affects over 17% of the population and can significantly impact quality of life. Cochlear implantation is a promising solution to restore hearing ability, but predicting its efficacy for the patient is challenging. To address this, we developed a machine learning system using a large dataset from 2200 adult patients who had post-lingual onset of hearing loss and underwent cochlear implantation. The dataset included epidemiological factors and clinical information. The target variable was the average postoperative monosyllabic score in the 1 year after operation timeframe.

Our system involved iterative stages, starting with exploratory data analysis to select appropriate features, build a data preprocessing pipeline, and train and evaluate decision tree models using k-fold cross-validation. Models were finally tested on a hold-out dataset, resulting in a mean absolute error of 18.9%. The decision tree visualization graphs provided interpretations for predictions, aiding clinicians in understanding the rationale and potential error.

Our system's predictive capabilities were evaluated on future data, resulting in a mean absolute error of 18.5%. The results demonstrate the potential of machine learning methods in predicting cochlear implant outcomes and improving patient care.

In summary, our machine learning system for predicting postoperative performance of cochlear implantation utilized a large dataset and involved several iterative stages of development. The system achieved a reasonable error, demonstrating promising potential for improving patient care.

Anna Warzybok-Oetjen: Matrix sentence tests: international application in diagnostics and research

Anna Warzybok-Oetjen, Shiran Koifman, Sabine Hochmuth, Maximilian Karl Scharf, and Birger Kollmeier

Matrix sentence tests have been developed in more than 20 languages in order to enable accurate, reliable, and internationally comparable speech recognition measurements. The primary application of these tests is to improve the precision of audiological diagnostics. However, they can also be used as a research tool, enabling cross language comparisons.

This contribution highlights two research projects that utilize the matrix sentence tests for research use. The first project addresses age-related hearing loss (ARHL), particularly a group of listeners who exhibit an untimely onset of ARHL. An in-depth understanding of this disease is achieved by characterization of individual pathophysiology and resulting individual sound processing deficits (phenotypisation) using an extensive audiological test battery. In cooperation with the Institut de l'Audition in Paris, also the genotype of the listeners is characterized. Linking genetic and audiological data presents a unique opportunity to establish a straightforward causal relationship between the numerous pathogenic variants in our patients that induce a loss of function and the consequences found in their respective phenotypes. In the long-term, we aim to identify cases of ARHL as candidates to targeted therapies (e.g., better fitted hearing devices or even gene therapy).

The second project aims to quantitatively understand how speech recognition in noise in tonal and non-tonal languages is affected by various factors. These includes different talkers, speaking style (like Lombard speech), language systems (tonal vs. non-tonal languages like Mandarin and Cantonese), and acoustical/perceptual factors like noise type, and individual hearing impairment. To achieve this, matrix sentences were recorded in different languages with different speakers, spoken with plain and Lombard speaking style. Results show relatively high variability in Lombard benefit across the speakers, varying from no difference in recognition thresholds between plain and Lombard speech up to improvement of 4 dB. Quantitative simulations using auditory models indicate that the perceptual data can be well predicted when spectral features of the signals are considered. For a group of hearing-impaired listeners, the Lombard benefit is present but significantly reduced. Aided measurements, with listeners own hearing aids, lead to improvement in speech recognition, including Lombard benefit.

Antje Wulff: Towards Interoperable and FAIR Datasets in Audiology

Digitalisation across all areas of life, including medical care and research, produces an enormous growth of data. These data sets are often of great value beyond their primary purpose of acquisition. Reusing, connecting, combining, and sharing data could represent an enormous leap in gaining new insights in research. This especially applies to major research networks and projects in which researchers intend to benefit from each other, such as Hearing4all. However, mining value out of the heterogeneous, disparate, complex, and multi-source big data silos is challenging. The 'multiple use of data' in the aforementioned sense is only successful if high-quality data management and stewardship are established and data integration is facilitated. That's why the FAIR principles were introduced as guidelines for making scientific data findable, accessible, interoperable, and reusable, thus enhancing reuse and exchange of data. An emphasis is put on enhancing the ability of machines to find and use data. Here, interoperability – as the capability of applications to work together and form a shared semantic meaning of data – is a key aspect. To facilitate interoperability, various healthcare standards exist, such as HL7 FHIR and openEHR. OpenEHR is an open standard specification for electronic health records and can be used to build an open health data platform. Fortunately, openEHR does not only ensure interoperability but is nearly fully compatible with all FAIR principles. In this talk, the principles of FAIRness in the openEHR standard will be highlighted, and a possible path towards interoperable and FAIR datasets in audiology by using openEHR and evolving an open data platform will be drawn.

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

Research Thread III aims to advance hearing healthcare towards precision medicine. The cluster will improve the auditory diagnostic repertoire for patients with a moderate, severe, or complete hearing loss and use innovative and improved therapies for the individual patient's treatment, as well as develop strategies to prevent loss of residual hearing or progression of hearing loss. Achievements from the first cluster period serve as the basis for the development of novel types of multimodal cochlear stimulators for diagnosis and therapy, including atraumatic, functionalized and biohybrid cochlear implant electrodes, electro-mechanical and -optical devices, central auditory implants and closed-loop auditory systems.

Eugen Kludt: Personalized Cochlear Implantation Using Fluoroscopy and Intraoperative ECAP Measurements

Eugen Kludt, Rolf Salcher, Kerstin Willenborg, Andreas Büchner, Andrej Kral, Thomas Lenarz

Fluoroscopy aids in cochlear electrode array placement. Coupled with intraoperative measurements like ECAP, it provides feedback on cochlear health and electrode position, enhancing implant optimization.

For 14 adult cochlear implantations, the electrode array was initially fully inserted and ECAPs were measured. Under fluoroscopy, the electrode array was retracted for optimal modiolus proximity, with measurements repeated. Using pre- and postoperative CTs and intraoperative images, a postoperative analysis was conducted. Six months later, electrode positions were analyzed against patients' WRS.

Our method achieved an average insertion depth of 399° ± 52°, surpassing a conventional control group. After retraction, electrodes neared the modiolus by 0.1 ± 0.17 mm. A significant ECAP threshold reduction correlated with modiolus proximity (change of 17 CL/mm, $R^2 = 0.4$, $p < 0.001$). ECAP thresholds of individual electrode contacts varied with modiolus distance, explaining 42% of the postoperative speech performance variation ($p < 0.01$).

