Hearing4all
Cluster of Excellence in the Auditory Valley Future Hearing

Carl von Ossietzky Universität Oldenburg

Medizinische Hochschule Hannover

Leibniz Universität Hannover

Hearing4all Symposium

The Future of Hearing

5/6 November 2020
Abstract Book

www.hearing4all.de

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

on behalf of all members of the Cluster of Excellence "Hearing4all" I would like to welcome you to our ninth international annual event. With this symposium we provide a perspective on "Medicine, basic research and engineering solutions for personalized hearing care (H4A 2.0)" which has been running now for nearly 2 years. All members of H4A are very excited about the great opportunities that the support of our cluster of excellence is providing to us and we are proud on our collaboration across groups, disciplines, research sectors and sites. Even though the Covid-19 pandemics has a major impact not only on the organization of the current meeting – our first online "Future of Hearing" Symposium – but also on our research work, we could achieve major process in all four research threads of our cluster - please convince yourselves!

During this year's symposium we will utilize the technical options of a pure online meeting to present the progress within our four research threads via panoramic and selected highlight talks in combination with distinguished invited lectures and extended poster sessions. Thomas Lenarz and myself are happy and honoured that internationally renowned, leading scientists from USA and Europe have accepted our invitation to present plenary lectures that are related to the four research threads characterizing our cluster. They will provide the bigger framework on the highest scientific level when talking about state-of-the-art hearing research and its applications as well as future developments.

The perhaps most important part of our symposium, i.e. the personal communication across all participant, which usually takes place in the coffee breaks and during the poster sessions, has to be transformed to a completely new way of interactions: The poster sessions with online breakout rooms to meet and chat in smaller groups. Besides representation of all projects from Hearing4all presented by those highly motivated and talented researchers who do the real work we also have invited external poster presentations from neighbouring groups. Please use this opportunity to get in contact with the members from our Cluster of Excellence and external guests and discover for yourself how we are all working towards the same goal: Hearing4all, for all people in all places at all times!

Birger Kollmeier
Chairman of the Cluster of Excellence Hearing4all

This year's symposium "The future of Hearing" will take place in two virtual rooms on the platform BigBlueButton. All talks will be held in the main room - "H4A The future of Hearing" - which allows for a public chat and interactive discussion. The poster sessions will be held in a separate room the "H4A Symposium Postersession". Within this room the posters will be presented in numbered breakout rooms.

Thursday, 05.11.2020 | 11:00 - 17:50

Time	Topic
11:00 – 11:15	Welcome and Introduction (Kollmeier, Lenarz)
11:15 – 14:30	Research Thread I: Auditory processing deficits throughout the lifespan (Thiel, Kral, Klump)
11:15 – 11:45	**Jean-Luc Puel** Toward new diagnostic tools
11:45 – 12:00	Coffee Break + Poster Preview
12:00 – 12:45	Overview and Highlights from Research Thread I (Thiel) 1. **Go Ashida:** Physiological modeling of binaural circuitry in the brain: simulating age-related changes and perception 2. **Amarins Heeringa:** Gerbil discrimination of speech-like sounds in behavior and auditory-nerve activity
12:45 – 13:45	Lunch Break / Poster Preview
13:45 – 14:00	**Dorothe Poggel / Mark Pottek** Joint Research Academy and the H4A & HWK Fellowship
14:00 – 14:30	**Yael Henkin** Lessons learned on the effects of increasing age and habilitated hearing loss on cortical binaural speech processing
14:30 – 14:45	Coffee Break

H4A The future of Hearing:
https://webconf.uol.de/b/bir-ux6-ne6-rtg

H4A Symposium Postersession:
https://webconf.uol.de/b/bir-kmo-gmk-yl4

Thursday, 05.11.2020 | 11:00 - 17:50

Time	Topic
14:45 – 16:50	Research Thread II: IT-based diagnostics and rehabilitation (Büchner, Kollmeier, Doclo)
14:45 – 15:15	**Ian Bruce** Insights from computational physiological models into optimizing hearing aid amplification
15:20 – 16:05	Overview and Highlights from Research Thread II (Büchner) 1. **Simon Doclo:** Acoustic Transparency in Hearables - Technical and Perceptual Sound Quality Evaluation 2. **Benjamin Krüger:** Individualized phantom stimulation for cochlear implant users with low frequency acoustic residual hearing 3. **David Hülsmeier:** Auditory-model-based aided patient performance prediction
16:05 – 16:20	Coffee Break
16:20 – 16:50	**Jacques Kinsbergen** The consumerization of hearing technology
16:55 – 17:40	Poster Session: Research Threads I and II
	Discussion with the poster authors in up to 6 parallel sessions
17:40 – 17:50	Closing of Day 1 (Kollmeier, Lenarz)

Friday, 06.11.2020 | 10:00 - 17:00

Time	Topic
10:00 – 10:05	Welcome (Birger Kollmeier)
10:05 – 10:55	Poster Session: All Research Threads
	Discussion with the poster authors in up to 6 parallel sessions
11:00 – 13:40	Research Thread III: Auditory precision medicine: research based novel intervention methods (Lenarz, Kollmeier, Behrens)
11:00 – 11:30	**Emmanuel Mylanus** Variability in performance with cochlear implants in adults; our search for answers
11:35 – 12:20	Overview and Highlights from Research Thread III (Lenarz) 1. **Geraldine Zuniga:** Cochlea Hydrodrive: A tool for soft electrode insertion 2. **Athanasia Warnecke:** Molecular signature of inner ear diseases 3. **Verena Scheper:** Towards a gapless neuron electrode interface in cochlear implants
12:20 – 13:10	Lunch Break / Poster Preview
13:10 – 13:40	**Gerald Urban** Longevity of auditory implants: Can we improve long term stability of functional implants by sensor and interface control?
13:40 – 13:55	Coffee Break
13:55 – 16:00	Research Thread IV: The Hearing Device of the future (Hohmann, Blume, Büchner)
13:55 – 14:25	**Shelly Chadha** Hearing care for all: inventing the future

Agenda

H4A The future of Hearing:
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H4A Symposium Postersession:
https://webconf.uol.de/b/bir-kmo-gmk-yl4

Friday, 06.11.2020 | 10:00 - 17:00

Time	Topic
14:30 – 15:15	Overview and Highlights from Research Thread IV (Hohmann) 1. **Hendrik Kayser:** Hearing research in the wild: development of portable research platforms for advanced hearing aid processing 2. **Sarah Blum:** Online Artifact Correction in Android Brain-Computer Interface Applications 3. **Marc-Nils Wahalla:** CereBridge: An Efficient, FPGA-based Real-Time Processing Platform for True Mobile Brain-Computer Interface
15:15 – 15:30	Coffee Break
15:30 – 16:00	**Jens Benndorf** Flexible and high-level programmable System-on-Chip hearing aid design in 22nm FDX technology with a ultra-low power budget
16:05 – 16:50	Poster Session: Research Threads III and IV
	Discussion with the poster authors in up to 6 parallel sessions
16:50 – 17:00	Farewell and closing remarks (Kollmeier, Lenarz)
17:00	End of Official Part of the Symposium
17:15 – 18:15	Scientific Advisory Board Meeting (internal)
18:15 – 19:00	Cluster Board Meeting (internal)

