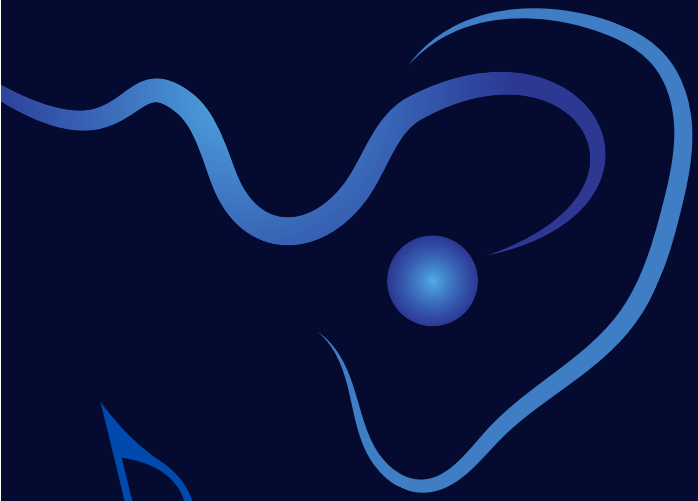


MUSIC & HEARING HEALTH

WORKSHOP

OCTOBER 6-7, 2022

UNIVERSITY OF OLDENBURG

AULA A11, AMMERLÄNDER HEERSTR. 69

Contents

Welcome

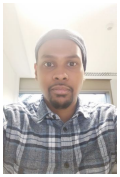
"How could I possibly admit to an impairment in that very faculty that ought by rights to be more highly developed in me than in other men, a faculty that I once possessed to the highest degree of perfection." Beethoven's despaired 1802 confession still speaks volumes for much of today's landscape on music and hearing. Despite advancements in hearing protection and technology, musicians continue to be at high risk of hearing loss and hearing-impaired individuals continue to have difficulty listening to music. At the same time, research has identified a range of music-based interventions for improving a range of health conditions. All of this calls for a renewal of our understanding of music and hearing health.

The Music Perception and Processing Lab led by Kai Siedenburg is pleased to introduce the first Music & Hearing Health Workshop. This workshop provides a forum for the discussion of a broad array of topics around music, hearing, and health. The workshop is funded by a Freigeist Fellowship of the VolkswagenFoundation.

We look forward to learning about the latest advancements in the field, discussions at posters, and gathering as a community,

The Oldenburg Music Perception and Processing Lab


Kai Siedenburg


Aravindan Joseph Benjamin


Deborah Derks


Karsten Gerdes


Anna Lena Knoll


Michel Bürgel


Simon Jacobsen


Robin Hake

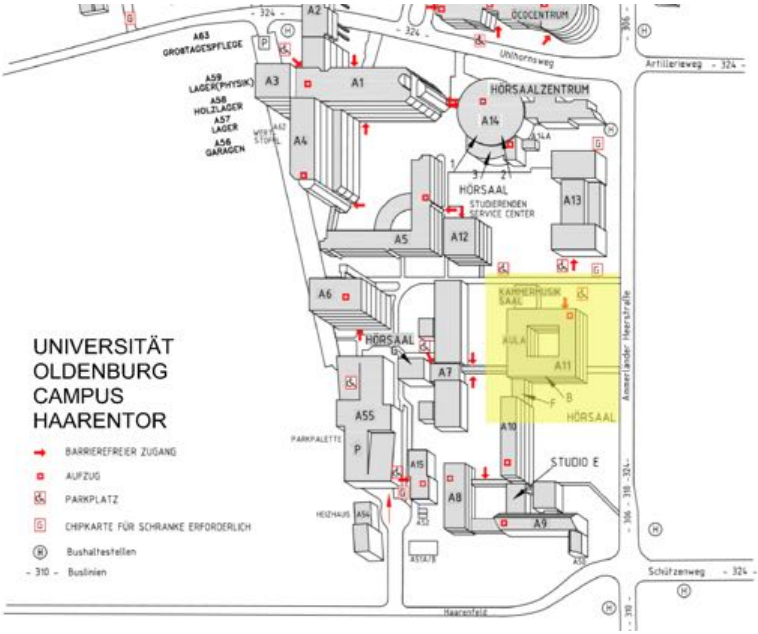

Maximilian Dechert


Noah Rickermann

Where to find us

Venue

- Address: Ammerländer Heerstr 69,26129 Oldenburg, Germany
- Aula A11, University of Oldenburg
- Oct 6-7, 2022
- Registration starting on Oct 6, 10:30h
- Free Wi-Fi



Information

About the Oldenburg Music Perception and Processing Lab

Research in the Oldenburg Music Perception and Processing Lab considers how normal-hearing and hearing-impaired listeners make sense of musical sound. Research activities in the lab specifically focus on auditory scene analysis as well as timbre and pitch perception. This incorporates conducting psychoacoustic experiments, developing auditory perception models, and designing audio processing algorithms. A long-term goal is to establish the critical link between music perception with hearing loss and auditory scene analysis, helping to put hearing loss on the agenda of music psychology, and, vice versa, reinforce music's role as a window into the impaired auditory system. Established in 2020, the lab is funded by a *Freigeist Fellowship* of the VolkswagenFoundation to Kai Siedenburg.

About Hearing Sciences in Oldenburg

The University of Oldenburg internationally ranges among the top institutions for hearing sciences. The cluster of excellence *Hearing4all 2.0*, in 2018 granted a second funding period of 7 years, seeks to overcome the serious problem of hearing loss in our ageing communication society by developing research-based solutions for all kinds of hearing loss in all hearing situations in all areas of everyday life. The collaborative research centre (SFB) 1330 *Hearing Acoustics: Perceptive Principles, Algorithms and Applications*, which was established in 2018, aims at investigating the principles of speech-based communication in detail and to foster the communicative abilities in the population by the improvement of hearing devices. An additional pillar of this research area is the manifold extra-university research landscape in Oldenburg that translates basic research into applications as conducted in the *Hörzentrum Oldenburg gGmbH* and the Fraunhofer IDMT institute division *Hearing, Speech and Audio Technology*.

Program

Thursday, October 6th

10:30	Arrival and Registration
11:00 – 12:00	**Welcome & Introduction**
12:00 – 13:00	**Keynote: Deniz Baskent**
13:00 – 14:00	Lunch
14:00 – 15:30	**Session 1: Hearing impairment**
15:30 – 16:00	Coffee break
16:00 – 17:45	**Session 2: Health effects**
17:45 – 18:15	**Special: Golden Ear Challenge**
19:00 – 21:00	Presenters Dinner
21:00	Get-together

Friday, October 7th

9:00 – 10:00	**Keynote: Chris Plack**
10:00 – 11:30	**Poster Session + Coffee break**
11:30 – 13:00	**Session 3: Re-mixing**
13:00 – 14:00	Lunch
14:00 – 15:30	**Session 4: Individual differences**
15:30 – 16:00	Coffee break
16:00 – 17:30	**Session 5: Exposure**
17:30	Closing panel

Special: Golden Ear Challenge

Thursday, Oct 6th, from 17:45 until 18:15 PM

We are excited about the opportunity to host a special event at the workshop, the *Golden Ear Challenge*. This challenge will be a live-experiment in which members of the audience will compete according to their music perception abilities. For this purpose, we have invited the **Kammerensemble Konsonanz** (www.konsonanz.com), a renown musical ensemble based in Bremen. Kammerensemble Konsonanz will perform excerpts a famous string quartet. Bring your smartphones to be able to participate. Are you able to spot performance errors? Only the best *golden ears* will reach the last rounds. The winner will receive '**the Golden Ear Award**'.

Keynote speakers

We are very proud that a number of excellent international scientists have accepted our invitation. We are particularly happy to welcome our keynote speakers:

- **Deniz Baskent**, *University of Groningen*
  What have we learned from musicians research? How can we use it for auditory training for hearing impaired individuals?

- **Chris Plack**, *University of Manchester*
  The effects of age on pitch and harmony perception

We cordially thank the speakers for their contributions and look forward to stimulating talks and discussions.

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What have we learned from musicians research? How can we use it for auditory training for hearing impaired individuals?