Real-time visual control during pull-back offers improved electrode positioning, influencing implantation outcomes. This technique optimizes insertion angle and minimizes electrode-modiolus distance. The approach potentially enhances speech intelligibility, and integrating imaging with intraoperative data reveals insights into cochlear health and implant outcomes.

Heike Schmitt: Towards molecular treatment strategies: possibilities of molecular perilymph diagnostics in patients with inner ear diseases

The inner ear is a complex organized organ. The molecular and cellular structures into the inner ear are highly sensitive to toxic substances and damaging processes. Besides genetic defects, inflammatory processes, disease-specific molecular changes, and aging for instance are supposed to contribute to the molecular pathophysiology of the inner ear leading to sensorineural hearing loss. Despite rapid progress, the underlying cellular and molecular mechanisms of hearing loss are not yet elucidated in detail at all. In order to investigate the microenvironment, e.g. the composition of human perilymph metabolites and proteins - focussing also inflammatory markers - to define differences between various etiologies, we established a technique for perilymph sampling in form of a "liquid biopsy" during cochlear implantation with subsequent measurement of the local microenvironment. For protein identification a highly sensitive shot-gun proteomics approach by mass spectrometry (LC-MS) and also a luminex-based multiplex protein arrays (MPA) was established. The perilymph metabolomics approach was established by a mass spectrometry (GC-MS). Sampling and molecular analysis of perilymph may not only improve the understanding of the pathological processes within the inner ear but may also enable novel molecular treatment strategies.

Maximilian Lenz: Investigating synaptic transmission and plasticity in the human neocortex

A defining feature of the brain is the ability for implementing experience-dependent changes at its synaptic contact sites, which is the expression of synaptic plasticity. This leads to long-lasting structural and functional adaptations in neural circuits. Although previous studies in various research models revealed the relevance of synaptic plasticity for basic brain functions, such as temporal and spatial orientation, learning and memory consolidation, insights in the rules of synaptic transmission and plasticity in the human brain remain limited. Here, we established an experimental approach to assess synaptic transmission and intrinsic neuronal properties in the human neocortex at single cell and subcellular resolution. By using acute slice preparations of human neocortical resections from tumor and epilepsy patients, we tested for factors that are accompanied by changes in excitatory neurotransmission. We demonstrated that both antiepileptic medication and retinoid signaling induced coordinated structural and functional adaptations of excitatory neurotransmission in principal neurons of the human neocortex. Therefore, our experimental strategy enables the investigation of neuronal network reorganization in the human brain upon various conditions, such as pharmacological treatments or alterations in sensory inputs.

Research Thread IV:
The H4A hearing devices of the future

Research Thread IV aims at developing a ground-breaking novel hearing device system technology through innovative sensing and stimulation principles, co-development of hardware, software and algorithms, and individualized system integration. This enables the cluster to achieve its ambitious goals, i.e., to implement Thread II "IT-based diagnostics and rehabilitation" and Thread III "Auditory precision medicine", utilizing the most advanced hearing devices available worldwide. This translational research focus will enable the cluster to serve all degrees of hearing impairment and to achieve Hearing4All in the future.

Ragini Sinha: Subjective Performance Evaluation of Single-channel Speaker-conditioning Target Speaker Extraction Systems

Speaker-conditioning target speaker extraction aims at estimating the target speaker from the mixture of multiple interfering speakers utilizing the auxiliary information about the target speaker. Most of the previous studies for target speaker extraction mostly focused on instrumental measures to evaluate the performance due to their cost effectiveness and fast computation. However, none of these measures can fully reflect the human perception of speech quality and intelligibility. In this study, we focus on the subjective evaluation of 2 different target speaker extraction systems (magnitude masking-based, time-domain-based) for both normal-hearing listeners as well as hearing-impaired listeners. We employed 3 different subjective evaluation methods, namely: paired comparison, speech intelligibility measurement, and categorically scaled listening effort. The subjective evaluation results show clear benefits of the time-domain-based system compared to both magnitude masking-based system and unprocessed mixture signals. The time-domain-based system is preferred in direct comparison, also it achieves significantly lower listening effort and better intelligibility for both listener groups. Hearing-impaired listeners experience even further reduction in listening effort even at low SNRs and greater improvement for speech recognition threshold compared to normal-hearing listeners. In contrast, the magnitude masking-based system shows no improvement over the unprocessed mixtures in any evaluation method for both listener groups.

Marc-Nils Wahalla: Online EEG-Signal Processing within the CereBridge mobile Brain-Computer Interface system

Measurement of brain electrical activity combined with online processing of the data could provide an additional layer of data for hearing aids. Porting suitable algorithms for EEG data analysis from stationary processing platforms to a mobile system requires special hardware architectures. For this purpose, a mobile FPGA-based hardware platform, the Cere-Bridge system, has been developed. In addition to the actual hardware, a test and evaluation framework for this mobile EEG recording and processing system was established. This allows the system to be used in all steps of algorithmic research and evaluation, thus providing a unified hardware system.

However, EEG signal processing algorithms typically researched for brain-computer interfaces (BCIs) using static computer platforms or pre-recorded data sets present several challenges when applied to a mobile processing system. These include rounding errors, algorithmic complexity due to limited processing power, unknown processing latency, and power consumption. Additionally, the process of integrating an existing algorithm from a software reference such as C or Matlab to the FPGA can be time consuming.

We show that high-level synthesis (HLS) can be successfully used to generate a suitable FPGA implementation. Several example algorithms, such as FFT or PCA, are used to show that HLS can achieve a correct implementation. At the same time, it can be further optimized with respect to its key properties, such as power dissipation or processing latency, by means of simple parameters.

Sreekari Vogeti: Modulating near-threshold auditory perception using transcranial alternating current stimulation

Transcranial alternating current stimulation (tACS) is a type of non-invasive brain stimulation that is applied to the scalp and is thought to synchronise ongoing neural oscillations to the frequency of the applied current. Perceptual stimuli can then be arranged at different parts of the phase to examine the relationship between phase and reported perception. Previous studies using different stimulation frequencies have found better and worse perception of auditory stimuli associated with positive and negative phases, respectively. These findings call into question whether the phase of particular frequencies modulate auditory perception or whether simply switching the polarity of the current would also produce the same effects. To examine these effects systematically, we used a within-subjects design to stimulate participants with alpha, delta, and non-sinusoidal positive and negative current stimulation while they identified near-threshold tones in noise. A sham condition without stimulation served as a control condition. The relationship between phase and single-trial behavioural data was assessed with permutation-based circular logistic regressions, which showed that behavioural data from the Alpha condition, but not from the Delta, DC or Sham conditions, conform to an oscillatory shape. These data add further insights to the existing literature which suggests that auditory perception is cyclic and may be modulated by tACS.