Keynote Speaker

Jean-Luc Puel
Montpellier University, Montpellier, France

Toward new diagnostic tools

Auditory nerve fibers (ANFs) convey acoustic information from the sensory cells to the brainstem using an elaborated neural code based on both spike timing and rate. As the stimulus tone frequency increases, time coding fades and ceases, resulting in high-frequency tone encoding that relies mostly on the spike discharge rate. Here, we recapitulated our recent single-unit data from gerbil's auditory nerve to highlight the most relevant mode of coding (spike timing versus spike rate) in tone-in-noise. We report that high-spontaneous rate (SR) fibers driven by low-frequency tones in noise are able to phase lock -30 dB below the level that evoked a significant elevation of the discharge rate, whereas medium- and low-SR fibers switch their preferential mode of coding from rate coding in quiet, to time coding in noise. For high-frequency tone, the low-threshold/high-SR fibers reach their maximum discharge rate in noise and do not respond to tones, whereas medium- and low-SR fibers are still able to respond to tones making them more resistant to background noise. Based on these findings, we first discuss the ecological function of the ANF distribution according to their spontaneous discharge rate. Then, we point out the poor synchronization of the low-SR ANFs, accounting for the discrepancy between ANF number and the amplitude of the compound action potential of the of the auditory nerve. Finally, we proposed a new diagnostic tool to assess low-SR fibers, which does not rely on the onset response of the ANFs.

Yael Henkin
Tel Aviv University, Tel Aviv, Israel

Lessons learned on the effects of increasing age and habilitated hear-ing loss on cortical binaural speech processing

'Binaural hearing' broadly defines auditory facets which rely on the interaction between the two ears. Several components of normal auditory perception are driven by binaural neural processing. Differences in the timing and intensity of sounds at the two ears are the major physical cues that binaural circuits exploit to improve perception in complex listening settings and to localize sound. Binaural processing is also known to manifest in binaural interaction components (BICs) that occur along the ascending auditory pathways. In humans, BICs have been studied predominantly at the brainstem and thalamo-cortical levels, however, understanding of higher cortically-driven mechanisms of binaural hearing is limited. In a series of studies, we explored the effects of increasing age and hearing loss habilitated by hearing aids and cochlear implants by means of cortical BICs. Using auditory event-related potentials and behavioral measures elicited by speech stimuli we provide evidence for: (1) The occurrence of cortical BICs during perceptual and post-perceptual stages of speech processing, reflecting ongoing integration of information presented to the two ears, in young normal hearing (NH) listeners; (2) Changes in cortical BICs in middle-aged vs. young NH listeners, coinciding with behavioral data showing reduced speech understanding in noise and localization abilities and supporting alterations in binaural processing already in middle-age; (3) The occurrence of cortical BICs in children that had access to bilateral input early in life by means of bilateral hearing aids or by a cochlear implant and a contralateral hearing aid (i.e. bimodal), supporting binaural processing; and differently, absence of cortical BICs in children that had limited access to bilateral input, supporting aberrant binaural processing. Collectively, cortical BICs have proven to be an advantageous objective tool for studying binaural hearing.

Ian C. Bruce
McMaster University, Hamilton, ON, Canada

Insights from computational physiological models into optimizing hearing aid amplification

Most of the widely used hearing aid gain prescriptions are based on the pure-tone audiogram and a psychophysical model of loudness and/or speech intelligibility. These perceptual models only incorporate the effects of cochlear hair cell impairment in an abstracted sense, and the implications of other cochlear pathologies such as synaptopathy (i.e., auditory nerve deafferentation) can not be taken directly into account.

In this talk I will review a framework that my lab has developed for using physiologically-detailed models of the auditory periphery to predict optimal hearing aid gains. Simulations results show that: 1) these physiological models predict the need for wide dynamic-range compression in hearing aids, 2) the mean-rate and spike-timing neural representations of speech can have remarkably different optimal amplification gains, and 3) this divergence in optimal gains increases dramatically in cases of synaptopathy. Overall, these results: i) provide substantial insight into the difficulty of deriving optimal hearing aid amplification schemes based on perceptual testing and models, and ii) motivate the use of detailed physiological models for further innovation in hearing aid amplification strategies.

Jacques Kinsbergen
Jacoti BV, Wevelgem, Belgium

The consumerization of hearing technology

Today, even after 120 years of existence, hearing aids are used by less than 10%[1] of the global population that need them, with only a 3%[2] adoption rate in low/middle income countries. Reasons for this underperformance include:

- User access and distribution model
- End user price
- Limited overall audio quality
- Stigma

Originally intending to improve speech understanding in those with moderate to profound hearing loss, resulted in devices with:

- Reduced bandwidths
- High amplification requiring intrusive feedback cancellation
- Complexity of fitting

This has become incompatible for those with mild to moderate hearing loss and an interest in audio quality beyond speech.

Additionally, the business model itself has further hindered the devices' adoption. Being reimbursed in many countries has removed the need for the industry to tailor its pricing[4] strategies. This has been compounded by the product price being bundled with the service provision[5], leading to the device dispenser fulfilling both role of clinical service provider and salesman.

The Covid-19 pandemic has precipitated a change to service delivery models, including audiology[6], from low- touch to no-touch and from product fee to service fee and local to remote audiology[7]. USA regulators are also demanding change with the creation of the OTC device category[8] and the approval in 2018 of the first self-fitting hearing device[10].

New device categories for hearing support have appeared also including PSAP's and hearables[9]. Consumer companies e.g. Apple[11], Samsung[12] and Jabra by GN Resound have also entered the market, with legally tuned medical claims, but with a positive reception by the market[13] offering Bluetooth Earbuds which exceed the capabilities of most hearing aids[14,15,16]. These devices offer huge economies of scale – Apple AirPods alone equates to the revenue of the entire hearing aid industry[17] – with product prices a fraction of that of a hearing aid.

After 9 years of innovation Jacoti BV[18] is able to offer:

- A mobile hearing aid application.
- A mobile audiometer as an iOS application.
- The combination of both as a self-fitting hearing aid.
- With server connectivity remotely accessible and tunable by hearing professionals.
- All of the above certified as medical device software applications.

With consumer electronic headsets/earbuds offering wireless connectivity, loaded with microphones and sensors built around a powerful DSP, the company ported its software into the chip[19] and effectively created a new class of product capable of satisfying a new group of global consumers.

The consumer will now be able to purchase a headset:

- Perform a hearing self-test[20]
- Produce a calibrated audiogram
- Apply an accepted fitting formula
- Store all data on a cloud platform
- Allow remote access by a qualified hearing professional for remote optimisation, if required

This headset will offer the mild to moderate hearing loss user a hearing aid mode and a Bluetooth streaming mode where the audio is enhanced to their unique needs.

The full power of this platform can be unleashed fully in further cooperated development of specialists in the field of audiology, AI, audio engineering and signal processing. True consumerisation of hearing technologies will lead to **“hearing without barriers”**, its quality and performance no longer related to the user's income or social status.