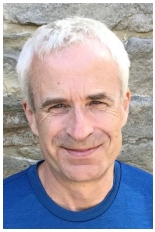
Deniz Başkent[1]

[1] University of Groningen

Bio. Deniz Başkent studied Electrical and Biomedical Engineering, and a desire to work more closely with people steered her towards hearing aids and cochlear implants. Deniz loves studying everything about hearing, its development, its impairments, its interaction with perception and cognition and comprehension. Deniz also loves singing together with others. In her current position at the University Medical Center Groningen, the Netherlands, Deniz was lucky to be able to bring together all her passions together. Her research team (dB SPL) includes great diverse expertise from audiology, otology, psycholinguistics, psychology, and music cognition, and even robotics. By combining all of the skills and expertise, dB SPL aims to unravel intricacies of perceptual and cognitive mechanisms of hearing and how these are altered with hearing impairment and hearing device processing, in a diverse group of populations (children, geriatric). dB SPL also aims to provide better ways of clinical and research testing, with increased engagement, using, for example, music training or robot interfaces. And last but not least, dB SPL actively supports the long tradition of the Music Night of the Conference on Implantable Auditory Prostheses (CIAP) via the Groningen Rainbows.

The effects of age on pitch and harmony perception

Chris Plack[1]
[1] University of Manchester, United Kingdoms



Chris.Plack@manchester.ac.uk

Bio. Chris Plack was educated at Christ's College, University of Cambridge, where he obtained a BA in Natural Sciences in 1987 and a PhD in 1990, specialising in psychoacoustics. He worked as a postdoctoral research fellow for two years at the University of Minnesota, and for two years at the University of Sussex, before being awarded a Royal Society University Research Fellowship in 1994. He moved to the University of Essex in 1998, and was promoted to Chair in 2001. He moved again to Lancaster University in 2005, before obtaining his present position of Ellis Llwyd Jones Professor of Audiology at the University of Manchester in 2008. He is also currently Professor of Auditory Neuroscience at Lancaster University. Chris Plack has published over 100 peer-reviewed journal articles, 12 book chapters, an introductory textbook on hearing, and two volumes as lead editor. In 2003 he was elected a Fellow of the Acoustical Society of America.

Overview - Sessions

Session 1: Hearing loss

Thursday, Oct 6th, from 14:00 - 15:30h

- **Alinka Greasley**, *University of Leeds*
  Characterising how mild, moderate, severe and profound levels of hearing loss affect music listening with hearing aids
- **Sina Tahmasebi**, *Hanover Medical School*
  Optimization of Sound Coding Strategies to Make Singing Music More Accessible for Cochlear Implant Users
- **Bernhard Richter**, *University of Freiburg*
  Ludwig van Beethoven – the Heard and the Unhearing

Session 2: Health effects

Thursday, Oct 6th, from 16:00 - 17:30h

- **Ulrike Frischen**, *University of Oldenburg*
  Short-term Effects of Listening to Music on Breathing and Emotional Affect in People Suffering From Chronic Lung Diseases
- **Stine Alpheis**, *Hanover Medical School*
  The Influence of Adverse Childhood Experiences on Stress-Reactivity and the Development of Musician's Dystonia
- **Chi Yhun Lo & Frank A. Russo**, *Toronto Metropolitan University*
  To what extent can group-based music support health and wellbeing outcomes for children and adults with hearing loss?

Session 3: Re-mixing

Friday, Oct 7th, from 11:30 - 13:00h

- **Trevor R. Agus**, *Queen's University Belfast*
  Precision Perceptual Engineering to Enhance Television Soundtracks
- **Jonas Althoff**, *Hanover Medical School*
  How do cochlear implant users remix instrumental classical music?
- **Hendrik Kayser & Volker Hohmann**, *University of Oldenburg*
  The open Master Hearing Aid Platform

Session 4: Individual differences

Friday, Oct 7th, from 14:00 - 15:30h

- **David Sears**, *Texas Tech University*
  Harmonic Priming and Temporal Order: Evidence from Aphasia
- **Franziska Degé**, *MPI for Empirical Aesthetics*
  tba
- **Martin Bleichner**, *University of Oldenburg*
  Individual sound perception in everyday life

Session 5: Exposure

Friday, Oct 7th, from 16:00 - 17:30h

- **Niels Hendrik Pontoppidan**, *Eriksholm/Oticon*
  Noise exposure from leisure noise compared to other noise sources
- **Omid Kokabi**, *Mimi Hearing Technology*
  Challenges in calculating ecologically valid sound dose estimations on consumer electronic devices
- **Samuel Couth**, *University of Manchester*
  The Song Remains the Same: No longitudinal effect of noise exposure on behavioural, electrophysiological, and self-report measures of hearing in musicians

Overview - Posters Friday, Oct 7th

Here, you find all poster abstracts for the **poster session on Friday, Oct 7th, 10:00-11:30h** in the alphabetic order listed below.

- **Alberte Baggesgaard Seeberg, Peter Vuust, Andreas Højlund, Mark Fletcher, Samuel Perry, Kathleen F. Faulkner and Bjørn Petersen** (P01),
  Feel the beat and improve the groove: multimodal rhythm perception in cochlear implant users
- **Alexandre Celma-Miralles, Alberte B. Seeberg, Niels T. Haumann, Peter Vuust and Bjørn Petersen** (P02),
  Cochlear implant experience enhances the ability to track the musical beat
- **Andres von Schnehen, Lise Hobeika, Dominique Huvent-Grelle, François Puisieux and Séverine Samson** (P03),
  The impact of cognitive functioning on sensorimotor synchronisation with simple and complex rhythmic sequences
- **Anil Nagathil and Ian C. Bruce** (P04),
  A deep-learning-based approximation of a cochlear filtering auditory model for applications in speech and music processing
- **Aravindan Joseph Benjamin & Kai Siedenburg** (P05),
  Multi-track mixing transforms and their implications on normal hearing and hearing impaired listeners
- **Ellie Harding, Etienne Gaudrain, Imke Hrycyk, Robert Harris, Barbara Tillmann, Bert Maat, Rolien Free and Deniz Baskent** (P06),
  Music emotion categorization with normal- and cochlear-implant hearing

- **Johannes Gauer, Anil Nagathil, Benjamin Lentz, Christiane Völter and Rainer Martin** (P07),
  A comparative evaluation of music preprocessing strategies for cochlear implant listeners

- **Laura Rachman, Eleanor Harding, Ryan Gray, Stefan Smeenk, Anastasios Sarampalis, Etienne Gaudrain and Deniz Başkent** (P08),
  Effects of age and musical expertise on perception of speech in speech maskers in adults

- **Lloyd May, So Yeon Park, Aaron Hodges, Blair Kaneshiro and Jonathan Berger** (P09),
  Designing for Empathetic Listening Interactions

- **Marie-Luise Augsten, Martin Lindenbeck and Bernhard Laback** (P10),
  Perception of simultaneous and sequential musical harmony in cochlear implant users

- **Martin Lindenbeck, Marie-Luise Augsten and Bernhard Laback** (P11),
  Musical Pitch with Cochlear Implants: Tones vs. Intervals & Temporal vs. Place Cues

- **Michela Santangelo, Valentina Persici, Letizia Guerzoni, Domenico Cuda, Reyna L. Gordon and Marinella Majorano** (P12),
  A longitudinal study of vocabulary development in children with cochlear implants: the role of music exposure and maternal musicality

- **Michel Bürgel & Kai Siedenburg** (P13),
  Autotune kills the radio star": Salience of frequency micro-modulations in popular music
- **Nelleke Jansen, Eleanor Harding, Hanneke Loerts, Deniz Başkent and Wander Lowie** (P14),
  A meta-analysis of the relation between musical abilities and speech prosody perception
- **Razvan Paisa, Peter Williams, Francesco Ganis, Niels Christian Nilsson and Stefania Serafin** (P15),
  Vibrotactile Actuated Concert for Cochlear Implant Users
- **Robert J. Acheson and Trevor R. Agus** (P16),
  The Threshold of Perceptual Significance for TV Soundtracks
- **Robin Hake, Ulrike Frischen, Esther Rois-Merz, Kirsten Wagener, Gunter Kreutz, and Kai Siedenburg** (P17),
  On hearing health and hearing protection of full-time and recreational musicians
- **Sophie Weber, Grit Böhme, Christa Schlenker-Schulte, Magdalena Schmidt, Agnes Weber and Ulrike Weber** (P18),
  Music Perception in Elderly People with Hearing Aids - Experiences and Influencing Factors

Abstracts

SESSION ABSTRACTS

A.E.Greasley@leeds.ac.uk

Characterising how mild, moderate, severe and profound levels of hearing loss affect music listening with hearing aids

Alinka Greasley[1]