Translational Research Centre:
Bridge to translation

The transfer from research to practice is of central importance in the Hearing4all cluster, because only in this way can the vision "Hearing for all" become reality.

This important task is coordinated by the Translational Research Centre (TRC) based at HörTech gGmbH. It supports the scientists in identifying results worthy of protection, mediates between the various stakeholders (scientists, committees and transfer points of the universities) and assists them in drafting contracts with industry. The TRC develops structures that regulate the handling of IP and patents within the Cluster of Excellence. In addition, the TRC initiates industry-funded contract research projects that build on the results obtained in the Cluster of Excellence in order to further develop them in a product-specific manner.

Jörg-Hendrik Bach: ACALES - subjective listening effort scaling from basic research to viable product

Background: Hearing-impaired people often report more demanding effort when communicating in background noise. Hearing aids may help alleviate this problem. In order to quantify listening effort, several methods have been established. Furthermore, listening effort has an operating range in comparatively high SNRs, where speech understanding suffers from ceiling effects. In this contribution, we present the development of the adaptive categorical listening effort scaling (ACALES) from a translational point of view.

Methods: ACALES (Krüger et al 2017a,b) is a subjective rating method somewhat similar to loudness scaling. Subjects rate the amount of effort to follow a target speaker on a 14-point scale (from "effortless" to "extremely effortful"). The method is adaptive to the relevant SNR range of the individual, and uses a simple two-slope fit to model individual listening effort.

Results: Test-retest reliability of ACALES is 1.0-3.8 dB depending on the masker. Age has no significant effect on listening effort ratings. With ACALES, benefit from hearing devices (hearing aids or CI), as well as benefit from spatial separation of noise and masker can be shown.

Transfer: Building on these basic insights, we developed ACALES into a practical clinical software tool. We present challenges and pragmatic solutions to create a viable clinical solution out of the scientific method ACALES. Limitations, trade-offs and relevant compromises of the final product are discussed.

Research Thread I:
Auditory processing deficits throughout the lifespan

I.01
The effects of contextual and morphosyntactic information on linguistic prediction and wh-question interpretation
Matthias Reiner, Petra Hendriks, Esther Ruigendijk

Language processing is predictive. Generated predictions consist of upcoming words and structures deemed most likely based on preceding information and might help compensate for hearing loss. However, it is still unclear what kind of information is used and how different sources of information interact. Evidence points to the use of morphosyntactic cues and contextual information in linguistic prediction. Take wh-questions:

Welcher $_{NOM}$ Frosch $_{SG}$ sieht die Vögel $_{PL}$?

To correctly interpret this question, listeners rely on cues like subject-verb agreement and case. Contextual information like discourse topic also informs predictions.
We utilize wh-question interpretation in a picture-selection task using eye-tracking to examine the role of both types of information on generating predictions.

I.02
Does morphosyntactic agreement in English help native and non-native listeners in noise?
Marcel Schlechtweg

English morphosyntactic agreement offers several linguistic and experimental benefits that enable us to test whether agreement has a functional role, i.e., whether it supports the listener when decoding what is expressed by a speaker. One example of English agreement is reflected in these cabs, where these and cabs agree with respect to the plural value. While we find overt agreement here, we do not find it in the cabs, where the does not indicate the number value of the following noun; it could be either a singular or plural noun. Different types of English agreement and their properties are examined to see whether any of these types facilitate(s) perception for the listener. We focus on perception in noise and quiet conditions, and we analyze data from native and non-native listeners.

I.03

Hearing loss in juvenile rats leads to excessive play fighting and hyperactivity, mild cognitive deficits and altered neuronal activity in the prefrontal cortex

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

In children, hearing loss has been associated with hyperactivity, disturbed social interaction, and cognitive disturbances. To investigate the effect of hearing loss on behavioral deficits juvenile deafened rats were tested on motor, social, and cognitive behavior and on physiology of prefrontal cortex (mPFC).

In the open field, deafened rats moved faster and farther. They also showed significantly more play-fighting and impaired concept learning in the radial maze test. Neuronal firing rate in the mPFC was reduced with enhanced irregular firing and altered oscillatory activity.

Juvenile hearing loss in rats leads to hyperactivity, pronounced play-fighting, and altered neuronal activities in the mPFC. Our animal model provides evidence of developmental consequences of juvenile hearing loss.

I.04

Neural Coding of Naturalistic Speech with Simulated Hearing Loss in Human Auditory Cortex

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

We used voxel-wise encoding models (VWEMs), where acoustic features are used to predict brain activity under clear and degraded naturalistic stimuli.

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)) at higher frequencies to simulate common types of hearing loss. We separately estimated VWEMs for the sound MPS of CS, S2, and N4 stimuli.

VWEMs with acoustic features predicted the fMRI responses in Heschl gyrus planum temporale, superior temporal gyrus posterior and anterior. Our results suggest an interaction between the intelligibility of speech in natural soundscapes and the processing of acoustic features in early auditory cortices.

I.05

Hearing loss in adult rats leads to less ultrasound vocalization, social interaction and cognitive disturbances in visuospatial attention

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

Hearing loss in the elderly is linked to difficult speech comprehension, cognitive decline, and dementia. Hearing loss was induced in adult rats via neomycin injection and we assessed motor activity (Open Field), social interaction, ultrasound vocalization (USV), and attention (Five Choice Serial Reaction Time Task, 5CSRTT). Deafened rats showed increased movement, reduced interaction, USV, and disturbed 5CSRTT learning as well as accuracy. They had lower omission rates but more incorrect hits and also shorter rewarding latency. This model is, showing hyperlocomotion, altered social behavior with less USV, and attention deficits, aligning with compromised activity in medial prefrontal cortex, as shown in prior publications, valuable for studying cognitive decline due to hearing impairment.