[1] https://www.who.int/pbd/deafness/news/Millionslivewithhearingloss.pdf?ua=1
[2] Aislyn Orji, Kaloyan Kamenov, Mae Dirac, Adrian Davis, Shelly Chadha & Theo Vos (2020) Global and regional needs, unmet needs and access to hearing aids, International Journal of Audiology, 59:3, 166-172, DOI: 10.1080/14992027.2020.1721577
[3] https://hearinglosshelp.com/blog/when-was-the-first-electric-hearing-aid-made-and-other-hearing-aid-firsts/
[4] https://www.hearingtracker.com/how-much-do-hearing-aids-cost
[5] https://www.audiology.org/audiology-today-septemberoctober-2019/decoupling-professional-audiological-services-sale-hearing
[6] De Wet Swanepoel, PhD, and James W. Hall III, PhD Making Audiology Work During COVID-19 and Beyond (2020)
[7] https://www.asha.org/uploadedFiles/State-Telepractice-Policy-COVID-Tracking.pdf
[8] https://obamawhitehouse.archives.gov/blog/2015/10/26/%E2%80%8Bpcast-recommends-changes-promote-innovation-hearing-technologies
[9] https://www.audiology.org/sites/default/files/publications/resources/20180130_AuD_Guide_OTC.pdf
[10] https://www.fda.gov/news-events/press-announcements/fda-allows-marketing-first-self-fitting-hearing-aid-controlled-user
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[18] www.jacoti.com
[19] https://www.qualcomm.com/products/qcc5100-series
[20] Duotone 2011 - Method and device for conducting a pure tone audiometry screening. Frans Coninx. European Patent EP 2 572 640 B1.

Emmanuel Mylanus
Radboud University Medical Center, Nijmegen, The Netherlands

Variability in performance with cochlear implants in adults; our search for answers

Since the introduction of cochlear implantation (CI) in the early seventies, CI-technology and knowledge regarding surgery and fitting have continuously developed, leading to improved performance with CI. Despite this overall improvement, performance still varies across CI recipients.
Several studies have shown that biographic factors, like etiology and onset of deafness and the degree of functional residual hearing, pre-implantation, are correlated with CI performance. Given the fact that more knowledge is at hand of otogenetic traits leading to hearing loss of various kinds, and that the underlying genetic mutations give rise to defects at specific locations in the cochlea, like the stria vascularis, inner hair cells, tectorial membrane and spiral ganglion cells, it may be easier to predict outcome on a group level.

Avoiding cochlear trauma on insertion with soft surgery and the use of hypotraumatic electrodes have positive effects on preservation of residual hearing. The question is whether this is reflected in the actual performance with the CI is a difficult question to answer. Some of the earliest hypotraumatic electrodes, like the relatively short Hybrid-L electrode were excellent in preserving residual hearing but were inferior in terms of cochlear coverage. Longer hypotraumatic electrodes seemed to be the answer to this problem but turned out to be not so hypotraumatic after all., probably as a result of the rate of transition of the electrode lead into the scala vestibuli. A more medial position of the slim modiolar electrode may be safer for the basilar membrane and lead to better performance because of the proximity of the neuronal structures. After controlling for age, Holden et al (2013) had found several electrode position related factors (scalar position, angular insertion depth and wrapping factor) significantly correlated with speech perception. In a recent study on explanatory factors of CI performance using ultra-high CT-scans, we have shown that indeed, the more modiolar position of the electrode may make a difference. Results of this study showed that implanting a precurved electrode instead of a straight electrode increases speech perception in quiet with approximately 12% independent of biographic and audiometric factors and scalar position of the electrode.

Initial trauma on insertion may be predisposing for fibrous tissue formation, and ossification within the scala. This may be visualized on ultra-high CT-scans and with impedance measurements and both seem to correlate with loss of residual hearing long-term after implantation. A prospective study is warranted to observe this process over time and observe whether this has a negative effect on performance.

Of course, one must not forget that cognitive processes are of great importance in speech recognition. Deterioration of cognition will have its (negative) effect. Although the majority of the elderly improve speech recognition significantly with CI compared to their conventional hearing aid, in this particular group we have observed lower performance at high age and a correlation between CI performance and level of education. In daily life, we make use of auditive and visual information. Especially in difficult signal-to-noise situations in either mode or in both, central processes determine outcome in performance. It is of interest to look at more subtle top-down effects; whether cognitive abilities, for example measured with a visual task, have an effect on the ability of a CI user to process a degraded auditive input provided with CI.

Gerald Urban
IMTEK-Sensors, Albert-Ludwigs-University Freiburg, Germany

Longevity of auditory implants: Can we improve long term stability of functional implants by sensor and interface control?

Widespread sensory and neurological disorders represent a major social and economic burden for an ageing global society. Active medical implants allow the partial restoration of impaired or lost physiological functions in many clinical settings. Especially hearing implants see a tremendous increase of implant numbers and are therefore a major goal for improvements. However, despite their therapeutic success, we are facing fundamental limitations with such devices in biointegration, the lack of direct and selective contacts between electrode arrays and excitable tissues, long term biocompatibility and biofunctionality.

Nowadays the currently used precision mechanics manufacturing limits size, complexity with respect to electrode channels and longevity of the material-tissue interface. Additionally, the influence of implant and electrode material and stimulation protocols on inflammation events and longevity are barely investigated. Changes of chemical micro-environment at the stimulation electrodes and additionally corrosion products of noble-metal electrodes will be presented.

As next proposed step a new generation of theranostic neuroimplants are necessary to overcome these problems: The development of novel electrical and biochemical sensor and actuator systems with sufficient long-term stability will enable basic understanding and intervention of biochemical and inflammation processes at the neurotechnical interface, increase implant longevity, and adapt stimulation parameters and protocols to the specific conditions of each individual patient.

Such integrated multi-marker monitoring systems capture relevant physical, biochemical and inflammation parameters are able to close the loop for patient-specific interventions in the future.

Shelly Chadha
World Health Organization, Geneva, Switzerland

Hearing care for all: inventing the future

Our knowledge about auditory processes, hearing loss, its causes, diagnosis and rehabilitation is constantly growing. The development and implementation of newer technologies and novel interventions, make it possible to address hearing loss across the life course. Despite these great advances, the vast majority of those in need of hearing care either cannot access the services they need, or chose not to do so. This gap can only be addressed through a concerted effort that involves all stakeholders in the field of hearing, and that follows a public health approach.

The World Health Organization lays out the framework of this approach in the soon-to-be-launched World Report on Hearing. The talk will provide an insight into the Report, outline the current status of hearing loss and hearing care globally and propose steps required to make 'hearing care accessible for all'.

Jens Benndorf
Dream Chip Technologies, Garbsen, Germany

Flexible and high-level programmable System-on-Chip hearing aid de-sign in 22nm FDX technology with a ultra-low power budget

In 2016, Dream Chip Technologies (DCT) formed together with the Institute of Microelectronic Systems (IMS) of the Leibniz University of Hanover (LUH) a consortium to submit a project proposal in the frame of the BMBF announcement "Mikroelektronik aus Deutschland – Innovationstreiber der Digitalisierung" aiming to bring hearing aid devices in all regards to a new level. Consequently, we chose the title "Smart Hearing Aid Processor (SmartHeaP)" for our project plan.