[1] School of Music, University of Leeds, United Kingdom

This talk will draw on findings from a study conducted as part of the Hearing Aids for Music project (www.musicandhearingaids.org), describing differences in the musical experiences of listeners with varying levels of hearing loss. 1,507 hearing aid users (age range 18-95, mean = 60 years; 49% female) completed an online survey comprising eight sections (demographics, musical engagement, hearing, hearing aid technology, recorded music, live music, discussions with audiologists). Respondents were grouped into hearing loss category for analysis by responses to a speech descriptor (mild 22%, moderate 42%, severe 34%, profound 2%), checked against audiometric data for a sample subset (n = 113). 87% agreed music was important, and 67% listen as often as they can. Despite this engagement, there were differences by hearing loss level. Those with severe and profound hearing losses were more likely to avoid listening to music, less likely to listen for pleasure, and more likely to find listening to complex styles (e.g. orchestral, opera) challenging. They were also less likely to report hearing aids were helpful for hearing out musical features (e.g. understanding lyrics, picking out instruments) and more likely to experience difficulties (e.g. distortion, too much bass). By contrast, those with mild and moderate losses were more likely to rate hearing aids as helpful for perceiving musical features and for listening to a wide range of styles, less likely to use assistive listening devices, and more likely to take their hearing aids out in live musical settings. The study underlines that music is an important part of the everyday lives of hearing-impaired listeners, despite their deafness. Whether providing those with milder losses with a volume control on their hearing aids to give them more control in live contexts, or managing expectations among those with severe losses about the difficulties they may experience perceiving musical features, the results provide an evidence-base for developing clinical strategies for improving listening experiences.

Optimization of Sound Coding Strategies to Make Singing Music More Accessible for Cochlear Implant Users

Sina Tahmasebi[1], Manuel Segovia-Martinez[2], Waldo Nogueira[1]

[1] Department of Otolaryngology and Cluster of Excellence "Hearing4all", Medical University Hannover
[2] Oticon Medical, Neurelec, Vallauris, France

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Cochlear implants (CIs) are medical implantable devices that can restore hearing to people suffering from profound sensorineural hearing loss. While CIs provide a good speech understanding in quiet, CI users face limitations in music appreciation. The main reasons are poor spatial specificity of electric stimulation, limited transmission of temporal fine structure of acoustic signals and restricted dynamic range that can be conveyed through electric stimulation of the auditory nerve. The CI coding strategy converts the acoustic microphone signals and computes the electric stimulation patterns delivered to the electrodes. These strategies are typically designed for speech rather than music. Previous research has shown that CI users enjoy music better when the singing voice or vocals are enhanced with respect to background instruments [Buyens et al., 2014; Pons et al., 2016; Tahmasebi et al. 2020]. This study investigated the optimization of CI coding strategies to make singing music more accessible for CI users. In this work, we aimed at reducing the complexity of music by selecting fewer bands for stimulation, attenuating the background instruments by strengthening a noise reduction algorithm, and optimizing the electric dynamic range through a back-end compressor in popular music. Based on the objective instrumental measures, five parameterizations of a CI sound coding strategy differing in the number of selected bands N in NofM, strength of the NRA, the use of the music compressor, and combination of all previous algorithms have been created for the perceptual evaluation. Ten CI users participated in new perceptual measures of speech understanding and melody identification of singing voice with and without background instruments as well as music appreciation questionnaires. Consistent with the objective instrumental measures, results gathered from the perceptual evaluations indicated that reducing the number of selected bands N in NofM and the use of a back- end compressor specifically for music listening can improve lyrics understanding and music appreciation for CI users.

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Ludwig van Beethoven – the Heard and the Unhearing

Bernhard Richter[1]

[1] Freiburg Institute for Musicians' Medicine (FIM), Germany

People around the globe were and are directly spoken to and deeply moved by Beethoven's music. Almost as well-known as his music is the fact, too, that Beethoven increasingly lost his hearing half-way through his life and that he created part of his works that are today regarded as important—the 9th Symphony and the Missa Solemnis, among others—as a virtually entirely deaf musician. We continue to be astounded by the phenomenon of a deaf person being able to compose in an unhindered way, so to say, fully in command of his musical creativity. The fact that—and the way in which—Beethoven himself profoundly perceived the psycho-social aspects of his gradual loss of hearing can already be understood in his Heiligenstadt Testament of 1802.

In addition, it seems interesting to place Beethoven's situation as a deaf patient in the medical context of his time and to ask: what was known at the time Beethoven lived of the physiology and pathophysiology of hearing and how, by contrast, is our knowledge of the same today? Starting from the basic knowledge of physiology of that time, it is furthermore pertinent to ask what the diagnostic possibilities for clarifying a hearing disorder were in the period Beethoven was alive and how one would proceed today. An exciting question is what possibilities there would be today to treat Beethoven's impaired hearing. Would a hearing aid or a cochlear solve his problems?

In the lecture, the topic of listening is discussed with reference to Beethoven.

Short-term Effects of Listening to Music on Breathing and Emotional Affect in People Suffering From Chronic Lung Diseases

Ulrike Frischen[1]
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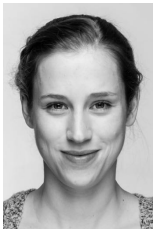
Chronic lung diseases (CLD) are often associated with abnormal, ineffective breathing patterns. In addition, depressive symptoms are common comorbidities. Some studies already suggest that nonpharmacological interventions can have positive effects on symptoms related to CLD. However, in the current state of research there is a lack of studies investigating the influence of music listening on breathing related parameters and emotional affect. In the present study, we conducted two quasi-experiments to investigate the immediate effects of attentive music listening and music listening combined with a breathing instruction on breathing rate, oxy- gen saturation, and emotional affect in people affected by CLD and healthy controls. In total, we recruited 58 participants affected by CLD and healthy controls. Participants with CLD and healthy controls were either quasi-randomized to a music-oriented instruction (Experiment 1) or to a breathing-related instruction (Experiment 2). In both experiments we measured physiological measures and emotional affect during a baseline measurement (silence) and during one "relaxing" and one "activating" piece of music. We conducted 3×2 repeated measures analyses of variances with condition (baseline/relaxing music/activating music) on the first and group (with/without CLD) on the second factor for both experiments. The results of the experiments suggest that there is no immediate effect of music listening on breathing related outcomes irrespective of the instruction of participants. Moreover, we found some indication that the disease severity might influence the processing of the music. Future studies could investigate whether music listening as a long-term intervention can lead to more promising results in relation to improved breathing.



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The Influence of Adverse Childhood Experiences on Stress-Reactivity and the Development of Musician's Dystonia

Stine Alpheis[1], Christopher Sinke[2], Tillmann Krüger[2], Eckart Altenmüller[1], Daniel S. Scholz[1]

[1] Institute of Music Physiology and Musician's Medicine – University of Music, Drama and Media, Hannover
[2] Clinic of Psychiatry, Social Psychiatry and Psychotherapy – Hannover Medical School

Musician's dystonia is a task-specific movement disorder characterized by muscle cramps and impaired voluntary motor-control whilst playing a musical instrument. It is usually not painful, but experienced as highly disabling and stressful, often ending the career as a professional performer. While musician's dystonia is mostly classified as neurological movement disorder, the exact etiology remains not fully understood. Recent studies suggest that adverse childhood experiences might pose a risk factor for the development of dystonia. Childhood adversities, such as neglect, abuse, or household dysfunction, are known to affect both mental and physical well-being. By influencing psychological dispositions (e.g., perfectionism and anxiety), stress reactivity, as well as sensorimotor areas in the brain, they target factors that are also frequently associated with dystonia. Especially alterations in the cortico- basal ganglia-thalamo-cortical loop and the limbic system might play a role for dysfunctional movement learning.

Our currently ongoing research project investigates whether musicians with dystonia have experienced more adverse childhood events and consequently exhibit a higher stress reactivity, which makes them more vulnerable to develop dysfunctional movement patterns. Dystonia patients and healthy controls are compared using functional magnetic resonance imaging (fMRI) and the Montreal Imaging Stress Task. This paradigm induces stress with arithmetic tasks and social-evaluative pressure during fMRI.

Preliminary analyses of the questionnaire data suggest that musician's dystonia patients have indeed experienced emotional neglect more often than healthy controls. It is further hypothesized that these patients show an increased stress reactivity. The neurological mechanism behind this association might be an increased activation of the basolateral amygdala in stressful situations, which enhances emotion- induced memory consolidation of dysfunctional movements. An involvement of adverse childhood experiences in the etiology would support the theory that musician's dystonia is not only the result of motor circuit dysfunctions, but also a manifestation of dysfunctional stress-coping-mechanisms. These findings would supply important contributions to improved and individually tailored treatment and prevention methods.

To what extent can group-based music support health and wellbeing outcomes for children and adults with hearing loss?