I.06

Speech Sound Discrimination by Young and Old Mongolian Gerbils

Carolin Jüchter, Rainer Beutelmann, Chieh-Ju Chi, Georg Martin Klump

Many elderly listeners have difficulties in speech perception, even if auditory thresholds in quiet are normal. Using young and old Mongolian gerbils as a model organism, we here study the discrimination of logatomes in order to investigate compromised speech perception with age.

The gerbils were trained to discriminate a deviant logatome in a sequence of logatome standards. Response latencies were measured to generate perceptual maps, visualizing the gerbils' internal representations of the sounds.

The perceptual representation of vowels was very similar in young and old gerbils. However, the perceptual distances of consonants by young and old gerbils were less correlated. The relative importance of the different articulatory features for consonant discrimination changed with age.

I.07

Narrative Skills of Children with Hearing Impairment

Lara Hardebeck, Ulla Licandro, Bénédicte Grandon, Esther Ruigendijk

Children with hearing impairment (HI) face delays in language development and educational risks. Narrative skills is a fundamental part of language development and therefore essential for successful participation in education and society. In this study, the narrative skills of school-age children with HI were investigated, showing great variability. They produced incomplete episodes, resulting in less complex narratives. Microstructural analyses revealed low lexical variety and syntactic complexity. Correlations with receptive vocabulary and phonological working memory revealed relations between narrative structure and word production. These findings highlight the importance of studying narrative skills of children with HI for a deeper understanding of their linguistic abilities.

I.08

A large dataset of single-fiber auditory-nerve recordings from young-adult and old Mongolian gerbils

Amarins N. Heeringa, Friederike Steenken, Lichun Zhang

As a part of both H4A and H4A 2.0, we have been studying the functional consequences of age-related cochlear degeneration on auditory-nerve fibers in Mongolian gerbils. This has resulted in a large dataset of over 1,000 single-fiber recordings from young-adult, middle-aged, and old gerbils. The dataset not only contains responses to simple acoustic stimuli, but also to more complex stimuli such as speech in background noise and Schroeder phase stimuli. As single-unit recordings from old gerbils have a very low yield, we believe this dataset is highly valuable. Now that these projects come to an end, we are publishing all raw data and make it easily findable, accessible, interoperable, and reusable for auditory modelers and neurophysiologists.

I.09

Cortical Auditory Potentials Evoked by Changes in Interaural Phase Difference

Swantje Hansen, Henri Pöntynen, Mathias Dietz

The Acoustic Change Complex (ACC) to changes in interaural phase difference (IPD) can be used to assess binaural hearing. The frequency region between 500 and 1000 Hz, which is associated with minimum interaural time difference thresholds, has not been investigated yet using this or similar paradigms. In the current study, it was investigated whether the ACC is indeed monotonically decreasing or if a maximum exists between 500 and 1000 Hz. Additionally, the asymmetry in responses between IPD changes from an IPD of 0° to 180° and vice versa has been investigated which is consistent with previous studies that show increased response magnitudes for changes from point-like spatial percepts along the auditory midline to spatially diffuse percepts than vice versa.

I.10

Age-related changes in olivocochlear efferent innervation in gerbils

Friederike Steenken, Asli Pektaş, Christine Köppl

Age-related changes in cochlear efferent innervation were immunohistologically evaluated in cochleae of young-adult and old gerbils. For this, efferent terminals and hair cells were labelled with anti-synaptotagmin and anti-myosin VIIa, respectively, and labelling was quantified at seven tonotopic locations along the Organ of Corti. Medial and lateral olivocochlear efferent innervation (MOC and LOC, respectively) was analyzed separately. We found that LOC innervation, projecting to auditory-nerve afferents beneath inner hair cells, was significantly reduced in old gerbils. MOC innervation, projecting to outer hair cells, was not affected by age after correcting for hair cell loss. Further changes such as axosomatic efferent connections to inner hair cells will be prospectively evaluated.

I.11

Sustained Theta as a Signature of Cognitive Load Processing during Challenging Listening

Brilliant, Yifat Yaar Soffer, Christoph S. Herrmann, Yael Henkin, Andrej Kral

In challenging listening situations, the brain processes both sensory and cognitive loads rapidly. To study the occurring neuronal processes during each load, we recorded EEG from human subjects performing two auditory tasks with different levels of cognitive load; in two conditions, simulating degrees of sensory load. We analyzed oscillatory activities related to these loads. While sensory load reduced the theta power as a result of target masking, cognitive load, on the contrary, resulted in a sustained theta increase exceeding the behavioral response. This result confirmed the role of theta as a common substrate of cognitive processing and suggests that cognitive processing lasts further beyond the initial perceptual stage and beyond the behavioral response.

Research Thread II:
IT-based diagnostics and rehabilitation

II.01

Towards an objective measurement of individual listening preferences: Trait consistency and state specificity

Giulia Angonese, Mareike Buhl, Jonathan A. Gößwein, Birger Kollmeier, Andrea Hildebrandt

Individual listening preferences should be considered when fine-tuning noise reduction algorithms for hearing aids. "Noise haters" prefer more noise reduction at the expense of signal quality. "Distortion haters" accept more noise to avoid distortion. We evaluate the psychometric quality of an objective measure of listening preference to categorise noise and distortion haters. A noise-distortion trade-off measure was part of a mobile longitudinal study of N=185 older unaided individuals with subjective hearing loss. Latent state and trait autoregressive mixture models reveal considerable trait stability, but also a significant amount of state variance. Noise and distortion haters can be identified, but the trait-state dynamics suggest additional classes that require interpretation.

II.02

BRUDEX Database: Binaural Room Impulse Responses with Uniformly Distributed External Microphones

Wiebke Middelberg, Daniel Fejgin, Simon Doclo

There is an emerging need for comparable data for multi-microphone processing, particularly in acoustic sensor networks. However, commonly available databases are often limited in the spatial diversity of the microphones or only allow for particular signal processing tasks. We present a database of acoustic impulse responses and recordings for binaural hearing aids, 36 spatially distributed microphones on a uniform grid and 12 source positions. This database can be used for many signal processing tasks, such as noise reduction, source localization, and dereverberation, as the measurements were performed using the same setup for three different reverberation conditions. The usability of the database is demonstrated for various signal processing tasks.