Power dissipation has been and still is the main reason why today's hearing aid devices are hardwired dedicated ASIC devices. Those devices can be optimised to consume as less power as possibly allowed by the deployed hardware technology, thus enabling them to be used for more than one day with just one single coin cell. The flip side is, realising ASICs based on hardwired signal processing algorithms is very costly and once manufactured they cannot be reprogrammed or functionally extended. The main project idea therefore was to make use of the meanwhile tremendously computational powerful and regarding power dissipation optimised general-purpose signal processor architectures as well as of the astonishing progress in ultra-low power semiconductor technologies in order to overcome this drawback. Both building blocks facilitate to realise an updatable and upgradable flexible high-level programmable System-on-Chip (SoC) design for future hearing aid devices. Deploying a 22nm FDX technology platform it can be ensured that the SoC will show ultralow power dissipation thus enabling long hours of operation with one batterie charge.

In order to be able to make use of modern complex state of the art signal processing algorithms developed for hearing aids, there will be also Near Field Magnetic Induction (NFMI) data links between the left and right device, because magnet fields are able to uninterruptible travel around the users heads. For the data communication between the environment the hearing aid devices will be additionally equipped with Bluetooth Low Energy modules since even comparable weak high frequency electro-magnetic waves can bridge several meters at high data rates. The possibility to exchange synchronous and asynchronous data with peripheral devices allows to implement further functions like self-fitting as well as media data streaming. The self-fitting function will free many users from the necessity to frequently consulting hearing aid acousticians while media streaming increases their communication and entertainment experiences.

I will report on the status of the SmartHeap project during my speech.

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.

Ashida G.: Physiological modeling of binaural circuitry in the brain: simulating age-related changes and perception

The ability of locating the source of a sound, called sound localization, is a fundamental function of the auditory system. Mammals, including humans, have specialized neuronal circuits for sound localization, which perform precise computation of minute differences of acoustic information between the two ears. Neurons in the lateral superior olive (LSO) in the auditory brainstem integrate excitatory synaptic input from the ipsilateral ear and inhibitory synaptic inputs originating from the contralateral ear. Because of this excitatory-inhibitory interaction, LSO neurons are sensitive to interaural level differences, as well as to envelope interaural time differences of amplitude-modulated sounds. To simulate these functions, we have developed several versions of models that are largely consistent with known physiological characteristics of LSO neurons. In this talk, we first review our modeling effort with the corresponding neuronal circuit and its properties. Second, as an application of the model, we present our recent simulation results on age-related changes in the binaural sound localization circuit. Previous anatomical studies found loss of inhibitory synaptic transmission along the auditory pathways, while physiological studies reported only minor functional changes in the LSO circuit. Our simulation results with a varied number of inhibitory inputs indicate that binaural tuning of LSO is generally robust against the loss of inhibition, and that this robustness is further enhanced by activity-dependent plasticity. As another application of the model, we used the LSO model to predict binaural sound lateralization in humans. Our modeling results indicate that the spike rate difference between the left and right LSO neurons is a good predictor of the perceived sound location measured in previous psychophysical experiments.
Overall, our LSO modeling approach was found useful to connect neuroanatomy, neurophysiology, and psychoacoustics.

Heeringa A. N., Jüchter C., Klump G. M., Köppl C.: Gerbil discrimination of speech-like sounds in behaviour and auditory-nerve activity

The old gerbil is a well-known animal model to study age-related hearing loss. When aged in quiet (i.e., without potentially damaging noise exposures), several pathologies can be observed in the gerbil cochlea, including degeneration of the stria vascularis and loss of primary auditory neurons, starting at the synapses with the inner hair cells. Our mission is to investigate how this cochlear aging affects functioning of the (remaining) auditory nerve fibers, the sole auditory input to the central nervous system. In addition to these invasive techniques, gerbils are very suitable to assess behavioral consequences of age-related hearing loss. These can then be compared to similar psychophysical experiments in humans with age-related hearing loss. As such, the gerbil has large translational value in investigating the underlying mechanisms of age-related hearing loss and correlating these to the accompanying psychophysical deficits.

Currently, we are investigating in gerbils the discrimination of speech-like stimuli in noise. Speech perception in noisy backgrounds has often been reported as a major handicap for patients with age-related hearing loss. In this talk, I will present the first results of an operant conditioning paradigm that assesses the effects of aging on vowel discrimination when presented in a consonant-vowel-consonant structure in speech-shaped noise. These exact same stimuli are also presented to young and quiet-aged gerbils while recording from their single-unit auditory nerve fibers. Preliminary data suggest age-related changes in vowel representation by auditory-nerve fibers.

HIGHLIGHT TALK

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.

Krüger B., Büchner A., Nogueira W.: Individualized Phantom Stimulation for Cochlear Implant Users with Low Frequency Acoustic Residual Hearing

Cochlear implantation allows the preservation of low frequency residual hearing during and after implantation. Most of today's cochlear implant (CI) speech processors include an acoustic component (hearing aid) to provide low frequency acoustic stimulation in combination with electric stimulation. The benefit of combined electric-acoustic stimulation (EAS) was the inspiration for the development of stimulation modes that convey low frequency information electrically. The so-called Phantom stimulation uses the two most apical electrodes in a partial bipolar configuration to shape the electrical field in the cochlea. Thereby, a sound sensation can be elicited that is lower in pitch than the sensation evoked by the stimulation with the most apical electrode alone.
The aim of this work was to evaluate possible benefits of Phantom stimulation for CI users with low frequency residual hearing. Speech reception obtained from electric stimulation alone was compared to the speech reception obtained from electric-acoustic stimulation and from electric stimulation combined with Phantom stimulation. Additionally, the effect of low frequency information conveyed via Phantom and acoustic stimulation simultaneously was investigated concerning mutual interaction and its impact on speech reception. The results show a significant improvement in speech reception through the additional presentation of low-frequency information using either acoustic or Phantom stimulation. However, electric stimulation in combination with acoustic stimulation leads to significantly better speech reception than electric stimulation in combination with Phantom stimulation. A deteriorated speech reception was observed if Phantom stimulation and acoustic stimulation conveyed spectrally overlapped low frequency information simultaneously. This interaction increased with decreased spatial distance between the cochlear region with residual hearing and the site of electric stimulation.

Reference:
Krüger, B., Büchner, A., Nogueira, W. Phantom stimulation for cochlear implant users with residual low frequency hearing. Ear Hear, under review, 2020.

Hülsmeier D., Schädler M. R., Kollmeier B.: Auditory-model-based aided patient performance prediction

Developing and selecting hearing aids is a time consuming process which is simplified by using objective models. Previously, the framework for auditory discrimination experiments (FADE) accurately simulated benefits of hearing aid algorithms in terms of root mean squared prediction errors (≤3 dB). One simulation with FADE requires several hours of (un)processed signals, which is obstructive when the signals have to be recorded.
We propose and evaluate a version of FADE which requires less data and therefore facilitates simulations in which signals can only be processed in real-time. This data-reduced FADE version (DARF) enables simulations of one speech recognition threshold (SRT) with about 30 minutes of signals of the (German) matrix sentence test, which is about the time required for one visit to the hearing aid acoustician. Benchmark experiments were carried out to compare DARF and standard FADE before simulating speech recognition with three pairs of real hearing aids. The differences between DARF and FADE simulations were small for stationary maskers (1 dB), but larger with strongly fluctuating maskers (5 dB). Hearing impairment and hearing aid algorithms seemed to reduce the differences. Simulated hearing aid benefits were found in silence (≥8 dB), in stationary and fluctuating maskers in co-located (stat. 2 dB; fluct. 6 dB), and spatially separated speech and noise signals (stat. ≥8 dB; fluct. 8 dB). The simulations were plausible in comparison to data from literature, but a behavioral study for comparison is still open.
DARF facilitates objective SRT simulations with real devices with unknown signal processing in real environments. Yet, a validation of DARF for devices with unknown signal processing is still pending since it was only tested with three similar devices.
Nonetheless, DARF could be used for model-based hearing aid fitting or during the development of hearing aids.