Chi Yhun Lo[1], Frank A. Russo[1]
[1] Toronto Metropolitan University, Canada

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The most cited problem for persons with hearing loss is communication difficulty in dynamic, noisy environments. This is true for both children and adults, although the impacts are vastly different. Whereas the concern for children may be their ability to form friendships and develop social skills in the classroom and playground; adults may contend with issues of social isolation or interpersonal misunderstanding and underemployment in the workplace.

Music training provides a unique means of intervention that may afford improvements in various quality of life outcomes. However, the impact of music training in persons living with hearing loss is typically explored in respect to the framework of auditory training and rehabilitation, with an emphasis on individual training. Furthermore, perceptual measures such as speech-in-noise remain the focus of outcome measures. These perspectives are important but somewhat narrow, and there is increasing recognition around the need to explore other outcome measures such as psychosocial wellbeing, emotion, and cognition to fully comprehend the intersections unique to the experience of children and adults with hearing loss. Group music training provides an intervention that is scalable because of the lower average cost per participant. In addition, the context of making music and interacting with others confers social benefits, and appears to be motivating, which may help with adherence to training. This presentation will discuss recent findings on how the context of music, age, and developmental trajectories creates different opportunities for children and adults with hearing loss.

Two exemplar projects will be discussed: group-based music therapy for children with prelingual hearing loss aged between 6 and 9 years; contrasted with group-based choir singing for adults with postlingual hearing loss.

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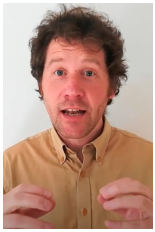

Precision Perceptual Engineering to Enhance Television Soundtracks

Trevor R. Agus[1], Robert J. Acheson[1]

[1] Queen's University Belfast, Belfast, UK

Processing strategies for hearing aids and other audio prostheses are by necessity real-time, with relatively low latencies. However, the evolving methods of television consumption raise the possibility that their soundtracks could be processing in advance off-line, whether in a device owned by the viewer or before distribution by the content provider. This option raises questions about how best to enhance audio given minimal constraints, which tests our understanding of auditory perception goals as well as the signal-processing strategies required to satisfy these goals.

We describe here efforts to create a dynamic-range compression algorithm that side-steps the usual trade-offs between slow and fast compression by acting locally in both time and frequency (cf. REF***). Such a process could allow us to preserve not just the audibility of a TV soundtrack, but also its patterns of specific loudness for different listeners, if that is a desirable goal. This also represents a first step towards re-mixing soundtracks to better preserve patterns of energetic masking. Off-line processing also offers opportunities to preserve or enhance cues to other perceptual elements, such as spatialisation or pitch saliency. We discuss here the challenges of moving from individual cues to a more holistic set of perceptually relevant features that ought to be preserved, and potential signal-processing tools that could be useful for these targeted perceptual goals.

How do Cochlear Implant Users remix instrumental classical music?

Jonas Althoff[1], Tom Gajecki[1], Liza Lengert[2], Waldo Nogueira[1]

[1] Department of Otolaryngology and Cluster of Excellence "Hearing4all", Medical University Hannover
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A cochlear implant (CI) is a neural prosthesis that partly restores the hearing sense to people suffering from hearing loss through direct electric stimulation of the auditory nerve. While speech understanding is significantly improved with CIs, music perception and appreciation remain severely limited, especially for music with increasing complexity. Previous studies have shown music appreciation benefit of separating popular music into four voices (vocals, bass, percussion, and accompaniment) and attenuating or increasing these elements. In this project, a study is performed expanding this idea upon instrumental classical music, which can be regarded as more complex for CI users due to the high amount of instruments involved.

Two datasets have been used in this study: The first one is based on complex full- orchestral pieces and the second one is based on less complex trios from different composers and eras. The orchestral pieces were taken from the Aalto anechoic orchestral database which is publicly available. The trios dataset has been created specially for the present study by synthesizing some pieces of the publicly available Classical Archives MIDI dataset. For pieces not containing percussion elements, synthetic percussions were added. A GUI has been designed allowing subjects to modify the voices of the musical pieces in intensity, spatial or spectral manner. Preliminary pilot experiments show that CI users were able to conduct the task successfully and that CI users present individual patterns regarding the enhancement of distinct music components. These results open the possibility to create novel signal processing algorithms to make music more accessible for CIs. This work was funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) Project 446611346.

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Hearing-aid research with the open Master Hearing Aid (openMHA)

Hendrik Kayser[1], Caslav Pavlovic[1], Volker Hohmann[1]

[1] Carl von Ossietzky University Oldenburg, Germany

The project "Open community platform for hearing aid algorithm research" (NIDCD R01DC015429) provides a software platform for real-time, low-latency audio signal processing: open Master Hearing Aid (openMHA). It contains a versatile set of basic and advanced methods for hearing aid processing, as well as tools and manuals enabling the design of own setups for algorithm development and evaluation. Documentation is provided for different user levels, in particular for research audiologists, application engineers and algorithm designers. The software runs on standard off-the-shelf hardware including lab setups and portable setups. Being of particular interest for the evaluation of new methods in real-word scenarios, a portable, integrated research platform for openMHA is provided in conjunction with the SBIR project R44DC016247: the Portable Hearing Laboratory (PHL). This contribution introduces openMHA and discusses current use cases and possible application scenarios of the software framework as well as the PHL. An overview over the tools, provided with the software package, that address the different user groups will also be provided.

Harmonic Priming and Temporal Order: Evidence from Aphasia

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Like language, much of the world's music exhibits organizational principles associated with the statistical distribution, temporal order, and hierarchical organization of events. These structural parallels suggest that domain-general cognitive mechanisms support the structural processing of evolving sequences, musical or otherwise. However, dissociations between deficits in processing tonal-harmonic and linguistic structure suggest domain-specific processing. For example, some people with aphasia (PWA) show impaired processing of linguistic syntax yet preserved processing of harmonic structure. In these cases, harmonic structure was typically manipulated via tonal-contextual (e.g., tonic vs. subdominant; semantic priming) information, rather than temporal (e.g., unscrambled vs. scrambled; discourse priming) information. If linguistic syntax is more analogous to temporal than to contextual musical structure, problems with temporal structural processing in music and language might still reflect a shared underlying (albeit unexplored) deficit.

To address this issue, I will discuss the findings from a behavioral study that compared experimental manipulations associated with the temporal coherence (event order) and contextual relatedness (tonal similarity) of harmonic progressions in a priming experiment involving neurotypicals and both fluent and nonfluent PWA. In short, all participant groups showed significant effects of temporal coherence and contextual relatedness, indicating spared processing of musical structure despite impaired language processing in both fluent and nonfluent PWA. Thus, listeners may integrate serial and tonal-contextual information using distinct processing mechanisms.

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Individual sound perception in everyday life

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How we perceive sounds is individually different and varies over time and in between contexts. We aim to objectively study individual, time and situation-dependent differences in sound perception using long-term mobile ear-EEG. Here we study in everyday life how people react to acoustic stimuli over time (2-3 hours). The participants are equipped with a mobile EEG setup, consisting of ear electrodes (cEEGrids), a mobile EEG amplifier system that allows controlled sound presentation (nEEGlace) and a smartphone, that controls stimulus presentation and concurrently records EEG and acoustic features of the experienced soundscape. With this setup the participants are recorded in two situations: in the lab while they complete different listening tasks and beyond the lab while they work on their computer or smartphone, talk to other people or go for lunch.

In all situations we present a paired-click paradigm. Two click sounds (ITI 500 msec) that are presented every 8-9 seconds, in 80% the two clicks are identical in 20% the second click deviates from the first one. In the lab we manipulate how participants have to listen to the clicks in four conditions: first, without instruction, second, while reading a newspaper article, third, while listening to an article, forth, attending to the sounds and counting the deviant clicks. Beyond the lab, participants do not receive specific instruction on how to relate to the sounds. We use the ERP responses of the four lab conditions to label the beyond the lab data to learn more about how people differ in how they "chose to" perceive acoustic stimuli under task free conditions beyond the lab in everyday life. I will present the current results and future applications of this approach.

Noise exposure from leisure noise compared to other noise sources

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The H2020 EVOTION collected clinical hearing health data and continuous sound environment data from several hundred hearing aid users across Europe for up to a year. The rich combination of clinical data and continuous data from the hearing aids enables many different aspects of noise and health among people with hearing aids, e.g., suggesting links between current behavior and the individual origins of hearing loss. In another analysis the data shows that the origins of noise induced hearing loss might require far greater societal action as it is not just the careless consummation of loud music and inadequate protection against occupational noise that can cause noise-induced hearing loss. Here our data indicate that perhaps public transport might play a role in causing hearing loss over time. The data collected does not enable firm conclusion regarding the origin of noise induced hearing loss. Likewise, the combination data and models are not validated for clinical use yet. Nevertheless, the combination of continuous data from devices worn at ear level and clinical data is likely to play a significant role in future handling of noise as it enables individual monitoring of exposure, prediction of individual impact from exposure, documenting compliance wrt regulation, which when taken together can also be used to impact public health policies on noise.