II.03

Covariance Blocking and Whitening Method for Successive Relative Transfer Function Vector Estimation in Multi-Speaker Scenarios

Henri Gode, Simon Doclo

In this contribution we present a novel method to estimate the relative transfer function (RTF) vectors of multiple speakers in noisy and reverberant environments, focusing on scenarios with two successively active speakers. The primary challenge is estimating the RTF vector of the second speaker during overlapping speech segments. While the state-of-the-art Blind Oblique Projection method aims at optimally blocking the second speaker, the proposed Covariance Blocking and Whitening (CBW) method first blocks the initial speaker and then applies noise whitening to compute the RTF vector of the second speaker. In simulations with real-world recordings, the proposed CBW method, when integrated into an LCMV beamformer, outperforms traditional methods in terms of SINR improvement.

II.04

A Goodness-Of-Fit Measure for Adaptive Procedures

Maximilian Karl Scharf, Anna Warzybok, Sabine Hochmuth, Birger Kollmeier

Adaptive tracking procedures in psychophysics may produce erroneous, "untypical" results and non-converging tracks due to, e.g., inattention of the test subject or external disturbances. This Poster presents a multi state psychometric model, which is used to rate the outcome of any psychometric measurement procedures that can be described with a sigmoid psychometric function.

The model calculates the log likelihood difference between a single and two psychometric functions potentially underlying a recorded adaptive track. We compare a binary classifier with this goodness-of-fit measure with expert ratings and show that it can be used as informed second opinion. Furthermore, we provide a method to calculate an appropriate discrimination threshold value for any psychometric test.

II.05

Model-based self-adjustment of hearing support in the context of the Virtual Hearing Clinic (VHC)

Lena Schell-Majoor, Birger Kollmeier

One aim of the Virtual Hearing Clinic (VHC) is to stronger involve the user in the process of fitting and adjusting hearing support. In order to enable the user to self-adjust the settings of the hearing support without extensive expert-knowledge, a general parameter space using two basically orthogonal metaparameters (i.e., aggregated parameters simultaneously altering several parameters in a prescribed way) was developed. The parameter space can be individualized to a specific listener using the audiogram. Furthermore, it is designed to ensure a certain speech intelligibility on the one hand and limit the loudness to an acceptable level on the other hand using validated models.

II.06

A Computational Model of the Electrically or Acoustically Evoked Compound Action Potential in Cochlear Implant Users with Residual Hearing

Daniel Kipping, Yixuan Zhang, Waldo Nogueira

In cochlear implant users with residual hearing, CAPs can be elicited via either acoustic (aCAP) or electric (eCAP) stimulation. We propose a computational model of eCAPs and aCAPs that consists of three components: a 3D FEM model of an implanted cochlea, a phenomenological neuron model, and a physiological compartment model of an ANF. Previously, eCAPs were estimated by convolving the spike times with a "unitary" response. This approach ignored that ANFs contribute individually to the CAP, and could not account for changes with different recording electrodes. Our model uses individual CAP contributions obtained from the compartment neuron model instead of a unitary response. We compare predicted eCAPs and aCAPs as well as eCAPs masked by acoustic stimulation to published data.

II.07

Design and Optimization of an End-to-End Deep Learning Sound Coding Strategy for Cochlear Implants through an Objective Metric and Perceptual Tests

Franklin Alvarez, Tom Gajecki, Waldo Nogueira

Cochlear implant (CI) users can achieve good speech understanding in quiet, however their hearing performance deteriorates in noisy environments. We propose an end-to-end Deep Neural Network (DNN) that emulates the electrical stimulation patterns of the advanced combination encoder (ACE) sound coding strategy while removing unwanted background noise. We refer to it as "Deep ACE"; however, the concept can be extrapolated to other CI sound coding strategies such as "Deep FS4" or "Deep F120". Deep ACE was evaluated against other denoising sound coding strategies using real CI users and by using the spike activity mutual information index (SAMII) as a speech understanding objective measure. Objective results show a consistent improvements using Deep ACE as observed in eight CI users.

II.08

Remixing Preferences for Instrumental Classical Music of Bilateral Cochlear Implant Users

Jonas Althoff, Tom Gajecki, Waldo Nogueira

Many cochlear implant (CI) users still struggle when listening to music. This work investigates remixing of classical instrumental music to improve music enjoyment for CI users. Two datasets with varying complexity were used. One newly created dataset contained trios, the other one orchestral music. CI users and normal hearing (NH) listeners were asked to remix the multitracks containing melody, bass, accompaniment, and percussion. Remixes could be performed in the amplitude, spatial, or spectral domains. Results showed that CI users preferred a higher gain for the percussion in the trio dataset than NH listeners and spatially distributed tracks towards the right. Additional preferences in CI users were observed when separating them into frequent or occasional music listeners.

Research Thread III:

Auditory precision medicine: research-based novel intervention methods

III.01

Neuronal Guidance Scaffold for Cochlear Implants made of Polymer Fibres

M. Seegers, J. Harre, M. Goblet, N. Ehlert, T. Lenarz, A. Warnecke, P. Behrens†

When a cochlear implant is implanted, there is a considerable gap between the implant's electrode and the spiral ganglion neurons (SGN). For this purpose, a polymer fibre-based neuronal guidance scaffold is being developed. To resemble the extracellular matrix (ECM), heparan sulphate (HS) and laminin are covalently bound to these fibres. This is followed by the addition of the growth factors brain-derived neurotrophic factor (BDNF) and neurotrophin-3 (NT-3). The supplied growth factors are meant to be released and then they should have an effect on the survival of the SGN and the promotion of neurite outgrowth. To increase electrode-nerve contact, the ECM components should promote the neurites to extend along the fibres once they come into contact with them.

III.02

Release of neuroprotective drugs from cochlear implants

L.V. Steingrube, J. Baumgarten, M. Goblet, J. Harre, T. Lenarz, A. Warnecke, N. Ehlert, P. Behrens†

The electrode nerve contact has to be enhanced in order to provide cochlear implant users a better hearing impression. For this purpose, a new composite material should be synthesised.

The silicone matrix of the electrode serves as the material's foundation. The silicone is first coated with a polymer via UV-mediated radical reaction to overcome its inertness. The successful coating was confirmed by IR, SEM and water contact angle measurements.

To this coating, nanoporous silica nanoparticles (NPSNPs) should be attached. These particles should carry the growth factors NT-3 and BDNF. These biomolecules are known to foster the growth and differentiation of neurons. Also, it is known that gradients of NT-3 can guide outgrowing neurites.