Highlight Talk

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.

Doclo s.: Acoustic Transparency in Hearables - Technical and Perceptual Sound Quality Evaluation

Acoustic transparency, i.e., an unaltered perception of external sounds when wearing a hearing device, is a prerequisite for a good sound quality and important for the acceptance of assistive or multimedia devices targeted at (near-to) normal-hearing listeners. In this study, the acoustic transparency of seven commercial hearables as well as two research hearing devices developed at the University of Oldenburg was evaluated by assessing the deviation between the open-ear and the hear-through case with a neutral setting. To this end, directionally resolved insertion gain measurements were made in a KEMAR, which allowed a technical evaluation of introduced artefacts. Furthermore, the sound quality was subjectively evaluated on the basis of binaural recordings with a KEMAR wearing the devices. The results reveal large differences between the devices, ranging from minor, almost imperceptible differences between hear-through and open-ear listening, to severe impairments of the listening quality resulting from a biased listening level, spectral distortions and destruction of binaural cues. Both research devices show a good performance that is comparable to the best commercial devices.

Zuniga M. G, Lenarz T., Rau T.: Cochlea Hydrodrive: A tool for soft electrode array insertion

Background: Automated insertion of cochlear implant electrode arrays (EA) promise to perform continuous and steady insertions at ultra-slow insertion velocities beyond human limitations. A novel device named Cochlea HydroDrive (CHD) proposes the use of a standard syringe as hydraulic actuator to deliver an EA.
Objective: This study evaluates if the CHD can successfully introduce an EA into a human cadaver cochlea at a predetermined slow insertion velocity and describes some steps involved in the insertion process with the CHD.
Materials and methods: A previously anonymized human cadaver head and a commercially available CI EA were used for experiment, which were performed in a temporal bone laboratory and experimental OR.
A mastoidectomy and facial recess were drilled in a standard fashion for CI surgery. A standard manual EA insertion was done to establish a control. The positioning of the CHD was then tested using a surgical retractor with a flexible arm. The tip of the CHD was directed to reach the round window. The EA was mounted onto the CHD. An infusion pump was then connected to the CHD and set to drive it at a predetermined insertion velocity of 0.1 mm/s.
A post-insertion CT scan was performed to confirm the position of the inserted EA.

Results: The CHD can: 1) be positioned suitably, as it attaches to the human head, stands alone and achieves appropriate direction for EA insertion; 2) respond to the hydraulic actuation once placed in the desired position; 3) introduce the EA into the human cadaver cochlea. Post-insertion CT demonstrates intracochlear positioning of the EA.

Conclusion: The first attempt to perform a CI EA insertion using the CHD was successful. Further testing to validate its performance and reliability is ongoing.

Warnecke A., Staecker H., Schmitt H., Prenzler N., Durisin M., Pich A., Lenarz T.:
Molecular Signature of Inner Ear Diseases

Sensorineural hearing loss is the most common neurodegenerative disorder and has been estimated to affect more than 450 million individuals worldwide. Development of pharmaceuticals for inner ear disease lags behind other organ systems due to difficulties in determining a cellular or molecular level diagnosis. Although advances in gene sequencing aid the identification of patients with genetically determined hearing loss is, there is no diagnostic tool available for the majority of acquired and progressive hearing loss. Audiological testing yields information on impairment but does not provide a molecular diagnosis and may not even correctly reflect the cellular site of lesion. Analysis of human perilymph from stapedectomy surgery has been evaluated since the 1960s to understand the physiology of the human inner ear. Recently, proteins related to inner ear disease have been identified in the serum and advances in proteomics have allowed the identification of peptide profiles in human perilymph raising hopes that more specific testing for inner ear disease may be on the horizon. A potential alternate approach to using proteomic analysis is to evaluate the expression of miRNAs related to hearing loss in correlation to inner ear disease. MicroRNAs (miRNA) are short, regulatory nucleic acids that are stable and have been identified in a wide variety of body fluids. In particular, they are being evaluated as marker for neurodegenerative diseases. We have identified miRNAs related to hearing loss, otosclerosis and Meniere disease. Current research suggests that miRNA identified in body fluids are transported by extracellular vesicles (EV). Using microfluidics technology and immunomagnetic isolation, we can identify EVs specific to the inner ear allowing cell specific isolation of miRNA from cochlear fluids. These investigations are yielding highly promising results and are paving an avenue towards a molecular signature of inner diseases in our patients.

Scheper V.: Towards a gapless neuron-electrode interface in cochlear implantation

A high number of excitable spiral ganglion neurons (SGN) and an outgrowth of their neurites to the cochlear implant (CI) electrode array are assumed to improve the hearing outcome in CI patients. Bridging the anatomical gap between electrodes, located in the scala tympani, and neurons, located in the bony axis of the cochlea, might allow a more focused stimulation. This could be achieved by supply of neurotrophic factors (NF) for neuroprotection and neurite regeneration and a growth matrix supporting the neurite outgrowth into the scala tympani towards the CI.

We were able to show that the number and length of outgrowing neurites is increased in stiffer compared to softer alginate. On 2 % chitosan, cells adhere but regenerate no neurites. In contrast, lower chitosan concentrations support the neurites growth on and into the gel. The combination of hydrogels and NF positively influenced the neurite regeneration. On decellularized equine carotid arteries (dEAC) neurite outgrowth was observable as well. Alginate encapsulated, NF-overexpressing mesenchymal stem cells (MSC) significantly increase the number of mono- and bipolar SGN and their neurite regeneration but do not attract neurites. Beside its suitability as neurite-matrix alginate reduces CI insertion forces massively in artificial cochleae when used as coating material.

To improve our methods which relied on commercially available culture chambers we designed and 3D-printed a chamber for neuronal explant cultivation considering the anatomical dimensions of the cochlear and addressing our special needs for drug delivery strategies.

Alginate, chitosan and dEAC are promising matrixes to bridge the neuron-electrode gap, especially if they are combined with NF. With our novel culture chamber we will be able to investigate the neurite-matrix-electrode interaction in a setting which is mimicking the anatomical situation.

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.