Challenges in calculating ecologically valid sound dose estimations on consumer electronic devices

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Healthy hearing is crucial for aural communication, fostering interpersonal connections and effective participation in society. Yet maintaining such is becoming challenging in the light of a growing and aging population with additional risk factors such as excessive occupational and recreational sound exposure. For environmental noise, the negative effects of a high sound exposure on hearing ability are well researched and documented.
Beyond that, WHO estimates that a significant portion of adolescents and young adults are at risk of developing noise induced hearing loss (NIHL) due to unsafe listening levels on portable devices for extended periods of time.
Attempts at mitigating the risk of developing NIHL on account of unsafe listening practices include regulatory approaches which limit the maximum permissible output of personal audio device use and attempts at quantifying an individual's sound dose in order to provide some alerting function. Capturing and calculating ecologically valid sound dose estimations, however, is technically and practically challenging.
This is in part due to diverse listening situations an individual may encounter (occupational and recreational) and variability in hardware specifications across various playback devices. In addition, the additional environmental sound exposure needs to be figured in for an absolute assessment of received sound dose by a user.
In this presentation we will focus on some of the technical challenges associated with measuring sound dose in a real life context from a consumer technology perspective, the variability introduced by different headphone responses, stimuli and device output levels.

The Song Remains the Same: No longitudinal effect of noise exposure on behavioural, electrophysiological, and self-report measures of hearing in musicians

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Background: Musicians may be at risk of sub-clinical hearing damage due to regular exposure to high levels of noise. More specifically, noise exposure could lead to cochlear synaptopathy – a loss of synapses between inner hair cells and the auditory nerve – which could lead to difficulties with speech perception in noise (SPiN), whilst hearing thresholds remain intact. Previous studies investigating cochlear synaptopathy in musicians have used a cross-sectional design, and so they only capture a snapshot of musicians' hearing function in relation to noise exposure.

Aims: To explore the effects of noise exposure on musicians' hearing longitudinally.

Methods: Early-career musicians and non-musicians completed a test battery including the Noise Exposure Structured Interview, pure-tone audiometry (PTA; .25 – 8 kHz), extended high-frequency (EHF; 12 and 16 kHz) thresholds, otoacoustic emissions (OAEs), auditory brainstem responses (ABRs), SPiN, and self-reported tinnitus, hyperacusis and hearing in noise difficulties. The test battery was completed on three occasions: baseline, +12 months, and +24 months. Ninety-four participants (64 musicians and 30 non-musicians) completed at least one follow up assessment and were included in the longitudinal analysis.

Results: Linear mixed effects models revealed very few changes to hearing function during the study period. EHF thresholds showed a significant increase (i.e., worsening) over time, but this was not related to musicianship or noise exposure. An exploratory analysis revealed a significant positive correlation between noise exposure and outer hair cell function (i.e., OAE level), which was consistent across all three time points.

Conclusions: These findings do not support a link between cumulative noise exposure and proxy measures of cochlear synaptopathy, although monitoring noise exposure over a longer period may be necessary to capture changes. This may be particularly relevant to early-career musicians as they progress through a period of intensive musical training, and thus timely interventions to protect hearing may be crucial.

Abstracts

POSTER ABSTRACTS

Feel the beat and improve the groove: multimodal rhythm perception in cochlear implant users

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Cochlear implants (CIs) are optimized for speech perception but poor in conveying music. However, CI users typically perform on par with normal hearing (NH) controls in simple rhythmic tasks. Yet, being able to perceive more complex real-world musical rhythms is important for the perception of groove, i.e., the pleasurable desire to move to music. NH listeners prefer moving to music of medium rhythmic complexity compared to high and low complexity. This relationship follows an inverted U-shape, reflecting a "sweet spot". For CI users to achieve a more complete perception of rhythm and groove it may be beneficial to complement the auditory signal of the CI. Findings suggest that electro-haptic stimulation (EHS) can enhance perception of various sound properties in CI users. Thereby, feeling the beat through rhythm-specific EHS could improve CI users' perception of groove. This project investigates rhythm and groove perception in CI users and the potential effect of EHS. 20 CI users and 20 NH controls will be tested both behaviorally and using EEG. Stimuli will consist of drumbeats varying in rhythmic complexity (low, medium, high) and number of instruments (one, two, three). These will be presented in three conditions: audio only, EHS only, and audio and EHS together. It will be measured how the different conditions influence:
1) participants' ratings of "wanting to move" and "experienced pleasure",
2) participants' abilities to tap along to the rhythm,
3) the neural correlates of rhythm and groove perception as measured by EEG. Frequency tagging will be used to assess participants' neural entrainment to the rhythms and the quality of their beat encoding.
This is work in progress. Preliminary findings are expected to be presented at the conference. The experience of rhythm is a central part of contemporary music and the basis of how we dance to and socialize through music. Enhancement of rhythm perception could impact CI users' quality of life. Additionally, enhancing rhythm perception may benefit sound localization and separation, including speech in noise and speech perception in general.

Keywords: *Musical groove, Rhythmic complexity, Electro-haptic stimulation*

Cochlear implant experience enhances the ability to track the musical beat

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Technical limitations of the cochlear implant (CI) challenge the transmission of musical features, which, for many CI users, diminishes music enjoyment post-implantation. However, rhythm has often been found to be well-transmitted through the implant. In this study, we explored the neural correlates of perceiving the beat of a classical four-tone pattern, the arpeggiated Alberti bass. We collected the electroencephalographic responses of twenty-one CI users and fourteen normal- hearing (NH) people using a musical multifeature mismatch negativity paradigm, which presents several repetitions of the Alberti bass. We measured eight recently implanted CI users twice, within the first six weeks of switching-on the device and approximately three months later, as well as thirteen experienced CI users (median experience= 7 years). We investigated the early development of neural entrainment in the recently implanted CI users and compared their responses after 3 months with experienced CI users and NH controls. We hypothesized that more experience with the implant would draw the neural responses of CI users closer to those of the NH participants. Applying a frequency tagging approach, we measured the frontocentral neural activity occurring at the periodicities of the Alberti bass: the beat, its first harmonic, and the binary and quaternary grouping of the beat. We found a significant increase in the frequency-tagged amplitudes of recently implanted users, suggesting an early adaption to perceive the beat within the first weeks of using the implant. These amplitudes increased in the experienced CI users, though they were still smaller than in the NH group. This suggests that a prolonged adaptation period takes place after the first three months of experience, enhancing the perception of the beat. In sum, these findings show that the brain undergoes neural changes post-implantation that enhance the tracking of musical rhythms approaching (but still not reaching) the neural responses of NH people.

Keywords: *cochlear implant, rhythm cognition, beat perception, EEG, brain adaptation*

The impact of cognitive functioning on sensorimotor synchronisation with simple and complex rhythmic sequences

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Background: Music-based interventions are suggested for older adults to prevent or delay the onset of neurocognitive disorders (NCDs; Jünemann et al., 2022) or to improve the quality of life of people with NCD (Kales et al., 2015). It has been suggested that stimulating sensorimotor synchronisation (SMS) might be effective in bringing about positive behavioural and psychological changes (Ghilain et al., 2019). The goal of this research is to understand how SMS abilities are affected by different aspects of cognitive functioning, since there currently exists some disparity in the literature regarding the nature and extent of sensorimotor decline in people with NCD. Methods: 52 older individuals (61-92 years old), recruited from a geriatric memory clinic, performed a SMS task after a full geriatric and neuropsychological assessment. The SMS task consists of tapping along to musical and metronomic stimuli containing sudden tempo changes. Results: People tapped with a higher consistency to a metronome than to music. People tapped close to the beat with music whereas their taps preceded the beat considerably when tapping to a metronome. People appeared to adapt more easily to accelerations than to decelerations, especially with the musical stimulus. Moreover, people with lower scores on the Mini-Mental State Examination, Activities of Daily Living (ADL), and Instrumental ADL scales tapped with a lower consistency than those with higher scores. Finally, people scoring higher on the Mattis Dementia Rating Scale memory subtest, and people scoring higher on orientation to space, tapped several tens of milliseconds ahead of the beat, as compared to people scoring lower on these scales. Discussion: Our research demonstrates that at least some aspects of cognitive functioning and functional independence are related to sensorimotor abilities. We discuss our results' implications for the development of music-based interventions, the ways in which they might exert their positive effects on mood, behaviour and cognition, and especially the importance of tailoring an intervention to an individual's cognitive profile.