III.03

Dual Porous Nanocomposite Coating as a Novel Implant-Associated Local Drug Delivery System for Cochlear Implants

Mosaieb Habib, Madeleine Goblet, Thomas Lenarz, Athanasia Warnecke, Peter Behrens†

Platinum is currently used as an electrode material in the cochlear implant (CI). After the implantation, it is important to restore and sustain healthy conditions in the cochlea. Neuroprotective drugs can be used to support remaining neurons and to induce the outgrowth of neurites. For optimal application, these drugs should be released locally and controlled.

Here, we present a novel nanocomposite material, composed of nanoporous silica nanoparticles (NPSNPs) embedded in a nanoporous platinum (NPPt) as an implant-associated local drug delivery system generated as a coating on the surface of Pt contacts. NPPt exhibits favorable electrochemical properties. NPSNPs offer a high surface area, large permanent porosity and a high versatility with regard to easily adjustable surface properties.

III.04

In-depth proteome analysis of ubiquitous proteins in human perilymph samples

Heike Schmitt, Andreas Pich, Athanasia Warnecke, Martin Durisin, Thomas Lenarz

The highly sensible structures in the cochlea are vulnerable to toxic substances and damaging processes caused by inflammation, disease-specific molecular changes, and aging for instance. Pathological conditions in the cochlea induced by these processes lead to sensorineural hearing loss (SNHL), but the molecular pathophysiology is not elucidated in detail at all. In our previous studies proteome analysis showed disease-specific differences in the level and occurrence of perilymph proteins. In this study the main focus is on the different level of perilymph proteins of patients with different etiology of SNHL and age. In perilymph samples of almost 100 hearing impaired patients ubiquitous perilymph proteins with a de- or increased level among different patient groups could be identified.

III.05

Assessing potential dose reduction in O-15 water PET by simulating low count data and denoising the sinograms

M. Voskamp, F. Büther, M. Mamach, J. Lücke, S. Salwig, H. Mousavi, F. M. Bengel, T. Lenarz, G. Berding

We simulated a reduction in used radioactivity for PET and applied sinogram denoising to examine the feasibility of a lower radiation exposure. O-15 water PET studies of 5 patients with auditory implants were included. Low count data was simulated by randomly reducing the number of coincident events by the factor 8 with 10 distinct versions. Reduced datasets were then denoised with the BM4D algorithm. Denoising prevented a significant reduction in the size of activation which was observed when comparing the (not denoised) reduced dataset to the original for one version across all patients and for all 10 versions in one patient. Our results indicate that a reduction in the radioactivity by a factor 8 would have been possible if used in combination with advanced denoising algorithms.

III.06

From Bench to Bedside: Extracellular vesicle-enriched Secretome from Mesenchymal Stromal Cells as New Therapeutic for the Inner Ear

S. Sasse, O. Kaiser, J. Harre, M. Gimona, E. Rohde, H. Staecker, T. Lenarz, A. Warnecke

Pharmacodynamic effects of extracellular vesicle (EVs)-enriched secretome fractions (VSF) in various animal models (mice, guinea pigs) resulted in anti-inflammatory, immune-modulatory, neuroprotective, hair cell protective and anti-fibrotic effects. VSF is a heterogeneous mixture of EVs, particles and soluble factors. A first in-human application of VSF in a patient receiving cochlear implantation confirmed the feasibility and in a five-year follow up period no adverse effects have been observed. Within biodistribution studies, positive fluorescent signal of labelled VSF could be detected after local application within the cochlea. The toxic potential of VSF was characterized in good laboratory practice (GLP)-conform studies in NMRI mice and the clinical trial is scheduled for next year.

III.07

Establishing a three-tone auditory oddball paradigm to investigate processing of auditory stimuli in rats

Franziska Decker, Jonas Jelinek, Katharina Korb, Franck Fogaing Kamgaing, Mesbah Alam, Joachim K. Krauss, Elvis J. Hermann, Kerstin Schwabe

The three-tone oddball paradigm allows studying the processing of behaviorally relevant auditory target events. Rats were trained in an oddball paradigm, which requires responding to a rare target tone (5000 Hz) while ignoring a rare distractor (1500 Hz) and a frequent standard tone (3000 Hz). Local field potentials (LFPs) for analysis of event related potentials (ERPs) were recorded from mPFC electrodes during behavioral testing. Amplitudes of N1 and P3 components were higher for the target than for distractor and standard tones. Shortening the length of stimuli, or prolonging the intertrial interval has no effects. This model offers an opportunity for in-depth exploration of auditory pathway processing.

III.08

Light-induced BDNF production in human cells for therapy in the inner ear

Sina Christoffers, Elena Wiebe, Cornelia Blume

Optogenetics offers an excellent method for spatially and timely regulated protein expression in cell therapeutic approaches, e.g. in the inner ear.

The blue light activatable CRY2/CIB system was used to induce brain-derived neurotropic factor (BDNF) transcription in human cells. Transfection with three plasmids wearing the system and illumination protocols were optimized in regard to the highest protein expression for human embryonic kidney cells (HEK). Light pulses of 60 seconds over 24 h were without relevant cell photo-toxicity. Illumination was tested with an LED and a laser light source.

We could demonstrate a multifold increase of BNDF expression upon light induction as compared to basal level (5 to 500 ng/mL). Light-induced BDNF was secreted and biologically active to enhance spiral ganglion cell survival and dendrite growth in neuronal cell culture.

The optogenetic approach is currently transferred to autologous cell systems, such as bone marrow-derived stem cells using nucleofection.

III.09

Mouse models with cell-type specific dysfunction in the inner ear

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

The mammalian Organ of Corti is composed of several highly specialized cell types: 1. The inner hair cells, which transform mechanical sound stimuli into an electrophysiological signal that is transmitted to the afferent terminals of type I spiral ganglion neurons. 2. The electromotile outer hair cells which act as cochlear amplifiers and are critical for hearing sensitivity and 3. Various types of supporting cells which are critical for the maintenance of the reticular lamina and build the tunnel of Corti and the spaces of Nuel but also provide trophic support towards spiral ganglion neurons.