Kayser H.: Hearing research in the wild: development of portable research platforms for advanced hearing aid processing

A crucial step towards the target user groups' benefit from a novel hearing-device processing method is a systematic evaluation in realistic every-day life situations during its development phase. However, laboratory setups and computer simulations are usually limited to very controlled and simple acoustic situations, and often focussed on a single algorithm that is considered in isolation from a complete hearing device processing chain that would be required for the final device. In order to test a new development in realistic usage scenarios in an early development stage, flexible hard- and software components are needed, which allow for an easily accessible implementation of the algorithms under test and which resemble the relevant properties of a real hearing device such as portability, proper ear-level devices as well as low-latency, real-time audio signal processing capability. In combination, these components form a research tool that can be used in the laboratory in controlled virtual acoustic environments as well as in field studies. The Portable Hearing Laboratory (PHL) is such a platform that has been developed in a project funded by the National Institutes of Health with the aim to provide researchers with open tools for hearing aid research.
In the cluster of excellence Hearing4all several sub-projects develop applications based on the PHL for the investigation of a number of relevant topics in hearing device research: alternative forms of ear-level devices, in-the-field EEG data acquisition, advanced fitting strategies, low-latency remote streaming of audio data into hearing devices, and increasing the acoustic feedback stability of the device itself in order to reach a level that is comparable with commercially available end-user devices. Future hearing aid processing methods that incorporate deep learning techniques into hearing aid processing are also tackled.
This contribution will introduce the PHL and current research projects using the PHL will be briefly introduced.

Highlight Talk

Blum S.: Online Artifact Correction in Android Brain-Computer Interface Applications

Brain-Computer Interfaces (BCIs) translate neural signals from the user directly into control statements for a connected device [1,2]. Future variants of BCIs, such as neuro-steered hearing aids, may for instance alter the auditory signal processing based on information extracted from the user's brain signals, reflecting attention to a particular sound source [3,4]. Many BCIs use electroencephalography (EEG) data. While EEG has many advantages compared to alternative methods, EEG data are prone to the influence of non-brain signals, so-called artifacts. These artifacts can hinder the correct interpretation of EEG data and therefore need to be detected and should subsequently either be removed or corrected from the data. Research on artifact-handling methods to accomplish this difficult task has raised in popularity in recent years, driven by the increasing number of so-called 'mobile EEG' setups which aim to realize EEG-based BCIs in real-world settings. In these settings, EEG may be acquired using off-the-shelf hardware that is available to the user even outside of research applications. One of these systems realizing an auditory BCI has been developed by our group [5]. SCALA processes EEG data on Android smartphones and provides feedback on the decision to the user. Until now, SCALA did not contain an artifact handling solution, because so far, no artifact handling method suitable for mobile devices was known in the community. Here, I will present our latest work on the development of an online artifact handling method for Android (based on Artifact Subspace Reconstruction (ASR) [6]) and the process of integrating this functionality into BCI applications such as SCALA.

[1] Lotte, F., Congedo, M., Anatole, L., Bougrain, L., Cichocki, A., Clerc, M., ... Yger, F. (2018). A review of classification algorithms for EEG-based brain – computer interfaces: a 10 year update. Journal of Neural Engineering, 4(2), 1–24.
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[4] Das, N., Van Eyndhoven, S., Bertrand, A., & Francart, T. (2017). Auditory attention detection: Application in neuro-steered hearing aids. The Journal of the Acoustical Society of America, 141(5), 3893–3893. https://doi.org/10.1121/1.4988739
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[6] Mullen, T. R., Kothe, C. A. E., Chi, Y. M., Ojeda, A., Kerth, T., Makeig, S., ... Cauwenberghs, G. (2015). Real-time neuroimaging and cognitive monitoring using wearable dry EEG. IEEE Transactions on Biomedical Engineering, 62(11), 2553–2567. https://doi.org/10.1109/TBME.2015.2481482

Highlight Talk

Wahalla M.-N.: CereBridge: An Efficient, FPGA-based Real-Time Processing Platform for True Mobile Brain-Computer Interface

Several approaches to improve and extend future hearing aid devices include bio-signals as an additional input for the audio processing system. In a scenario with several speakers talking simultaneously for example, algorithms based on processing of electro-encephalography (EEG) signals can detect on which speaker a subject is mostly focusing respectively where the current auditory attention of the subject lies.
For testing and evaluation of EEG-based algorithms in laboratory environments, a personal computer is often used for the signal processing. Although, in a real-world application a mobile hardware solution is required. This is especially important for closed-loop systems where an order of time-series events will influence the processing and these events can differ in real-world applications compared to laboratory environments.
Therefore, a novel, mobile FPGA-based platform for EEG signal processing has been designed and implemented. While featuring highly efficient adaptability to targeted algorithms due to the ultra low power Flash-based FPGA, the stackable system design and the configurable hardware ensure flexibility for the use in different application scenarios. Powered through a single Li-ion battery, the miniaturized system area of half the size of a credit card leads to high mobility and thus allow for real-world scenario applicability. Although several wired interfaces were implemented e.g. for connection of a hearing aid hardware system, a Bluetooth Low Energy extension can be connected without any significant area cost, if a wireless data or control signal transmission channel is required. The resulting system is capable of acquiring and fully processing of up to 32 EEG channels with 24 bit precision each and a sampling rate of 250-16k samples per second with a total weight less than 60 g.

The posters will be presented in the room "H4A Symposium Postersession . To join the presentations and discussions in the respective breakout rooms, you have to log in to the Postersession room and then choose which breakout room you want to enter (Room 1, Room 2, etc).

Thursday, 05.11.2020 | 16:55 - 17:40

ID	Time and Room	Presenter and Title
I-01	16:55 – 17:10 Room 1	**Inka Kuhlmann** Good days and bad days in hearing - How daily affect and motivation relate to hearing performance variability?
I-02	17:10 – 17:25 Room 1	**Kerstin Schwabe** Processing of auditory information in forebrain regions: behavioral and electrophysiological studies in normal hearing and deaf rat models PDF
I-03	17:25 – 17:40 Room 1	**Dorota Habasinska** Statistical learning correlates as revealed by EEG ERP and source analysis
I-04	16:55 – 17:10 Room 2	**Carolin Jüchter** Mongolian Gerbils as a Model for the Discriminability of Speech Sounds
I-05	17:10 – 17:25 Room 2	**Bénédicte Grandon** Grammatical and lexical processing in people with hearing impairment (with or without a hearing aid). A pilot study on reading
I-06	17:25 – 17:40 Room 2	**Lea Sollmann** Dendritic Complexity of Layer V Pyramidal Cells in Congenitally Deaf Auditory Cortex

H4A Symposium Postersession:

https://webconf.uol.de/b/bir-kmo-gmk-yl4

ID	Time and Room	Presenter and Title
II-01	16:55 – 17:10 Room 3	**Mareike Buhl** Audiological classification using Common Audiological Functional Parameters (CAFPAs)
II-02	17:10 – 17:25 Room 3	**Hamid Mousavi** Inferring the Maximal Causes of Hearing Impairment Using a Non-Linear Bayesian Network
II-03	17:25 – 17:40 Room 3	**Jonathan Gößwein** Semi-supervised self-adjustment fine-tuning procedure for hearing aids for asymmetrical hearing loss
II-04	16:55 – 17:10 Room 4	**Sven Herrmann** Model-Based Diagnostics of Hearing Disorders PDF
II-05	17:10 – 17:25 Room 4	**Jana Roßbach and Saskia Röttges** Non-intrusive Binaural Prediction of Speech Intelligibility based on Automatic Speech Recognition
II-06	17:25 – 17:40 Room 4	**Thomas Biberger** Integration of nonlinear cochlear filters in a functional auditory model: Results from psychoacoustic evaluation experiments