Keywords: *aging, children, dementia, music, neurodegenerative disorders, rhythm, timing, motor activity*

A deep-learning-based approximation of a cochlear filtering auditory model for applications in speech and music processing

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Computational models of the auditory periphery help to understand hearing mechanisms and can lay the foundation for bio-inspired speech and audio enhancement algorithms in hearing devices. Such models normally simulate cochlear processing, as well as neural transduction in the hair cell and auditory nerve. While they can provide accurate descriptions of auditory processing, they typically entail a high computational complexity. This prevents their application in real-time signal processing algorithms or in machine-learning tasks when used as part of a loss function.

A solution to this problem is to approximate such auditory models by deep neural networks (DNNs), which learn the non-linear and time-varying relationship between an input signal and its neural response based on training data generated with the original auditory model (e.g., Drakopoulos et al., 2021; Nagathil et al., 2021). Advantages of such approximations are accelerated execution and full differentiability of the DNN models, making them applicable in the context of DNN-based speech and audio enhancement in hearing devices.

In this work we present a DNN-based approximation of the normal-hearing cochlear filtering and hair-cell transduction stages of the widely used auditory model by Zilany and Bruce (JASA 2006). The DNN model was trained using a large data set containing clean speech, noisy speech, and music at a wide range of sound pressure levels. It was evaluated with previously unseen test data and, additionally, with pure tones and click sounds. The DNN approximation exhibits a high accuracy for all test signals and thus generalizes well. Although the original auditory model implementation was executed on four CPUs in parallel, the DNN model performed 5 times faster on a single CPU and up to 250 times faster on a GPU. Future work will extend the DNN model towards hearing-impaired auditory processing, faciliating time-efficient DNN-based hearing loss compensation for speech and music signals.

Keywords: *auditory model, deep neural network, cochlear filtering, inner hair cell, speech, music*

Multi-track mixing transforms and their implications on normal hearing and hearing impaired listeners.

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Multitrack mixing and production are central to the enjoyment of music across the globe. As these practices can be rather arduous, automating them can be beneficial. Several attempts at automating mixes were successfully investigated in previous literature. However, most if not all of them have been tested on only a small sample of trained participants with no reported hearing impairment. Furthermore, as the models and topologies required by automatic mixing are complex and can carry with them a high likelihood at being inefficacious, it is vital that few, necessary aspects or features of the mix be targeted when implementing them. For the purpose of creating automatic mixing paradigms for hearing impaired (HI) listeners, this study investigates the preference of control audio effects such as Lead to Accompaniment Ratio (LAR), Lead-Bass-Drums to Accompaniment Ratio (LBDR), panning width, and spectral balance in a collection of multitrack mixes among a sample of 26 normal hearing (NH) and 20 hearing impaired (HI) listeners further categorized into those of mild hearing impairment and those of moderate to severe impairment (10 participants on either group). Moreover, the preference of the degree by which equilization (EQuing) was transformed as a percentage of that available in an original multi-track mix or the factory mix was also investigated among the participant groups. This so called transformation was achieved for the effect by linearly extrapolating between that made available by a mixing engineer in a factory mix and a reference spectrum which is the ensemble average of the spectra of the most commonly occuring instruments in the open-source Medeley database. These include: lead vocals, bass guitar, drums, acoustic guitar, piano, and synth instruments. Results show the HI participants investigated prefered a marginally elevated LAR than NH participants. The mild HI participants alone had marginally elevated spectral balance preferences than the NH participants. Lastly, there were noticeable albeit statistically insiginificant differences in EQ transform preferences between the three groups investigated. In a followup experiment, LAR, spectral balance, and EQ transform preferences are being investigated for HA participants with and without the use of their bilateral hearing aids. It is hypothesized that there will be significant differences in the audio effects preferences between the two conditions among these participants.

Music emotion categorization with normal- and cochlear-implant hearing

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Previous studies of cochlear implant (CI) users' music emotion perception reported that emotional arousal (whether a piece is relaxing or stimulating) can be conveyed by temporal cues such as tempo. However, it is not clear whether or how other temporal features contribute to the perception of emotional arousal. Emotional valence in music (whether the emotion is positive or negative) has been reported to be cued by spectral information salient to pitch and harmony, which is more challenging for CI users to perceive, and it is unclear up to now the extent to which the quality of spectral content contributes to emotional valence perception. Using vocoders, we varied the quality of temporal and spectral content in musical excerpts during a music emotion categorization task with 23 normal-hearing participants. The four emotions were high or low in valence and arousal: (joy – high arousal high valence, fear – high arousal low valence, serenity – low arousal high valence, sorrow – low arousal low valence). In vocoder simulations, we used two carriers (sinewave or noise; primarily modulating temporal information), and two filter orders (low or high; primarily modulating spectral information). Participants categorized vocoded emotions above chance level, but the performance was poorer than in non-vocoded control conditions. Among vocoded conditions, improvement of temporal content (using sinewave carriers) and spectral content (using high filter order) both improved music emotion categorization, but to differing degrees, with a large effect with temporal content improvement. This indicates that the payoff for increased quality of temporal information in the acoustic signal is high for emotional arousal perception, and that future efforts to improve temporal cue perception during music listening may be beneficial to CI users' music emotion perception. Vocoder results will be compared with new data with CI users and the same music emotion categorization task with non-vocoded musical excerpts only.

Keywords: *cochlear implants, music emotion, vocoders, arousal, valence*

A comparative evaluation of music preprocessing strategies for cochlear implant listeners

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Although many cochlear implant (CI) listeners achieve a remarkable degree of speech understanding in quiet, their access to music often remains poor. Besides several individual factors this is caused by the limited number of frequency channels and the current spread inside the cochlea. Hence, a number of music preprocessing strategies have been proposed. They aim at emphasizing the melody and rhythm of music signals while attenuating the accompaniment, a strategy which has been shown to improve music enjoyment in earlier studies.

In this work, we compare four preprocessing methods and an oracle remix strategy in a listening experiment with 15 CI listeners stating their preference over an unprocessed reference for each method. The investigated methods use different musical source separation and dimensionality reduction techniques and yield output signals with reduced spectral complexity.

Three of the four tested methods and the oracle remix were significantly preferred over the unprocessed reference (p 0.02). The preference scores also depend on the particular music piece and genre. On average, the highest preference scores were obtained for deep-learning-based remixes of source-wise harmonic and percussive components. The outcomes also support earlier findings from a vocoder-based experiment where an additional reduction of the harmonic portion of "drums" source stem enhanced the listeners' preference compared to fully retained drum signals.

The deep-learning-based pre-processing method is versatile and allows a user- and genre-specific parameter tuning to further optimize music enjoyment in CI listeners.

Keywords: *cochlear implant, music processing, music source separation*

Effects of age and musical expertise on perception of speech in speech maskers in adults

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Speech perception in interfering background speech relies on perceptual mechanisms such as segregating target speech from masking speech using the voice cue differences, and on cognitive mechanisms such as selective attention and inhibition of irrelevant information. These mechanisms have previously been suggested to be affected by both aging and musical expertise (typically referred to as "musician effect").

Two important voice cues that listeners can rely on to distinguish different speakers are the mean fundamental frequency (F0), related to voice pitch, and the vocal-tract length (VTL), related to speaker's size. Some studies have reported a decreased sensitivity to F0 differences in older adults, possibly affecting their ability to perceive different speakers. Furthermore, age-related cognitive changes may lead to difficulties in attention direction and inhibition. Compared to non-musicians, some studies reported musicians to show enhanced processing of acoustic features such as F0, as well as enhanced cognitive abilities such as those related to auditory attention and working memory.

Few studies further showed a musician advantage for speech perception in speech maskers, in both same or different voice cues for target and masker. However, reports of musicians outperforming non-musicians in such tasks have not always been consistent across both young and older adults. This could mean the effect is small and/or depends on the definition of musicianship, pointing to the need for further studies.

In this study, we investigated the extent to which older compared to young adults benefit from voice cue differences in a speech perception in speech masker task, by manipulating differences in F0 and VTL between target and masker speakers. Further, we investigated the effect of musical expertise in younger and older adults within the same speech perception in speech masker task.