Here we present the generation of genetic mouse models which allow for the temporally controlled Tamoxifen-induced labelling or ablation of either inner hair cells, outer hair cells or supporting cells in the Organ of Corti. By using cell-type specific expression of inducible Cre-recombinase the expression of fluorescent TdTomato reporter proteins or Diphtheria toxin A, which induces apoptotic cell death can be induced. First results of the morphological and molecular changes that are observed after cell labelling and ablation of individual cell types will be presented.

Research Thread IV:
The H4A hearing devices of the future

IV.01
Bringing Hearing4all algorithms to real life
Theresa Jansen, Nils Westhausen, Marvin Tammen, Marcos Cantu, Tobias Herzke, Volker Hohmann, Hendrik Kayser

The project "Bringing Hearing4all algorithms to real life" evaluates the benefit for hearing aid users of state-of-the-art real-time signal enhancement algorithms developed in Hearing4all. Two deep learning-based approaches and an advanced mask estimation-based approach were tested in complex acoustic scenes using virtual acoustics. These algorithms as well as classical signal enhancement approaches for reference were implemented in a research hearing aid setup using the real-time signal processing framework open Master Hearing Aid (openMHA). After the individual hearing aid fitting speech reception performance and listening effort was measured with 20 hearing-impaired subjects. This contribution presents the experimental setup, current state and first results of the ongoing project.

IV.02
KUPEGA: Application Specific Integrated Circuit Design for Convolutional Neural Networks on Hearing Aids
Simon Christian Klein, Holger Blume

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 connected 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.

IV.03

Supervised Learning-Based Multi-Frame Wiener Filtering for Binaural Speech Enhancement

Marvin Tammen, Simon Doclo

Head-mounted listening devices such as hearing aids often capture undesired sounds along with the target speech, degrading speech quality and intelligibility. Typically, binaural speech enhancement algorithms tackle this issue by exploiting spatial correlations. Recently, multi-frame speech enhancement algorithms such as the multi-frame Wiener filter (MFWF) have gained traction, which instead exploit temporal correlations. In this contribution, we present a binaural extension of the MFWF that exploits both spatial and temporal correlations, with its parameters estimated using temporal convolutional networks (TCNs). Simulation results demonstrate the benefit of using the binaural MFWF structure over directly estimating the filter coefficients using TCNs.

IV.04

Time-synchronized streaming of smartphone sensor signals

Paul Maanen, Sarah Blum, Stefan Debener

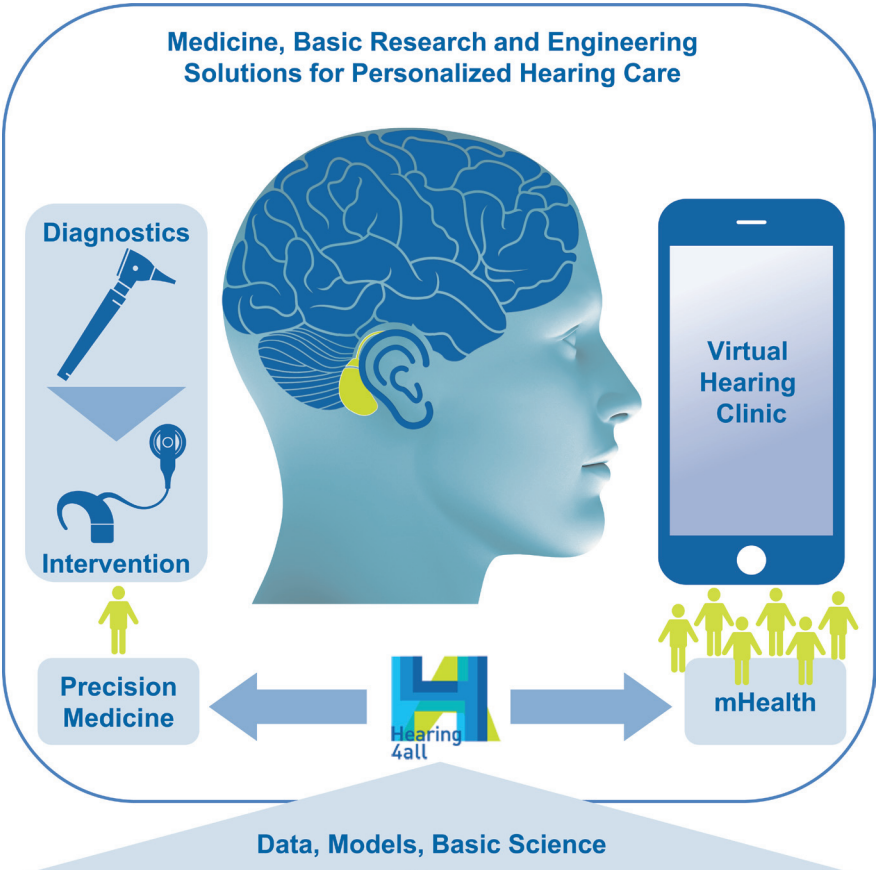
Modern smartphones house numerous sensors with significant research potential, particularly in mHealth. However, integrating sensor data from different devices poses synchronization challenges. We've developed two Android apps: SENDA streams sensor data via a local network, and RECORDA records and syncs these streams. Our latest SENDA version includes three enhancements: Location data streaming, integration of Movella Dot body-worn sensors, and camera-based machine learning feature streaming (e.g., hand and pose landmarks, audio classifier labels via Google MediaPipe). We'll showcase app functionality with a live demo on a standard smartphone during the poster presentation.

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.

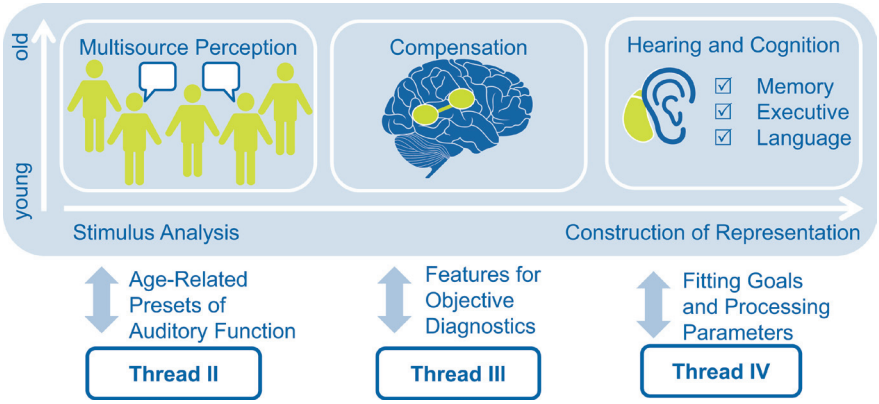
We will concentrate on the three most important aspects of characterising individual hearing ability across the lifespan that are especially important for diagnostics and treatment with hearing devices: Hearing in complex, multisource environments (including better understanding of source segregation 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.