Poster Sessions

H4A Symposium Postersession:

https://webconf.uol.de/b/bir-kmo-gmk-yl4

Friday, 06.11.2020 | 10:05 - 10:50

ID	Time and Room	Presenter and Title
II-07	10:05 – 10:20 Room 1	**Hanna Dolhopiatenko** Towards Decoding Selective Attention from Single-Trial EEG Data in Cochlear Implant users based on Deep Neural Networks PDF
II-08	10:20 – 10:35 Room 1	**Jasper Ooster** Computer! Test my hearing: Speech audiometry at home
II-09	10:35 – 10:50 Room 1	**Tobias Bruns** Challenges of autonomous speech audiometry via VoIP
III-01	10:05 – 10:20 Room 2	**Jennifer Harre** Extracellular vesicles as new therapeutic for the inner ear
III-02	10:20 – 10:35 Room 2	**Liza Lengert** Investigating the optoacoustic effect of medical-grade lasers
III-03	10:35 – 10:50 Room 2	**Inga Wille** Fiber-based Neuronal Guidance Scaffold

ID	Time and Room	Presenter and Title
III-04	10:05 – 10:20 Room 3	**Mosaieb Habib** A novel composite coating for neuronal electrodes: Nanoporous platinum containing nanoporous silica nanoparticles PDF
III-05	10:20 – 10:35 Room 3	**Stefan Raufer** Predicting the Clinical Performance of a Direct Acoustic Cochlear Implant
IV-01	10:35 – 10:50 Room 3	**Steffen Dasenbrock** Development and Validation of a Portable Setup for Acoustic Stimuli Presentation and EEG Recording PDF
IV-02	10:05 – 10:20 Room 4	**Simon Klein** KUPEGA: An Application-Specific Hardware-Accelerator for Neural Networks
IV-03	10:20 – 10:35 Room 4	**Max Zimmermann** Optimizing adaptive feedback cancellation on a portable Hearing Aid research platform
IV-04	10:35 – 10:50 Room 4	**Max Zimmermann** System for interactive remote hearing research using virtual acoustics

Poster Sessions

H4A Symposium Postersession:

https://webconf.uol.de/b/bir-kmo-gmk-yl4

Friday, 06.11.2020 | 16:05 - 16:50

ID	Time and Room	Presenter and Title
III-06	16:05 – 16:20 Room 1	**Georg Berding** Fundamental reduction of radiation exposure in activation studies of the auditory system with O-15 water PET by advances in device technology and possibly by using deep learning methods in reconstruction PDF
III-07	16:20 – 16:35 Room 1	**Mika Sato** Temporal Characteristics of Electrophonic and Electroneural Responses
III-08	16:35 – 16:50 Room 1	**Felix Peter Aplin** Paired pulse ICMS in Guinea Pig
III-09	16:05 – 16:20 Room 5	**Sabine Haumann** Cochlear Analyzer
IV-05	16:05 – 16:20 Room 2	**Suheda Yilmaz-Bayraktar** Investigating the swelling behaviour of hydrogel building polymers compoundedwith silicone rubbers of different medical grades
IV-06	16:20 – 16:35 Room 2	**Ailke Behrens** Characterization of 3D printed Electrodes for Electrocortical Recording
IV-07	16:35 – 16:50 Room 2	**Dirk Oetting** Aided spatial speech perception in subjects with hearing loss. Why do we observe large individual differences?

ID	Time and Room	Presenter and Title
IV-08	16:05 – 16:20 Room 3	**Daniel Hölle** Mobile ear-EEG to study auditory attention in everyday life PDF
IV-09	16:20 – 16:35 Room 3	**Martin Bleichner** The nEEGlace: A mobile ear-EEG setup to conduct auditory experiments in everyday life.
IV-10	16:35 – 16:50 Room 3	**Marcos Cantu** Real-time Low-Latency Speech Intelligibility Enhancement with an Eyeglass-Integrated Assistive Listening Device
IV-11	16:05 – 16:20 Room 4	**Nils L Westhausen** Dual-Signal Transformation LSTM Network for Real-Time Noise Suppression
IV-12	16:20 – 16:35 Room 4	**Tomas Gajecki** Enhancement of Interaural Level Differences For Bilateral Cochlear Implant Users
IV-13	16:35 – 16:50 Room 4	**Arnd Meiser** Evaluating the Sensitivity of Ear-EEG using Forward Modeling

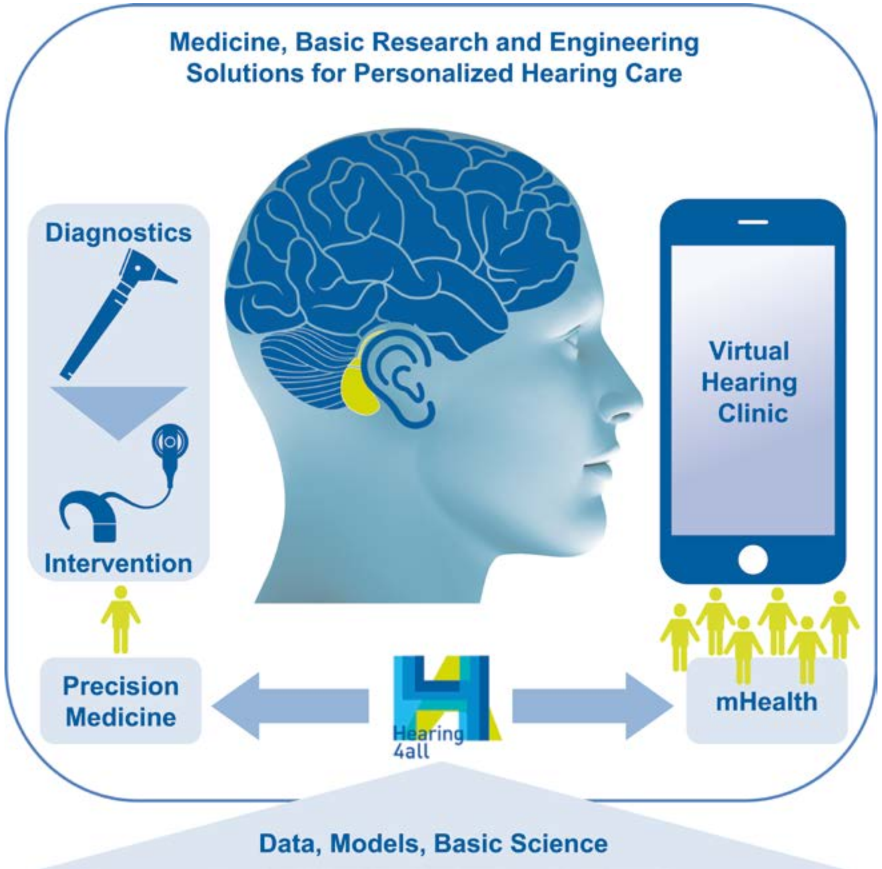
Hearing4all 2.0 –
Medicine, Basic Research and Engineering Solutions for Personalized Hearing Care

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.