Keywords: *speech perception, speech maskers, musical expertise, aging*

Designing for Empathetic Listening Interactions

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Listening experiences among people using assistive hearing technologies, such as hearing aids and/or Cochlear Implants (CIs), are diverse and impacted by various physiological and social factors (Prevoteau, 2018). Given individual differences in such factors and in subjective preferences related to music enjoyment, there is a need for personalized, customizable solutions to improve music listening experiences for assistive technology users.

We conduct an exploratory study to gain insights into the empathetic processes involved in audio mixing and appreciation. We hypothesize that direct involvement of hearing assistive technology users in the mixing process would improve their end listening experience, and that preferred mixing strategies would differ substantially by participant.

Ten expert listeners (ELs) (each of whom has used a CI for over one year), and ten professional audio engineers (AEs) were recruited. AEs were initially asked to mix and process audio segments to produce a baseline mix aimed toward mainstream commercial release. They then modified the mixes in three rounds: (1) while mixing through a CI simulator, (2) while receiving written feedback and correspondence from an EL, and (3) while receiving mixing feedback from another professional AE. ELs were asked to provide feedback to AEs regarding parts of the mix they enjoyed and changes that could improve their listening experience. All participants completed initial and exit interviews and surveys to better understand the nuances of this iterative, empathetic creation process.

First insights emerging during ongoing data collection highlight common strategies leading to improved experiences such as reduction of the number of instruments, compression, and filtering; as well as the impact of correspondence and CI simulation on AE mixing strategies. We also gain understanding into how differences in hearing abilities are more broadly considered by AEs. Future work includes CI user-led in-person mixing sessions and the development of a simplified music personalization interface.

Keywords: *Music Personalization, Music Accessibility, Music Perception, Cochlear Implant Music Enjoyment, Music Engagement*

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Perception of simultaneous and sequential musical harmony in cochlear implant users

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Musical harmony is essential in music perception. Nevertheless, harmony perception is severely limited in cochlear implant (CI) users. One potential limitation in CI listeners is that the simultaneous occurrence of music chord components leads to complex interactions between electrodes in the cochlea. A possible solution might be a sequential (i.e., arpeggio-like) instead of simultaneous presentation of chord components. We tested post-lingually implanted CI users on short three-part musical sequences which were composed of harmonic complex tones. The last chord of a sequence was either harmonically conclusive or violated. The violations varied in difficulty level: It was either a sensory (i.e., out of scale/dissonant) violation or a syntactic (i.e., within scale/consonant) violation. Discrimination ability was measured in a two-alternative forced-choice (2AFC) paradigm: Participants responded if the final chord was conclusive or not (yes/no task). Two further parameters were varied: timing (simultaneous vs. sequential) and spectral separation of chord components (wide vs. close). We hypothesized that 1) sequential presentation of harmony components elicits better discrimination performance than simultaneous presentation due to less electrode interactions, and 2) sensory/dissonant violations elicit better performance than syntactic/consonant violations as they should be more salient in CI-mediated listening and require less sequential harmonic integration. For comparison, participants were furthermore tested in a standard triad discrimination task also composed of harmonic complex tones. Pilot results confirmed that, in the harmony discrimination test, sensory violations yield larger effects than syntactic violations but are inconsistent with the hypothesis regarding sequential vs. simultaneous presentation of chords. These results will be compared to and discussed in the light of the triad discrimination results.

Keywords: *cochlear implants, musical harmony, musical syntax*

Musical Pitch with Cochlear Implants: Tones vs. Intervals & Temporal vs. Place Cues

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Most users of cochlear implants (CIs) struggle with music perception. In normal hearing, both temporal cues, encoded via phase-locked spiking, and place cues, encoded in the tonotopic pattern of nerve-fiber activity per se, contribute to accurate perception of complex musical sounds. In CI users, both temporal and place cues are distorted due to a combination of technical, physiological, and psychological factors; among them, most prominently, limited frequency resolution of the electrode-neuron interface, lack of transmission of temporal fine structure, and reduced neural health. Still, many CI users listen to and enjoy music and a considerable proportion also practices music daily. In this contribution, we address two perceptual aspects of musical pitch perception in CI users. First, many CI users have temporal-pitch discrimination thresholds larger than a semitone when measured using tones. We hypothesize that tone discrimination is not the best predictor of musical pitch, as tones rarely occur in isolation. To this end, using harmonic complexes with one to ten components, we measured both tone discrimination (e.g., two successive tones one semitone apart) and interval discrimination (e.g., minor vs. major third). Second, current clinical CI stimulation strategies do not provide accurate place cues in everyday life. To this end, we hypothesized that CI users favor temporal over place cues and tested them on two tests of relative (i.e., temporal vs. place) pitch, again using harmonic complex tones. So far, pilot results suggest, first, that discrimination sensitivity may be better for intervals than for isolated tones. Second, place cues may dominate over temporal cues and CI users may be able to reweight both cues. These results may help improve our understanding of musical pitch perception with CIs and guide future music training paradigms.

Keywords: *cochlear implants, pitch discrimination, relative pitch*

A longitudinal study of vocabulary development in children with cochlear implants: the role of music exposure and maternal musicality

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Children with cochlear implants (CIs) exhibit great variability in their vocabulary outcomes (Majorano et al., 2018), despite a younger age at implantation favors better language development (Boons et al., 2013). Among the variables possibly affecting early vocabulary skills are individual differences in music exposure and engagement and in parental musicality, as studies show that these factors influence language outcomes in children with typical and atypical development (Ladányi et al., 2020; Nayak et al., 2021; Torppa & Huotilainen, 2019). To explore this hypothesis, we conducted a longitudinal study on 16 Italian children with CIs with severe to profound deafness. We tested the sample before implantation (mean age=16 months, SD=7.7, range=9-32) and at three, six, and twelve months after CI activation. Children's vocabulary was measured using the MacArthur-Bates-Communication Development Inventory (MB-CDI) and video-recordings of mother-child interactions at each session. Children's music exposure over the first year after CI activation was acquired by data logs from children's devices. Self-report questionnaires measuring musicality and engagement with music were administered to mothers (Müllensiefen et al., 2014; Politimou et al., 2019). Preliminary analyses with maternal education as covariate showed that mothers' musicality predicted children's production scores in the MB-CDI three months after activation. Linear regressions showed that average daily exposure to music in the three months after activation significantly predicted children's comprehension scores in the MB-CDI three months after activation. In both cases, when added in the model, mothers' self-reported musical variables significantly increased the proportion of variance explained. These findings suggest that mothers' musical abilities and children's music exposure and engagement in the first months after implantation play an important role in affecting children with CIs' expressive and receptive vocabulary. Therefore, for infants and toddlers with CIs, being musically engaged and exposed may mean having enhanced language outcomes, with implications on socio-educational and clinical levels.

Keywords: *cochlear implants, children, vocabulary, music exposure, music engagement, parental musicality*

"Autotune kills the radio star": Salience of frequency micro-modulations in popular music

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Singing voices attract auditory attention in music unlike other sounds. In a previous study, we investigated the salience of instruments and vocals using a detection task, in which cued target sounds were to be detected in musical mixtures. The presentation order of cue and mixture influenced the detection of all targets except the lead vocals, indicating a unique salience of vocals in musical mixtures. The aim of the present online study was to investigate the extent to which phonological cues, musical features of the main melody, or frequency micro-modulations (FMM) inherent in singing voices contribute to vocal salience. FMM were either eliminated by using an autotune effect (Experiment 1) or transferred to other instruments (Experiment 2). Detection accuracy was influenced by presentation order for all instrumental targets and the autotuned vocals, but not for the unmodified vocals, suggesting that vocal salience is not driven by phonological cues nor the musical features of the main melody. Transferring FMM from vocals to instruments or autotuned vocals reduced the magnitude of the order effect considerably. These findings suggest that FMM are an important acoustical feature contributing to vocal salience in musical mixtures.

A meta-analysis of the relation between musical abilities and speech prosody perception

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Studies investigating the relationship between musical abilities and speech prosody report that trained musicians show alterations or enhancements in the perception of prosody [1, 2], or report positive correlations between music perception and prosody perception in populations overall [3, 4]. However, effect sizes differ between studies, and some studies find no benefits [5]. We conducted a meta-analysis of previous research investigating the correlation between musical ability and the perception of speech prosody, with two aims: to assess the size of this effect across studies, and to examine what factors contributed to the differential results found thus far. Studies were systematically collected and relevant measurements were extracted. We used a multilevel random effects model to compute a summary effect of the included correlations ($k = 472$). Next, we added potential moderators as fixed factors to the model. We expected a higher correlation for non-native compared to native prosody perception, due to potential ceiling effects in native perception [6]. We also expected a higher correlation for music perception metrics compared to music training metrics, as these capture musical abilities more directly [7]. The summary effect gave a significant positive correlation between musical ability and prosody perception ($r = 0.37$). This finding supports the notion of transfer between the domains of music and speech in overlapping neural networks [8]. However, a bias assessment indicated that effects sizes were skewed towards larger positive effects, possibly due to publication bias. The moderator analysis showed that non-native perception gave a significantly larger effect compared to native perception, and music perception measures showed a larger effect compared to music training, in line with our hypotheses. This indicates that musical ability may especially benefit prosody perception in foreign languages, and moreover supports the use of music perception metrics as opposed to training metrics for empirical studies.