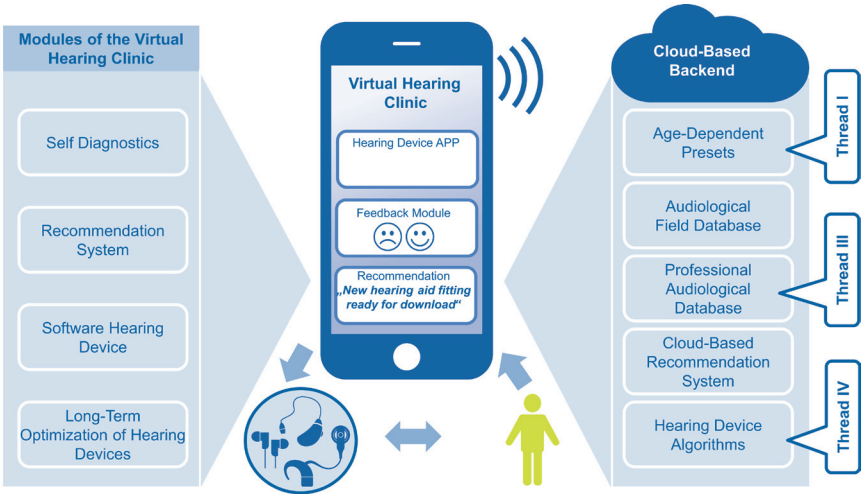


IT-based diagnostics and rehabilitation

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.

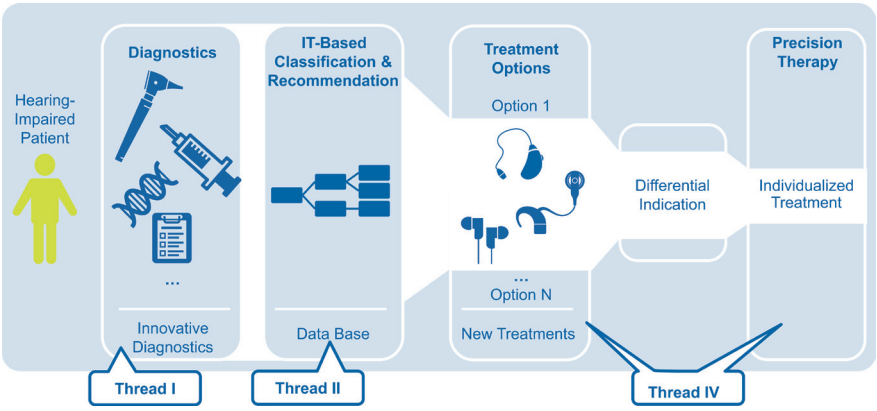
- The interface between auditory diagnostics and (virtual) hearing devices with respect to hearing device fitting and functioning will connect Threads II and IV.

Auditory precision medicine: research-based novel intervention methods

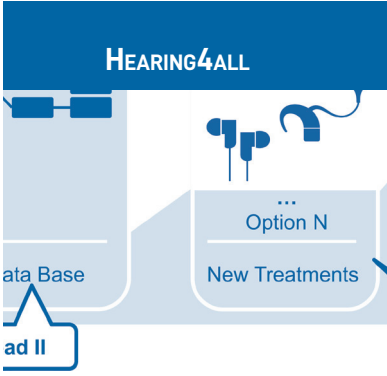
Coordinators
Thomas Lenarz (MHH), Birger Kollmeier (UOL), Peter Behrens† (LUH)

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.

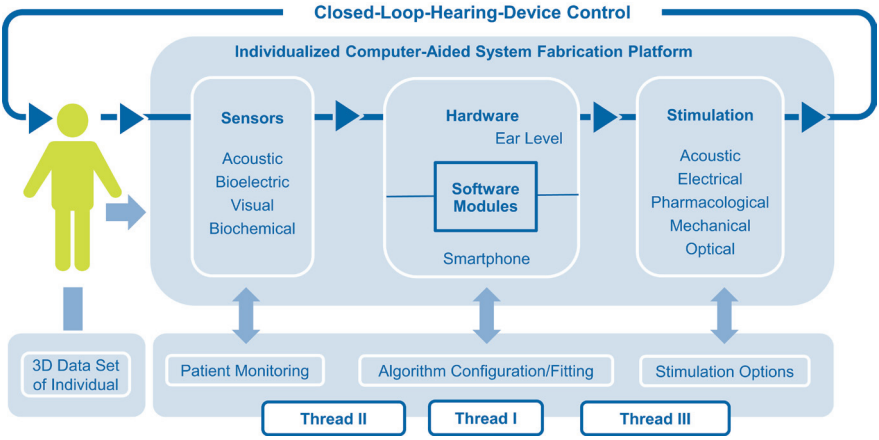
- The technology of the "hearing device of the future" and the options to simulate and predict aided performance, as pursued by Research Thread IV, underlies to the development of actuators and biological components for precision therapy performed in Research Thread III.

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.).

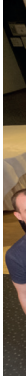


Research Thread IV develops hearing devices of the future and interacts with the other research threads by exchanging concepts, results and data.

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

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Carl von Ossietzky University of Oldenburg

Thomas Lenarz (Clinical Spokesperson)
Hannover Medical School

Principal investigators

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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)
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Hannes Maier (MHH)
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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

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Fraunhofer Institute for Digital Media Technology IDMT, Oldenburg Branch for Hearing, Speech and Audio Technology HSA

Fraunhofer Institute for Toxicology and Experimental Medicine ITEM (ITEM)

Jade University of Applied Sciences (Jade HS)

Laser Zentrum Hannover e.V. (LZH)

Cooperation Partners

Hanse-Wissenschaftskolleg (HWK) – Institute for Advanced Studies

Deutsches Institut für Kautschuktechnologie e.V. (DIK)

HörSys GmbH

KIZMO GmbH - Klinisches Innovationszentrum für Medizintechnik Oldenburg