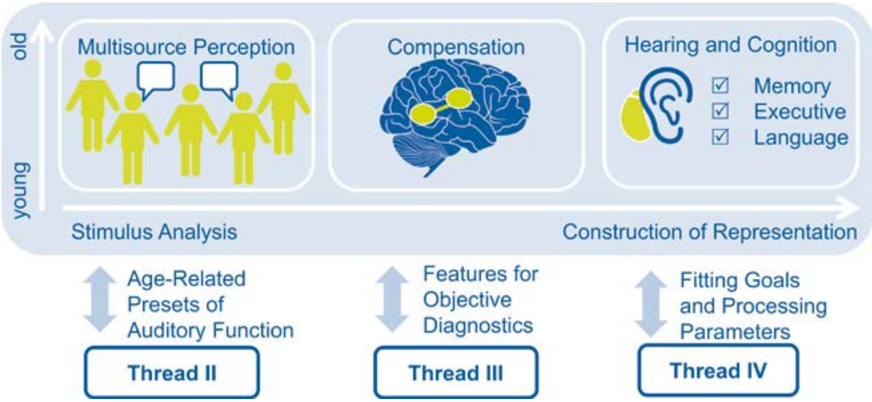
We will concentrate on the three most important aspects of characterising individual hearing ability across the lifespan that are especially important for diagnostics and treatment with hearing devices: Hearing in complex, multisource environments (including better understanding of source segregation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

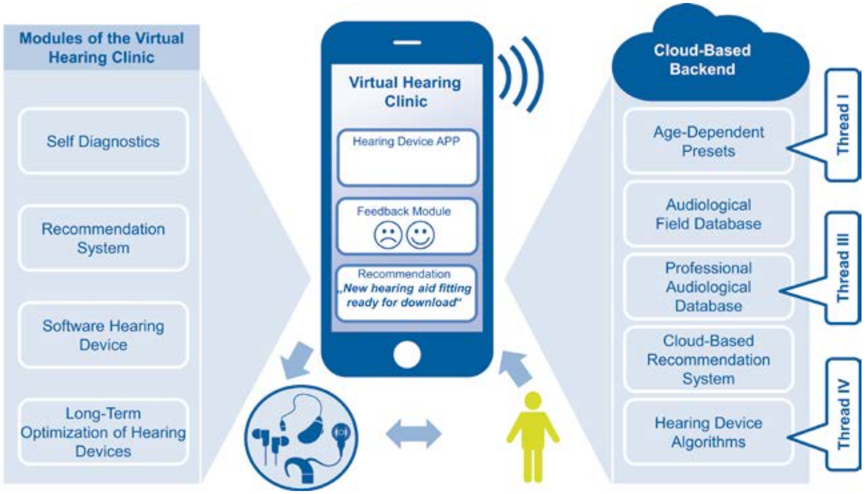


IT-based diagnostics and rehabilitation

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:

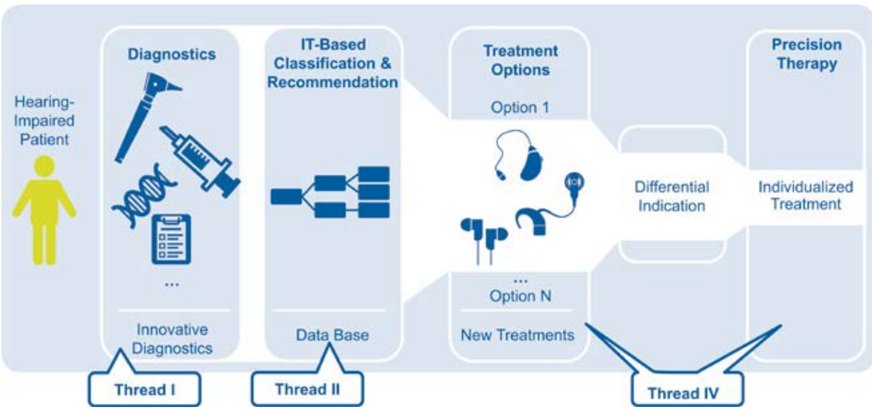
- Research Thread I will provide age-related expectations to be used for the various auditory functional parameters as well as ways to interpret the relationships between auditory functions across age.
- Research Thread III will manage and analyse the professional, clinical database and will provide 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)

Ojectives: 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.

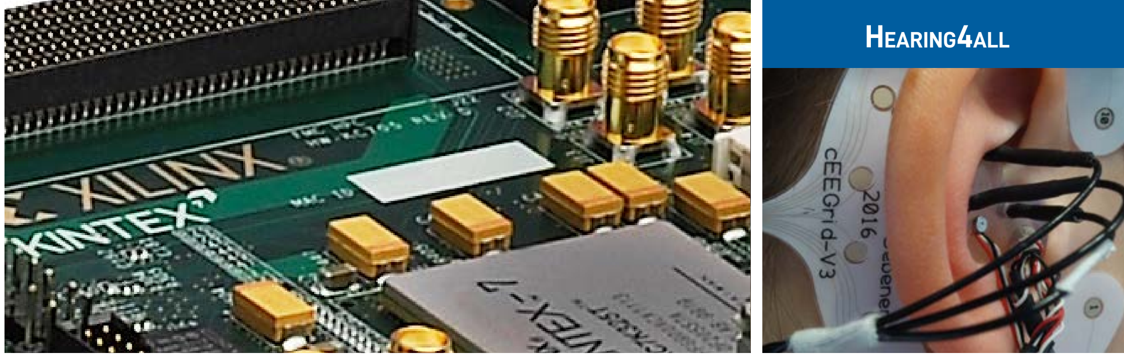
Prevention, diagnosis and treatment of hearing loss with respect to the wide variety of the different causes will require the development of novel approaches for extensive and in-depth diagnosis and targeted novel therapy options for precision treatment that supplement the technological and clinical 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
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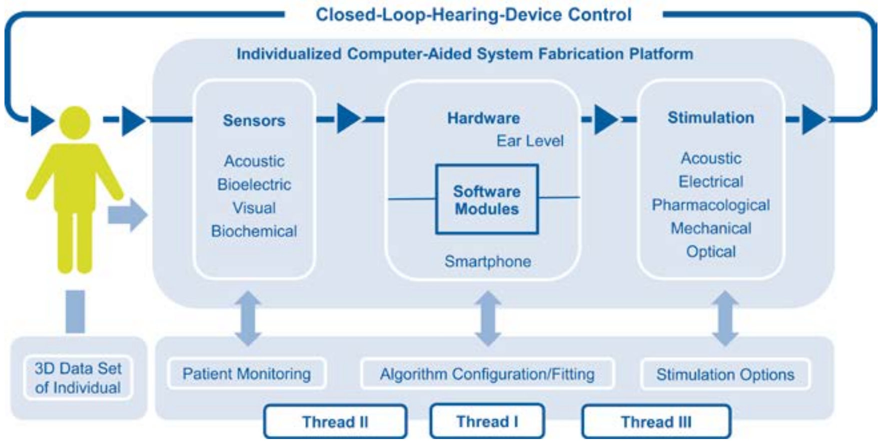
Objectives: Based on the solutions from H4A 1.0, unprecedented, highly integrated system concepts, hardware and software solutions for research and applications will result from interdisciplinary research on comprehensive system technology. This translational research focus will enable the cluster to 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.

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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 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