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Vibrotactile Actuated Concert for Cochlear Implant Users

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This article describes the design, implementation, and evaluation of vibrotactile concert furniture aiming to improve the live music experience of cochlear implant(CI) users. The system was the result of a series of participatory design sessions involving CI users with different hearing assistive setups: bi-implant, bi-modal, and mono-implant. The resulting design goals were (1) should afford multiple interaction modes to accommodate the variate needs of CI users, (2) should enhance the concert experience by providing congruent vibrotactile feedback, (3) should feel like furniture not apparatus, and (4) should encourage a social experience. Two hardware setups were built and evaluated during a jazz concert (6 songs), by CI users, hearing aid users, and audiologists. The main setup consisted of two leaning benches paired with four angled footrests; the benches were each actuated with a ButtKicker Mini Concert, while the footrests had a single ButtKicker LFE attached to them. The benches were reproducing the signal captured by the vocalist's microphone, and the footrest played the one from the double bass. The second setup consisted of a single tactile display designed to be grabbed, built around the Brüel Kjær 4809 transducer; both the bass and vocal signals were reproduced through it. A total of 5 CI users took part in a group interview after the concert, as well as an email questionnaire. The experience was well received for several reported reasons (1) The bass frequencies were not overwhelming as they would be in a concert since the acoustic level was low, (2) participants could associate voice melody with the bench vibrations, and (3) it provided a clear feel for both bass and singing. Furthermore, it was discovered that tactile mixing and mastering are crucial, and the fact that microphone bleed can be a problem.

Keywords: *Vibrotactile music, Vibrotactile displays, Cochlear implant music, Hearing assistive device*

The Threshold of Perceptual Significance for TV Soundtracks

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Hearing loss can impede our ability to hear the television in ways that a simple increase in volume cannot fully compensate for. The broad aim of this project is to create adapted versions of television audio such that the important elements of the audio are comfortably audible for a person with hearing loss, with minimal artefacts. The results of this experiment are intended to provide parameters that drive low-artifact dynamic-range compression. We investigated whether quieter parts of the audio could be discarded without affecting the listening experience. This used binary masked versions of the audio to measure the cut-off at which a difference in the audio was detected, the threshold of perceptual significance. Spectro-temporal regions were muted, based on their audibility as estimated through a gammatone filter-bank, smoothed spectro-temporally to reduce onset and offset artifacts and ringing. The binary masked audio was realised through a time-varying filter, implemented as a Fourier-like construction in the spectral domain. The experiment took the form of a series of two-alternate forced choice trials in which participants were presented with binary masked and unprocessed audio clips from different BBC television shows. The participants were then asked to identify the audio clip that sounded more artificial. It was hypothesised that the threshold of perceptual significance would be above the thresholds of pure-tone audibility. The architecture of the dynamic range compressor is also introduced, which was designed more broadly to be able to test the limits of minimal-artifact dynamic-range compression.

Keywords: *TV Soundtracks, Dynamic Range Compression, Hearing Loss*

Development of an adaptive test of musical scene analysis ability

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A critical aspect of music perception is the ability of the auditory system to organize the acoustic world into coherent events and streams – a process known as auditory scene analysis. Even though music psychology has long acknowledged the fundamental role of ASA in shaping music perception, no standardized test to precisely quantify listeners' ASA ability in realistic musical scenarios has been published yet. A new adaptive and ecologically valid test was developed, suitable for measuring ASA abilities in the context of music for both normal hearing (NH) and hearing impaired (HI) individuals. An A–not-A-task required participants to decide whether the single target instrument was part of a 2-sec mixture. In order to tailor the test's level of difficulty to participants with different abilities, the excerpts varied in terms of (A) the choice of target instrument, (B) the number of instruments in the mixture, and (C) the level-ratio of the target in comparison with the mixture. Within a calibration online-experiment, 525 NH and 125 HI listeners ($\mu = 31$ years, $SD = 14.3, range = 18 - 82$) were recruited. Thereby, the level-ratio ($F(3, 590) = 85.93, p < .001, \eta 2 = .29$), the choice of target instrument ($F(3, 472) = 34.89, p < .001, \eta 2 = .18$), and the number of instruments in the mixture ($F(3, 236) = 19.47, p < .001, \eta 2 = .07$) found to be suitable factors to discriminate between the abilities of the individuals. On the basis of a Bayesian item response theory model, an adaptive version of the MSA test was developed, which is now freely available within the software environment R. During the course of a complementary in-lab study, the final adaptive version of the MSA was validated in comparison with other measurement instruments, showing a moderate-to-good test-retest reliability of ICC = .66 (p ¡ .001) and moderate correlations within other music related tests. The MSA will provide an efficient tool for evaluating ASA performances in the context of music for individuals with a broad dispositional spectrum, which will contribute to a better understanding of the nature of ASA.

Keywords: *test construction, auditory scene analysis, music, hearing impariment*

A survey on hearing health of professional musicians in German orchestras

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Good hearing abilities naturally serve as a key component of good musicianship and are particularly critical for professional musicians. However, previous studies have shown that professional musicians are at particularly high risk for their hearing health. A study by Gembris et al.[1] on orchestral musicians in Germany showed 34% of all respondents stating to suffer from hearing problems. A systematic review by Di Stadio et al.[2] found that 32% of classical musicians had elevated hearing thresholds. Despite this high risk, it is not known how the use of hearing protection and hearing aids is rated among professional classical musicians and to what extent there are barriers to overcome. The aim of this study is to explore these questions in detail. An anonymous online survey was administered in collaboration with the German Orchestral Association, probing musicians' hearing health conditions and attitudes towards hearing health, assessments of sound level exposure, the usage of hearing protection and their experience with hearing aids. 327 professional orchestral musicians participated in the study. Preliminary analyses indicate that 87% of musicians considered sound level exposures to be a risk of their hearing health and 58% reported using hearing protection. 25% of musicians reported a diagnosed hearing loss (21% mild, 4% moderate). Finally, 40% of musicians worried about the negative image of hearing aids. The study generally bears implications regarding the promotion of hearing health in professional musicians.

Keywords: *music, hearing health, hearing impairment, musicianship*

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Music Perception in Elderly People with Hearing Aids - Experiences and Influencing Factors

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The project "Autonomie-Ressource Information und Kommunikation aktiv hören (AutaRKaktiv hören)" (ZS/2019/07/99750) is integrated in the research network "Autonomy in Old Age (AiA)" and funded by the EU (EFRE) and the federal state of Sachsen-Anhalt. It aims to minimise the negative consequences of elderly hearing impaired not using their hearing aids. In a mixed methods approach, 170 elderly people fitted with hearing aids were surveyed in a standardised questionnaire, while in a qualitative study 20 people were surveyed in semi-structured interviews face to face and/or via e-mail/messenger exchanges. 75,0 % of the questionnaire participants replied they could hear well regarding listening to music, which is in good agreement with Leek et al. (2008). Asked for situations in which wearing their hearing aids feels uncomfortable, participants did mention musical activities, however, it seems to be a minor problem compared to environmental noises (e.g. traffic). Of the interviewed participants, eleven commented on their music perception, whose experiences ranged widely from having no hope for listening to music ever again, being frustrated with concerts, to not particularly caring about music perception, to even loving the "saturated" and "soft" sound they experience with their hearing aids. In neither survey, quantitative or qualitative, a relationship could be found between the quality of music perception and age, gender, or the length of daily hearing aid use. Consistent with previous findings (Looi et al. 2019), results indicated little difference between those with a mild versus moderate hearing loss, however, poorer experiences were reported by those with a severe hearing loss. Whereas the statistical analysis did not show significant correlations between music perception and describing hearing-situations to the audiologist during the fitting process, the interview data would seem to suggest that making the quality of music perception a crucial criterion during the process of testing hearing aids is a positive factor for satisfying music experiences later-on. This poster will present how participants described their music perception as well as the influencing factors for good music perception that could be detected.

Keywords: *music perception, elderly hearing impaired, hearing aid*

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Notes


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